Emergency War Surgery

Previous page:
Hero's Highway shuts down. Airmen from the 332nd Expeditionary Medical Group carry a stretcher under the Hero's Highway flag during an aeromedical evacuation training exercise. The historical flag was recently cased in a ceremony on September 1, 2011.
Photograph: US Air Force photo no. 110707-F-GU448-007.
Photographer: Senior Airman Jeffrey Schultze.

Emergency War Surgery

Fifth United States Revision

2018

Borden Institute
US Army Medical Department Center and School
Health Readiness Center of Excellence
Fort Sam Houston, Texas

Office of The Surgeon General
United States Army
Falls Church, Virginia

"All the circumstances of war surgery thus do violence to civilian concepts of traumatic surgery. The equality of organizational and professional management is the first basic difference. The second is the time lag introduced by the military necessity of evacuation. The third is the necessity for constant movement of the wounded man, and the fourth—treatment by a number of different surgeons at different places instead of by a single surgeon in one place—is inherent in the third. These are all undesirable factors, and on the surface they seem to militate against good surgical care. Indeed, when the overall circumstances of warfare are added to them, they appear to make more ideal surgical treatment impossible. Yet this was not true in the war we have just finished fighting, nor need it ever be true. Short cuts and measures of expediency are frequently necessary in military surgery, but compromises with surgical adequacy are not."

—Michael E. DeBakey, MD
Presented at Massachusetts General Hospital
Boston, October 1946

THE FIFTH UNITED STATES REVISION

of

EMERGENCY WAR SURGERY

IS DEDICATED TO THE

COMBAT PHYSICIAN

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The information contained in this book reflects a generous collaborative effort of providers from all three services.

Thanks to the real engine behind this landmark readiness publication, the Borden Institute. They are the driving force and spent countless hours making sure we had the support needed to complete the book on time. They were instrumental in ensuring that this publication was a priority, and selflessly provided guidance and encouragement during all stages of its production.

Special recognition to the many volunteers who embraced the importance of updating this key readiness publication. We met a few days before, and during, the 2017 Labor Day weekend to collectively ensure the best possible outcome. Their contributions made significant practice updates throughout. Thank you.

Miguel A. Cubano, MD, FACS
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Foreword

Nearly 3 decades ago, I was a young surgeon on my first forward deployment during Operations Desert Shield and Desert Storm. It was the first time I witnessed military surgical teams saving lives in a war zone, often in harsh conditions, with limited resources, and under significant duress. Little did I know then how routine deployed medicine would become.

Military surgeons face unique medical challenges not typically found in civilian settings—from blast wounds, burns, and multiple penetrating injuries to head trauma, hemorrhage control, and amputations. I am deeply honored to recognize their collective knowledge and expertise in this fifth edition of *Emergency War Surgery*. There is no comparable textbook on the best practices and principles of forward deployed trauma surgery.

This update to the 2013 edition includes the latest lessons, techniques, and principles learned from US military engagements in Afghanistan, Iraq, and elsewhere. In the last decade and a half, the exceptional combat casualty care our military medical professionals have provided has led to the lowest mortality rate in the history of warfare. With the inclusion of the substantial advancements recently made in how we treat patients, this edition of *Emergency War Surgery* will become an even more valuable resource, particularly for our military medical personnel who will undoubtedly make even greater strides in the future.

Over the years, this textbook has attracted readers beyond the surgical and critical care communities. It has been translated into 20 languages and has become an important reference for anyone in combat operations. It is especially useful for non-surgical personnel to identify patients who need more advanced care. And, for the first time, it incorporates Tactical Combat Casualty Care (TCCC) to provide evidence-based, lifesaving techniques and strategies for providing the best trauma care on the battlefield.

The authors of the fifth edition of *Emergency War Surgery* represent all three medical services in the US military. Under the leadership of my colleague and friend, CAPT Miguel A. Cubano, MD, their seamless cooperation parallels the way the departments of the Army, Navy, and Air Force work together, not only on the battlefield fighting the enemy, but also in the operating room saving the lives of our wounded, ill, and injured.

All Americans are indebted to those who serve, whether on the front lines of battle or in far-flung operating rooms. Your dedicated service, and that of your families, ensures that we provide the best healthcare to the men and women protecting our nation.

R. C. Bono
VADM, MC, USN
Director, Defense Health Agency

July 2018
Washington, DC

Preface

Readiness is the one aspect of preparation for battle that we can control. A medical force that immediately delivers expert care, treats challenging injuries, improves combat practice among surgeons; a cadre of medical professionals who have relevant skills and knowledge, and can adapt and apply them to current military demands—this is the embodiment of readiness. Service subject matter experts in all medical subspecialty fields continue to shape and align the body of medical battlefield knowledge, as illustrated in this fifth edition of the *Emergency War Surgery* handbook. This edition reflects updates in Clinical Practice Guidelines and other new information accumulated since the 2013 edition's publication, especially in the areas of blood collection and transfusions. A new Tactical Combat Casualty Care (TCCC) chapter is included, and several new illustrations have been created as additional aids for users. Military medicine is committed to train, build, and maintain expert professionals, which continues to yield results in the most valued domain: readiness.

Medical supporting the "tip of the spear."

Nadja Y. West, MD
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Commanding General, U.S. Army Medical Command

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Vice Admiral, Medical Corps
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July 2018
Washington, DC

Introduction

"Legacy is our most significant contribution."
— CAPT Miguel A. Cubano, February 9, 2018

Thirty-five years ago my father, COL Miguel A. Cubano, gave me his copy of the 1967 edition of the *Emergency War Surgery* (EWS) handbook, developed for countries within the North Atlantic Treaty Organization (NATO). The gift was significant because my father knew of my lifelong dream of becoming a military surgeon. Reflecting on the legacy that continues in this fifth revision of EWS, my old 1967 edition took on a very important role. While reading it again, I realized that many concepts are still as relevant today as they were 50 years ago. The amputation chapter, for example, emphasized the need to remove nonviable tissue and conserve as much length of the limb as possible, and to never close the residual limb (stump) during the first operation due to the increased likelihood of infection. Conversely, many other concepts have been very dynamic or changed completely. This is evidenced in the now obsolete "artificial respiration" using a series of lifting motions of the victim's shoulders, followed by compression of the chest to promote inspiration and expiration. What has remained constant over the years is the commitment of the men and women of the armed forces medical departments, who contribute their knowledge and expertise to provide the best chance for lives to be saved on the battlefield.

The sustained commitment and loyalty of EWS authors and contributors toward those who serve in uniform is a compelling legacy for generations of physicians. Some names that immediately come to mind are Bohman, Holcomb, Jenkins, Rich, DeBakey, Bellamy, Eastridge, and others that for many of our readers are just names, but for me represent the essence of our legacy.

This readiness publication is NOT a collection of anecdotal treatments; rather, it is a comprehensively researched compendium of solutions to the majority of trauma scenarios

seen during combat operations. The subject matter expert (SME) authors have incorporated the latest version of the published Clinical Practice Guidelines (CPGs). This edition has had the largest readiness-focused tri-service SME contribution in the book's history. SMEs from the Army, Air Force, and Navy contributed to each of the 37 chapters, providing their particular perspective (geographical or environmental) to the same pathological situation.

This book does not replace proper surgical and critical care training, but will provide the reader with the readiness skills and proven concepts to maximize the chances for our wounded warriors to survive their injuries. Tactical Combat Casualty Care (TCCC) has been included for the first time as an integral part of the EWS. This chapter will provide first responders with the tools to adequately address wounds at the point of injury.

This revised publication directly supports the ongoing dynamic changes in military medicine as an immediate basic tool for trauma training and education. The execution of these duties and oversight by senior leaders will help us navigate the challenges of the future. Collectively, our medical community will continue finding ways to improve life- and limb-saving as it has done for hundreds of years.

Like my father 35 years ago, once you finish using the book please pass it on to your sons and daughters, nephews or friends, because you never know, maybe one day they will be asked to perform the indescribable honor of leading the next EWS revision . . . our legacy endures!

CAPT Miguel A. Cubano
Commanding Officer
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Corpus Christi, Texas
June 2018

Chapter 1

Weapons Effects and War Wounds

Introduction

An understanding of the pathophysiology of war wounds will allow the surgeon to best care for the patient. The most important tenet is:

TREAT THE WOUND, NOT THE WEAPON

Epidemiology of Injuries

- The primary weapons of war can be divided into explosive munitions and small arms.
  - **Explosive munitions:** Artillery, grenades, mortars, bombs, rockets, mines, improvised explosive devices, etc.
  - **Small arms:** Pistols, rifles, and machine guns.
- Three major epidemiological analyses have been conducted to evaluate the cause of battlefield injury, as well as outcome:
  - During the Bougainville campaign of World War II (Table 1-1), a medical team was sent to gather data on the injured, including the cause of injury. This campaign involved primarily infantry soldiers and was conducted on the South Pacific island of Bougainville during 1944.
  - US Army and Marine casualties from the Vietnam War were collected by the Wound Data and Munitions Effectiveness Team (WDMET) in Vietnam.
  - The Joint Theater Trauma System (JTTS) was developed and implemented in 2004, modeling the success of civilian trauma systems in the United States. The JTTS was developed to support operations in Iraq and Afghanistan to ensure that every military casualty has the optimal chance for survival and maximal potential for functional recovery.

- Combat injury causes in recent and historic conflicts are compared in Table 1-1. Anatomic distribution of penetrating wounds are compared in Table 1-2.

Table 1-1. Causes of Battle Injury in US Casualties: Bougainville Campaign (World War II), Vietnam, and Military Operations 2007–2017

Weapon	Bougainville (%)	Vietnam (%)	Military Operations 2007–2017 (%)
Bullet	33	30	19.2
Mortar/Rocket/Artillery	50	22	7.8
Grenade	12	11	4.6
RPG	—	12	4.5
Booby trap/IED	2	17	60.4
Other	3	8	3.5

RPG: rocket-propelled grenade; IED: improvised explosive device.
Data source for recent military operations: Department of Defense Trauma Registry.

- DoDTR data illustrates mechanisms of injury (Fig. 1-1) and anatomic distribution of penetrating injury (Fig. 1-2) for military operations 2007–2016.

The most common battlefield injury pattern is multiple fragment wounds involving multiple anatomical sites.

  - There are two areas of projectile–tissue interaction: permanent cavity and temporary cavity (Fig. 1-3).
    - **Permanent cavity:** Localized area of cell necrosis, proportional to the size of the projectile as it passes through.
    - **Temporary cavity:** Transient lateral displacement of tissue, which occurs after passage of the projectile. Elastic tissue (eg, skeletal muscle, blood vessels, and skin) may stretch and then rebound after passage of the projectile with variable degrees of tissue injury and

Table 1-2. Anatomical Distribution of Primary Penetrating Wounds

Conflict	Head/Neck/Face (%)	Thorax (%)	Abdomen (%)	Extremity (%)	Polytrauma (%)	Other (%)
World War I	17	4	2	70	NR	7
World War II	4	8	4	75	NR	9
Korean War	17	7	7	67	NR	2
Vietnam War	14	7	5	74	NR	—
Northern Ireland	20	15	15	50	NR	—
Falkland Islands	16	15	10	59	NR	—
Gulf War (UK)	6	12	11	71	NR	—
Gulf War (US)	11	8	7	56	NR	18
Chechnya	24	9	4	63	NR	—
Somalia	20	8	5	65	NR	2
Military operations 2007–2017	8.3	0.6	0.7	5.4	69.6	15.4

Data source for recent military operations: Department of Defense Trauma Registry.
NR: not recorded

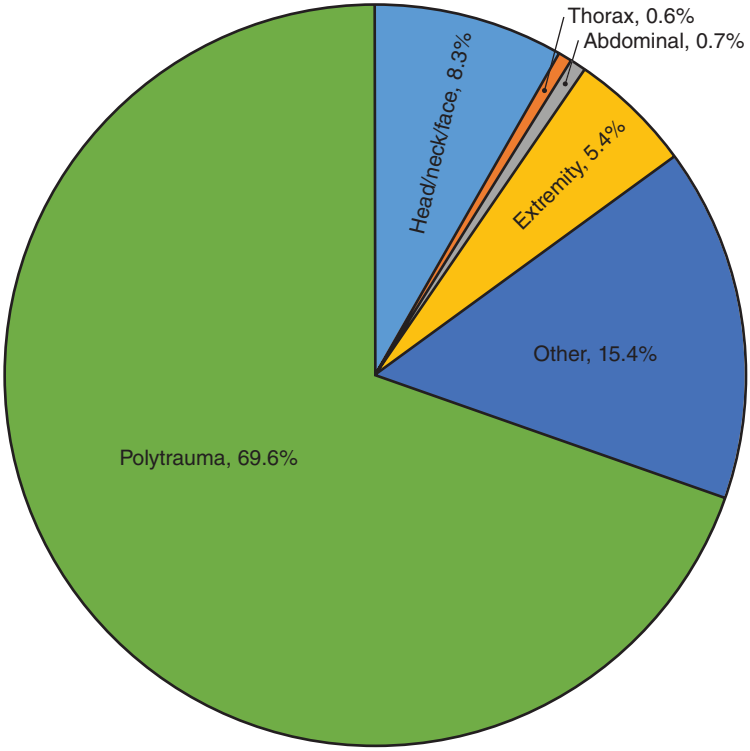

Fig. 1-1. Mechanism of injury, military operations 2007–2017.
Data source: Department of Defense Trauma Registry.

delayed necrosis. Inelastic tissue (eg, bone or liver) may fracture in this area.

- ♦ The shock (or sonic) wave, though measurable, has not been shown to cause damage in tissue.

- **Blast injuries (Table 1-4).**
  - Explosives undergo rapid exothermic reaction when detonated. The degree to which this reaction occurs is dependent on the characteristics of the explosive agent.
    - ♦ Low-order explosives react by rapid burning or conflagration.
    - ♦ High-order explosives produce extreme heat, energy, and a pressure wave known as the "blast wave." The

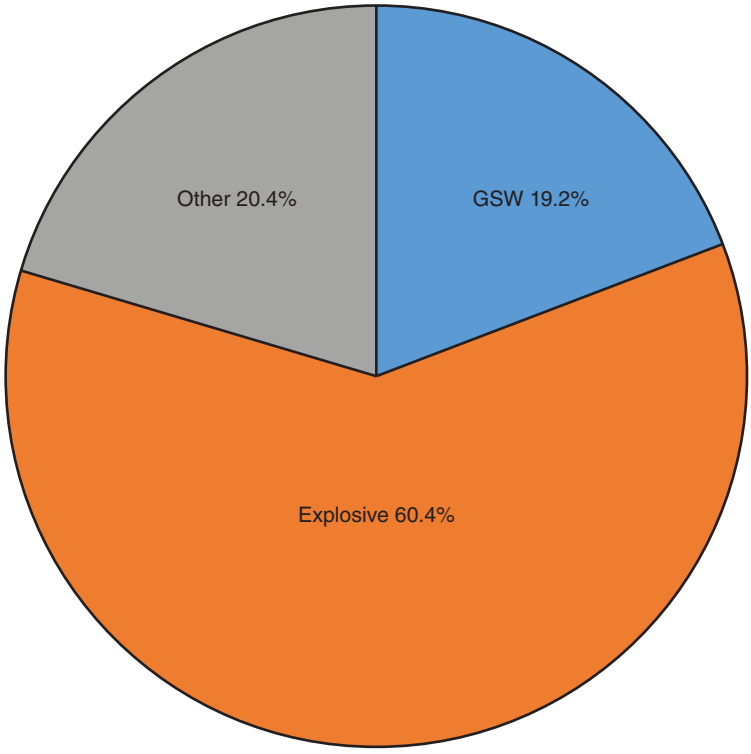

Fig. 1-2. Anatomical distribution of penetrating injury, military operations 2007–2017.
GSW: gunshot wound
Data source: Department of Defense Trauma Registry.

blast wave is reflected and sustained by fixed objects and confined environments (eg, rooms, vehicles, etc), which may potentiate the effects of blast energy. By the same mechanism, water—a noncompressible medium—transfers more blast energy than air, and underwater blast may cause greater injuries.

- Blast injuries are divided into **four categories**:
  - **Primary blast injuries** are caused by the blast wave. The mechanism of injury is the impartation of blast energy to the body, particularly in air-filled organs. Survival and

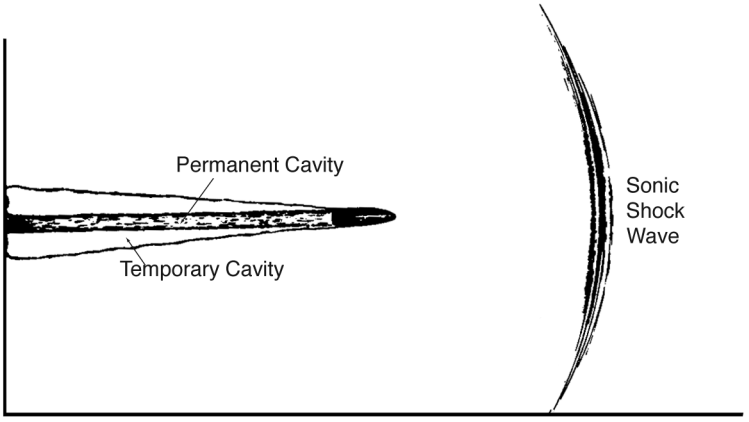

Fig. 1-3. Projectile–tissue interaction, showing components of tissue injury.

Table 1-3. Common Misconceptions About Projectile Wounds

Misconception	Reality
Velocity is the most important determinant of tissue damage.	Velocity is one factor in wounding. An increase in velocity does not increase the amount of tissue damage.
Projectiles yaw in flight, which can create irregular wounds.	Unless a projectile hits an intermediate target, the amount of yaw in flight is insignificant. Yaw occurs after striking tissue.
Exit wounds are always larger than entrance wounds.	It may be difficult to distinguish between entrance and exit wounds. Wound trajectories must be carefully assessed to avoid missed injury.
Full metal-jacketed bullets do not fragment, except in unusual circumstances.	The 5.56-mm rounds from M-4 and M-16 rifles reliably fragment at the level of the cannelure after traversing about 12 cm of tissue in soft tissue only.
All projectile tracts must be fully excised due to the effects of the temporary cavity.	Wounds should be washed out with initial debridement of foreign bodies and necrotic tissue only. Wounds often require subsequent debridement due to extensive contamination, embedded debris, and progression of necrosis.

Table 1-4. Classification of Explosive Injury

Category	Characteristics	Body Part	Types of Injuries
Primary	Unique to high-order explosives; results from the impact of the blast wave	Gas-filled structures most susceptible: lungs, gastrointestinal tract, middle ear	Tympanic membrane rupture and middle ear damage (common) Blast lung (pulmonary barotrauma) (uncommon) Abdominal hollow viscus perforation and hemorrhage (rare)
Secondary	Results from flying debris and weapon casing and content fragments	Any body part	Penetrating chest trauma Eye penetration (can be occult)
Tertiary	Results when bodies are thrown by blast wind or crushed by fallen structure	Any body part	Fracture, traumatic, amputation, solid organ injury, traumatic brain injury
Quaternary	All explosion-related injuries, illnesses, or diseases not due to primary, secondary, or tertiary mechanisms; includes exacerbation or complications of existing conditions	Any body part	Burns (flash, partial thickness, and full thickness) Radiation illness Inhalational injury

injury from primary blast are contingent on a number of factors, including energy of the blast, confined versus open space, and distance from the explosive source. Casualties who survive may have tympanic membrane rupture, pulmonary barotrauma, and bowel contusion and perforation. Primary brain injury may also occur.

- **Secondary blast injuries** are penetrating wounds caused by fragments from the casing and contents of the explosive device and secondary debris (eg, dirt, rocks, body parts). Fragments produced by explosive weapons vary in size, shape, composition, and initial velocity. Close proximity injuries can result in decapitation, dismemberment, and extreme tissue devastation. Extremity injuries predominate in survivors.
- **Tertiary blast injuries** are blunt force trauma caused by physical displacement of the victim against a standing object, or crushing of the victim under a fallen structure, resulting in fractures, brain injury, or solid organ injuries. Entrapment can lead to compartment syndrome and crush syndrome (rhabdomyolysis).
- **Quaternary blast injuries** are caused by thermal, chemical, and/or radiation effects (eg, burns, inhalation injuries).

- Casualties injured by explosives are cared for using standard trauma management principles; however, the complex nature of combined barotrauma, penetrating, blunt, and burn injury must be understood and thoroughly investigated to avoid missed injuries.
- The blast wave effects rapidly dissipate as distance from the epicenter increases (Fig. 1-4).
- Blast exposure may also occur in weapon systems operators, such as when firing 81-mm and 120-mm mortar weapons systems. Repeated blast exposure during training and combat operations may be associated with cognitive impairment and chronic symptoms.
- Blast pressure gauges have been utilized in combat operations with a goal of determining the specific pressures associated with injury. In general, the pressure measurements have not correlated well with injuries sustained; however, safety guidelines recommend

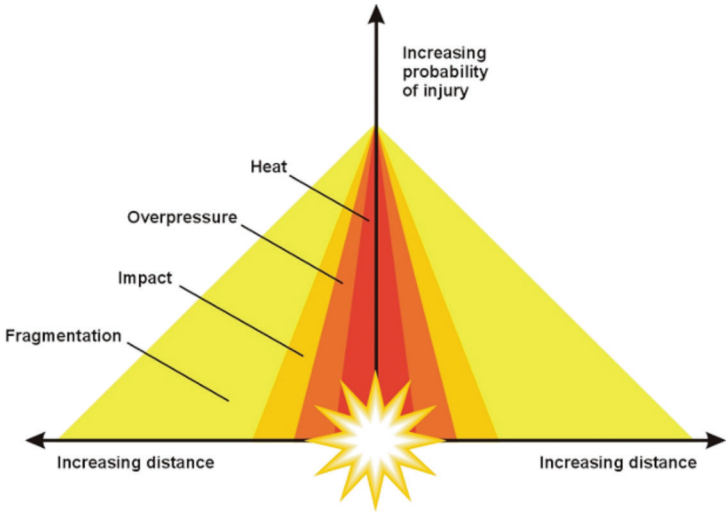

Fig. 1-4. The probability of sustaining a given trauma is related to the distance from the epicenter of the detonation.

maintaining single exposure limits of 4 psi or less, with peak overpressure exposure less than 15 psi.

- The tympanic membranes are most sensitive to injury by the blast wave, while higher pressure may lead to injury of the lungs and the gastrointestinal (GI) tract hollow organs. GI injuries may have a delayed presentation due to perforation of an ischemic segment of bowel.
- Injury from blast is proportional to both the peak blast pressure and the duration of sustained blast pressure. An increase in either peak pressure or duration will contribute to increased severity of injury.

- **Thermobaric.**
  - Thermobaric devices (eg, fuel-air explosions) work by increasing the duration of a blast wave. The device initially explodes and puts a volatile substance into the air (fuel vapor). A second explosion then ignites the aerosolized material, producing an explosion of long duration. The effects from this weapon are magnified when detonated in an enclosed space.

- Air displaced after the explosion creates a blast wind that can cause tertiary blast injuries.

- **Thermal.**
  - Thermal burns occur as the result of combustion when the device explodes.
  - Patients who were in close proximity to a blast may have sustained burns in addition to open wounds, complicating resuscitation as well as management of soft-tissue injuries.

- **Antipersonnel landmines.**
  - There are three types of conventional antipersonnel landmines common throughout the world: static, bounding, and horizontal spray.
    - **Static** landmines are small, planted landmines (100–200 g of explosive) that are detonated when stepped on, resulting in injury to the lower limb(s):
      - Partial or complete traumatic amputation, most commonly at the midfoot or distal tibia.
      - Debris and other tissue are driven up along fascial planes, with tissue stripped from the bone (Fig. 1-5).
    - Factors influencing the degree of injury include size and shape of the explosive, point of contact with the foot, amount of debris overlying the mine, and the type of footwear.

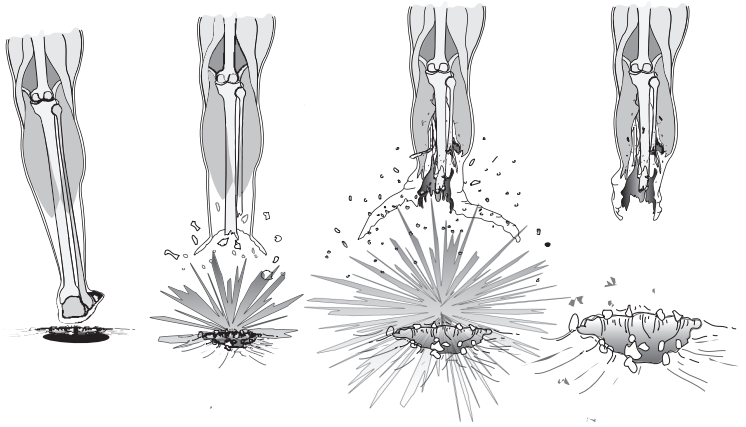

Fig. 1-5. Mechanisms of injuries caused by antipersonnel landmines.

- **Bounding** mines propel a small explosive device to about 1–2 meters of height and then explode, causing multiple small fragment wounds to those standing nearby. These landmine casualties have the highest reported mortality.
- **Horizontal spray** mines propel fragments in one direction. This landmine can be command-detonated or detonated by tripwire. As an example, the US Claymore mine fires about 700 steel spheres of ¾ gram each over a 60° arc. Horizontal spray mines produce multiple small fragment wounds to those nearby.

- The **improvised explosive device (IED)** is an unconventional weapon. Another piece of ordnance, such as a grenade or a mortar shell, may be used as the explosive component, or the device may be completely fabricated out of locally available materials.
  - The vehicle-borne improvised explosive device (VBIED) is a specific type of IED consisting of a non-tactical vehicle loaded with explosives and projectiles to inflict damage to personnel, vehicles, and infrastructure.
  - Similarly, a suicide-vest improvised explosive device (SVIED) utilizes individuals, often women and children, to inflict casualties via local or remote detonation.
  - Drone-dropped IEDs are a recent tactic involving release of an IED from a drone aircraft that may detonate before hitting the ground.
  - Injuries caused by IED may involve any imaginable type of impaled objects, including bone and body parts of a suicide attacker.

- **Small arms.**
  - Pistols, rifles, and machine guns.
    - Trends for small arms since World War II include rifles that have increased magazine capacity, lighter bullets, and increased muzzle velocity.
    - On the following pages are some examples of the characteristics of commonly encountered military firearms. The illustrations show the path of missiles fired from 5 to 10 meters into ordnance gelatin blocks. Variations of range, intermediate targets (eg, body armor), and body tissue will alter the wounds seen.

- The Russian-made AK-47 rifle is one of the most common weapons used throughout the world. For this particular bullet (full metal jacketed or ball), as shown in the gelatin block, there is a 25-cm path of relatively minimal tissue disruption before the projectile begins to yaw. In dynamic, live tissue injuries, however, the actual performance of the bullet may vary, and some wounds may demonstrate relatively minimal tissue disruption while others may have a large cavitation effect with extensive tissue necrosis (Fig. 1-6).

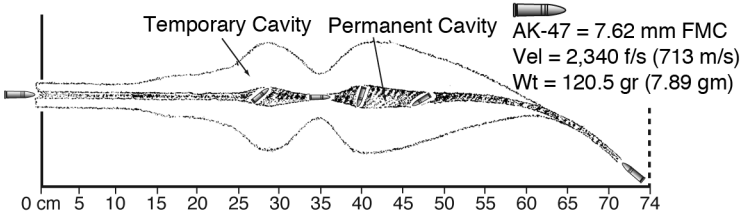

Fig. 1-6. Idealized path of tissue disruption caused by a bullet fired by an AK-47 (10% gelatin as a simulation). FMC: full metal case; Vel: velocity; Wt: weight.

- The AK-74 rifle is a smaller-caliber Russian-made assault rifle. The standard bullet does not deform in the tissue simulant, but does yaw relatively early (at about 7 cm of penetration).
- The M-4 and M-16 series rifles fire 5.56-mm full metal-jacketed bullets at approximately 950 m/s. The average point forward distance in tissue is about 12 cm, after which it yaws to about 90°, flattens, and then breaks at the cannelure (a groove placed around the midsection of the bullet) (Fig. 1-7).
- The 7.62-mm NATO (North Atlantic Treaty Organization) rifle cartridge is still used in sniper rifles and machine guns. After about 16 cm of penetration, this bullet yaws through 90° and then travels base forward. A large temporary cavity is formed and occurs at the point of maximum yaw (Fig. 1-8).

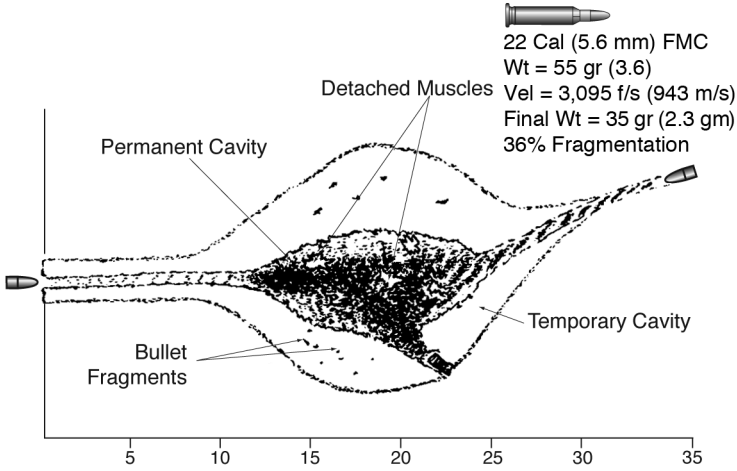

Fig. 1-7. Idealized path of tissue disruption caused by a bullet fired from an M-16 rifle (10% gelatin as a simulation). Cal: caliber; FMC: full metal case; Vel: velocity; Wt: weight.

- Larger-caliber weapons include machine guns (mounted or portable) and rotary cannons (Gatling-type with multiple barrels in a rotating cluster to allow greater sustained rate of fire) with a range of bullets, including .50 caliber (13-mm) rounds up to 30-mm rounds, which create correspondingly greater amounts of tissue disruption.

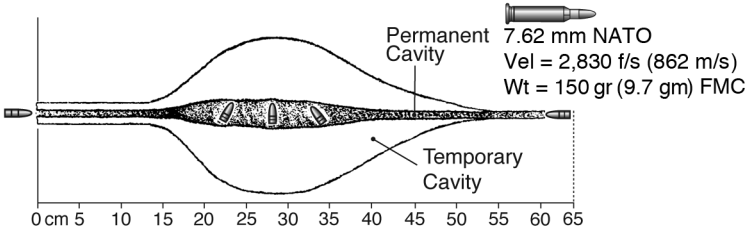

Fig. 1-8. Idealized path of tissue disruption caused by a 7.62-mm projectile (10% gelatin as a simulation). FMC: full metal case; NATO: North Atlantic Treaty Organization; Vel: velocity; Wt: weight.

- **Armored vehicle crew casualties.**
  - Since the first large-scale use of tanks during World War I, injuries to those associated with armored vehicles in battle have been a distinct subset of combat casualties.
  - Armored vehicle examples include mine-resistant ambush protected vehicles, tanks, infantry fighting vehicles, armored support vehicles, and "light armored vehicles."
  - There are three main types of antiarmor weapons: shaped charge, kinetic energy round, and antitank landmines.
    - **Shaped charge.**
      See Fig. 1-9a.
      - The shaped charge or high explosive antitank (HEAT) round consists of explosives packed around a reverse cone of metal called a melt sheet or a liner. This is the principle behind the warhead of the rocket-propelled grenade (RPG).
      - Shaped charges range in diameter from the 85-mm RPG-7 to the 6-inch diameter tube-launched, optically tracked, wire-guided (TOW) missile.
      - Injury effect of shaped charge munitions:
        - First, there is the jet of the shaped charge itself. This may cause catastrophic wounds to casualties who are hit, or it may ignite fuel, ammunition, or hydraulic fluid.
        - Second, there is a debris injury factor called spall, which is material knocked off from the inside face of the armored plate. This produces a spray of small, irregularly shaped fragments inside the compartment (Fig. 1-9b).
    - **Kinetic energy round.**
      - The kinetic energy round contains an aerodynamic piece of hard metal (eg, depleted uranium or tungsten) shaped like a dart. The metal is usually encased in a carrier or sabot that falls away from the projectile after it leaves the barrel. Fragments of depleted uranium should be treated during initial wound surgery as any retained metal foreign body. There is a potential risk over many years that casualties with retained depleted uranium fragments may develop heavy

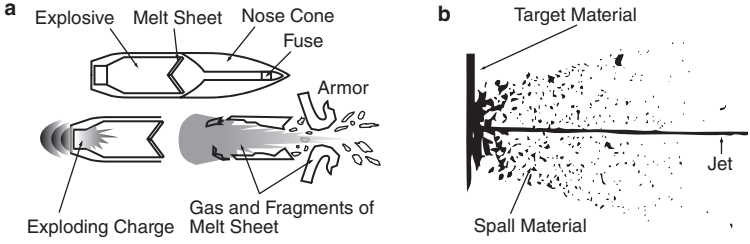

Fig. 1-9. (**a**) Disruptive mechanisms of the shaped charge warhead. (**b**) Diagram taken from photograph of an actual detonation of a shaped charge warhead against an armor plate caused by antitank land mines.

metal poisoning. This concern by itself does not justify extensive operations to remove such fragments during initial wound debridement.

- ◊ Injuries to those inside a vehicle are due, in part, to the direct effects of the penetrator or from fragments knocked off the inside face of the armored plate. The range of fragment masses may be from a few milligrams to over a kilogram.

- ♦ **Antitank landmines.**
  - ◊ Antitank mines are those with a large explosive filler of 4–5 kg. Injuries are often due to blunt trauma from crewmembers being thrown around inside the vehicle after it detonates the mine.
  - ◊ Closed-head injuries and fractures of the extremities and spine are common.
  - ◊ Mechanisms of injury (Fig. 1-10).
    - ■ Multiple injuries take place as the result of defeated armor (as described previously).
    - ■ **Thermal:** Burns occur because of ignited fuel, ammunition, or hydraulic fluid, or as the direct result of the antiarmor device.
      - □ Two large studies, one on British World War II tank crewmen and one on Israeli casualties in Lebanon, showed that about one-third of living, wounded casualties have burns.
      - □ The severity of burns range from superficial to full thickness. Most burns are superficial

to exposed skin, most often of the face, neck, forearms, and hands. These are often combined with multiple fragment wounds.

- **Blast overpressure** can occur when a munition breaches a vehicle's armor, exposing the interior of the vehicle to the blast overpressure within a confined space. When explosions occur outside a vehicle, the blast wave may be dissipated by the vehicle's armor.
- **Toxic fumes,** such as smoke inhalation, carbon monoxide, hydrogen fluoride or cyanide released as byproducts of combustion and vehicle fire-suppression systems, may cause chemical inhalation injury and hypoxia.

- **Inhalation injury.**
  - There are three types of inhalation injury:
    - Upper airway (above glottis), caused by direct heat injury.
    - Lower airway (below glottis), caused by retained soot and chemicals within the airways.
    - Poisoning, caused by absorption of carbon monoxide, cyanide, or other toxin into the blood stream.
  - Treatment of inhalational injury is supportive and may include early intubation, judicious fluid management, and possibly steroid administration if unresponsive. If available, bronchoscopic lavage may be used to remove debris.
  - Triage considerations: Triage inhalational injury as immediate if hypoxia or pulmonary edema is present, consider triage as expectant if hypotensive and cyanotic. Reevaluate nonemergent patients every 2 hours.
- **Unexploded ordnance.**
  - Unexploded ordnances (UXOs) may occasionally become embedded in a casualty without exploding.
  - UXOs include rockets, grenades, mortar rounds.
  - Some UXOs must travel a specific distance (50–70 m) or number of rotations in order to arm.
  - Fuses are triggered by different stimuli (impact, electromagnetic, laser).

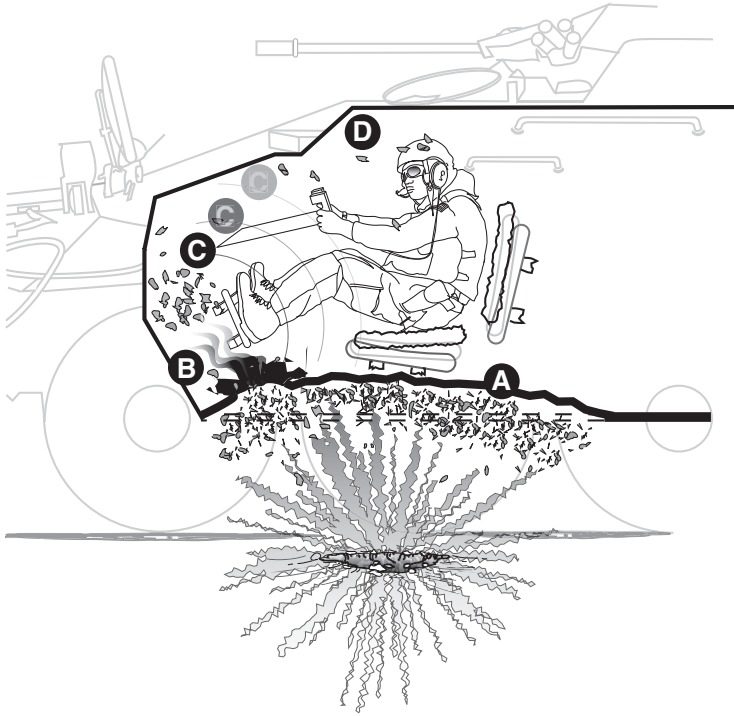

Fig. 1-10. Injuries sustained as a result of defeated armor, (**A**) translational blast injury, (**B**) toxic gases, (**C**) blast overpressure, and (**D**) penetrating missile wounds.

- **Notify explosive ordnance disposal team immediately!**
  - Thirty-two of 36 victims and all treating teams survived removal, with four casualties reported moribund on arrival who died before operation (historical review of US casualties).
  - No incident was identified in which a round exploded during transportation, preparation, or removal.
  - The casualty should be triaged as **nonemergent**, placed far from others, and **operated on last**.
  - Preplan for how to handle both transport and surgery.
  - Transport.

- ♦ If by helicopter, ground the casualty to the aircraft (there is a large electrostatic charge from rotors).
- Move into a **safe area**.
  - ♦ Revetment, parking lot, or back of building.
- **Operate in a safe area, preferably with blast shielding, not in the main OR area.**
- Operative management.
  - ♦ Use blast protection for surgeon and staff.
  - ♦ Place sandbags around the operative area, use flak vests and ballistic eye protection.
  - ♦ Avoid triggering stimuli.
  - ♦ Avoid electromagnetic charge (do not use defibrillator, monitor, electrocautery, blood warmer, ultrasound or CT machines).
  - ♦ Plain radiography is safe. It helps identify the type of munition.
- Anesthesia.
  - ♦ General anesthetic is usually preferred. May utilize total intravenous anesthesia.
  - ♦ Avoid or minimize use of oxygen. Keep oxygen tanks at a distance.
  - ♦ Have anesthesiologist leave after induction.
- Operation: The surgeon should be alone with the patient.
  - ♦ Employ gentle technique.
  - ♦ Avoid excessive manipulation.
  - ♦ Consider amputation if other methods fail.
  - ♦ Remove en bloc if possible.

The decision to remove a chemical/biological UXO is a command decision. Immediately after removal, hand the munition to explosive ordnance disposal personnel for disposal.

For Joint Trauma System Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs/

Chapter 2

Roles of Medical Care (United States)

Introduction

Military doctrine supports an integrated health services support system to triage, treat, evacuate, and return the casualty to duty in the most time-efficient manner. The system begins with the casualty on the battlefield and ends in hospitals located within the continental United States (CONUS) and other safe havens. Care begins with first responder (self-aid/buddy aid and combat lifesaver), rapidly progresses through tactical combat casualty care (TCCC; care under fire, tactical field care, and tactical evacuation care) and advanced trauma management to stabilizing surgery, followed by critical care transport to a higher taxonomy of care where more sophisticated treatment can be rendered.

A basic characteristic of organizing modern health services support is the distribution of medical resources and capabilities to facilities at various levels of command, diverse locations, and progressive capabilities. This is referred to as the **four roles of care (Roles 1–4)**. As a general rule, no role will be bypassed except on grounds of medical urgency, efficiency, or expediency. The rationale for this rule is to ensure the stabilization and survivability of the patient through advanced trauma management and far-forward resuscitative surgery prior to movement between medical treatment facilities. Different roles denote differences in capability of care. Each higher role has expanded capabilities.

Role 1

- The first medical care military personnel receive is provided at Role 1 (also referred to as unit-level medical care). This role of care includes:
  - Immediate lifesaving measures.
  - Disease and nonbattle injury prevention and care.

- Combat and operational stress preventive measures.
- Patient location and acquisition (collection).
- Treatment provided by designated combat medics, treatment squads, or animal care specialists for working animals. (Major emphasis is placed on those measures necessary for the patient to return to duty or to stabilize them and allow for evacuation to the next role of care. These measures include maintaining the airway, stopping bleeding, preventing shock, protecting wounds, immobilizing fractures, and other emergency measures, as indicated.)

- **Self-Aid and Buddy Aid.** All military personnel are trained in a variety of basic first-aid procedures. These procedures include aid for chemical casualties with particular emphasis on lifesaving tasks. This training enables the military personnel to apply first aid to alleviate potential life-threatening situations.
- **Combat Lifesaver.** The combat lifesaver is a nonmedical military personnel selected by their unit commander for additional training beyond basic first-aid procedures. A minimum of one individual per squad, crew, team, or equivalent-sized unit should be trained. The primary duty of this individual does not change. The additional duty of the combat lifesaver is to provide enhanced first aid for injuries based on his or her training before the medical care arrives. Combat lifesaver training is normally provided by medical personnel assigned, attached, or in sustainment units. The senior medical person designated by the commander manages the training program.
- **Medical Personnel.** Role 1 provides primary healthcare, specialized first aid, triage, resuscitation, and stabilization. Normally included within the basic Role 1 capabilities are routine sick call and the management of minor sick and injured personnel who can immediately return to duty. Role 1 also includes casualty collection and preparation of casualties for evacuation to the rear. Expanded medical treatment is provided by medical personnel with enhanced medical skills (eg, the expeditionary combat medic [ECM], Special Forces medical sergeant [18D], Special Operations combat medic [SOCM W1/W4], independent duty corpsman/medical technician [IDC/IDMT], pararescueman [PJ], physician assistant, or physician).

Role 2

- Role 2 provides advanced trauma management and emergency medical treatment including continuation of resuscitation started in Role 1. Role 2 provides a greater capability to resuscitate trauma patients than is available at Role 1. If necessary, additional emergency measures are instituted, but they do not go beyond the measures dictated by immediate necessities. Role 2 care has the capability to provide packed blood products, limited x-ray, laboratory, dental support, combat and operational stress control, PVTMED, and Role 2 veterinary medical and resuscitative surgical support. Role 2 has a limited hold capability (i.e., no bed capacity). Role 2 is classified into Role 2 light maneuver (2LM) and Role 2 enhanced (2E).
  - Role 2LM are light, highly mobile medical units designed to support land maneuver formations (normally brigade level). A Role 2LM medical unit is able to conduct advanced resuscitation procedures up to damage control surgery. It will evacuate its post-surgical cases to Role 3 (or 2E for stabilization and possible primary surgery) before evacuation to Role 4.
  - 2E provides basic secondary healthcare, built around primary surgery, intensive care unit, and ward beds. A 2E MTF is able to stabilize post-surgical cases for evacuation to Role 4 without the requirement to first route them through a higher Role 3 facility.

Role 3

- In Role 3, the patient is treated in an MTF or veterinary facility (for working animals) that is staffed and equipped to provide care to all categories of patients, to include resuscitation, initial wound surgery, specialty surgery (general, orthopedic, urogenital, thoracic, ENT, neurosurgical) and post-operative treatment. This may include definitive surgery for local nationals depending on the current rules of engagement. This role of care expands the support provided at Role 2. Patients who are unable to tolerate and survive movement over long distances receive surgical care in a hospital as close to the supported unit as the tactical situation allows. This role includes provisions for:

- Evacuating patients from supported units.
- Providing care for all categories of patients in an MTF with the proper staff and equipment.
- Providing support on an area basis to units without organic medical assets.

Role 4

- Role 4 medical care is found in US base hospitals and robust overseas facilities. Mobilization requires expansion of military hospital capacities and the inclusion of Department of Veterans Affairs and civilian hospital beds in the National Disaster Medical System to meet the increased demands created by the evacuation of patients from the area of focus. The support-base hospitals represent the most definitive medical care available within the medical care system.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 3

Mass Casualty and Triage

Introduction

Mass casualties have the potential to rapidly overwhelm multiple levels of care and evacuation. Because the Joint Theater Trauma System (JTTS) has been adapted to provide rapid movement of casualties through the continuum of care, mass casualty events may occur at military treatment facilities with little or no advance notice. Asymmetric warfare may further complicate the mass casualty event by inclusion of combatant, noncombatant, or third country nationals among the injured. The mass casualty scenario demands a rapid transition from routine to contingency medical operations initiated by the earliest recognition of this specter within the fog of war. The transition will be facilitated by a mass casualty response plan that must be designed, exercised, and assessed to reflect relevant site and evacuation capability.

A mass casualty event overwhelms immediately available medical capabilities to include personnel, supplies, and/or equipment.

Effective mass casualty response is founded on the principle of **triage**, the system of sorting and prioritizing casualties based on the tactical situation, mission, and available resources. It is the most effective means for establishing order in a chaotic environment and the best method for providing the greatest benefit to the greatest number of patients within the limitations of time, distance, and capability. Triage is a constant and dynamic process as casualties move within and through the echelons of care.

The ultimate goals of combat medicine are: the return of the greatest possible number of warfighters to combat and the preservation of life, limb, and eyesight.

The decision to withhold care from a casualty who in another less overwhelming situation might be salvaged is difficult for any physician, nurse, or medic. Decisions of this nature are unusual, even in mass casualty situations. Nonetheless, the overarching goal of providing the greatest good to the greatest number must guide these difficult decisions. Commitment of resources should be decided first based on the mission and immediate tactical situation and then by medical necessity, irrespective of a casualty's national or combatant status.

Triage Categories

Triage is performed at each echelon of care. **Traditional categories of triage are immediate, delayed, minimal, and expectant**.

- **Immediate:** This group of injured requires attention within minutes to 2 hours on arrival to avoid death or major disability. The procedures in this category should focus on patients with a good chance of survival with immediate intervention. Injuries include:
  - Airway obstruction or potential compromise.
  - Tension pneumothorax.
  - Uncontrolled hemorrhage.
  - Torso, neck, or pelvis injuries with shock.
  - Head injury requiring emergent decompression.
  - Threatened loss of limb.
  - Retrobulbar hematoma.
  - Multiple extremity amputations.
- **Delayed:** This group includes those wounded who will require surgery, but whose general condition permits delay in treatment without unduly endangering life, limb, or eyesight. Sustaining treatment will be required (eg, fluid resuscitation, stabilization of fractures, and administration of antibiotics, bladder catheterization, gastric decompression, and relief of pain). Injuries include:
  - Blunt or penetrating torso injuries without signs of shock.

- Fractures.
- Soft-tissue injuries without significant bleeding.
- Facial fractures without airway compromise.
- Globe injuries.
- Survivable burns without immediate threat to life (airway, respiratory) or limb.

- **Minimal:** Patients comprising this group have relatively minor injuries (eg, minor lacerations, abrasions, fractures of small bones, and minor burns) and can effectively care for themselves or be rendered minimal medical care. These casualties may also constitute a manpower resource, utilized to assist with movement or care of the injured. When a mass casualty incident occurs in close proximity to a medical treatment facility (MTF), it is likely that these will be the first casualties to arrive, bypassing or circumventing the casualty evacuation chain. Such casualties may inundate the facility leading to early commitment and ineffective utilization of resources. To prevent such an occurrence, it is imperative to secure and strictly control access to the MTF immediately upon notification of a mass casualty event.
- **Expectant:** This group has injuries that overwhelm current medical resources at the expense of treating salvageable patients. The expectant casualty should not be abandoned, but should be separated from the view of other casualties and intermittently reassessed. These casualties require a staff capable of monitoring and providing comfort measures. Injuries include:
  - Any casualty arriving without vital signs or signs of life, regardless of mechanism of injury.
  - Transcranial gunshot wound (GSW) with coma.
  - Open pelvic injuries with uncontrolled bleeding and class IV shock.
  - Burns without reasonable chance for survival or recovery.
  - High spinal cord injuries.

Triage Management

Those previously classified as minimal injuries that are evacuated to a surgical unit should not be brought through the resuscitation area. These casualties should be diverted to an area near the

facility where they are reassessed, receive care and—condition permitting—be available to assist with movement of the severely injured. The remaining casualties should be divided into three categories: emergent, nonemergent, and expectant. These categories are useful in dividing casualties into those requiring immediate surgical treatment (emergent), and those that are less severely injured, still require care in the near term (6–12 hours), but have low expected mortality (nonemergent). It is anticipated that 10%–20% of casualties presented to a surgical unit will require urgent surgery, but this is incident dependent. The vast majority of the wounded will not require intensive decision-making, intervention, and care.

Triage is a fluid process at all levels, with altered situations and resources requiring a change in category at any time and in any setting. In the extreme example, a casualty may be triaged from emergent to expectant during surgery, abruptly terminating the operation ("on-table triage").

Special Triage Considerations

Patients who do not easily fit into the standard categories or who pose a risk to other casualties, medical personnel, or the treatment facility may require special consideration.

- **Wounded contaminated in a biological and/or a chemical battlefield environment:** These casualties must be decontaminated prior to entering the treatment facility. Prehospital care may be provided outside of the medical facility by appropriately protected medical personnel prior to decontamination.
- **Retained, unexploded ordnance:** These patients should be segregated immediately and treated last. See Chapter 1, Weapons Effects and War Wounds, which describes the special handling of these wounded.
- **Noncombatant local or third country nationals:** Due to the asymmetric nature of modern warfare, these individuals may be brought into the military trauma system for care during a mass casualty event that may or may not include United States or allied forces. Although the mission and tactical situation must be considered first, in most situations medical necessity will guide triage decisions. It is crucial to recognize

the capabilities of local national healthcare resources and to factor these limitations *prospectively* into care and triage decisions. Such decisions must be based on the best and most timely information available.

- **Enemy prisoners of war/internees/detainees:** Although treatment is based on medical necessity, it is essential that the threat of "suicide bombers" and "human booby traps" be prevented by carefully screening and disarming all casualties prior to moving into treatment areas, including the triage area. See Chapter 32, Care of Enemy Prisoners of War/Internees.
- **US, allied, and third nation contractors:** Although these individuals will also receive care based on mission, tactical situation, and medical necessity, it should be recognized that less stringent predeployment health assessments or requirements may permit a population with significant chronic health co-morbidity to enter a theater of war as a population at risk. The effect of co-morbidity on survivability may need to be considered in triage decision-making. (**Example**: A casualty on antiplatelet therapy with a life-threatening hemorrhagic injury in a setting where availability of blood components is limited.)
- **Combat stress:** Rapid identification and immediate segregation of stress casualties from injured patients will improve the odds of a rapid recovery. With expeditious care, these casualties can be returned to duty (80%). Do not use them as litter bearers because this may increase the trauma you seek to treat.
  - Place patient in one of two groups.
    - **Light stress:** Immediate return to duty or return to unit or unit's noncombat support element with duty limitations and rest.
    - **Heavy stress:** Send to combat stress control restoration center for up to 3 days reconstitution.
    - Use the **BICEPS** mnemonic where resources/tactical situations allow:
      - **Brief:** Keep interventions to 3 days or less of rest, food, and reconditioning.
      - **Immediate:** Treat as soon as symptoms are recognized—do not delay.

- ◊ **Central:** Keep in one area for mutual support and identity as soldiers.
- ◊ **Expectant:** Reaffirm that we expect return to duty after brief rest; normalize the reaction and their duty to return to their unit.
- ◊ **Proximal:** Keep them as close as possible to their unit. This includes physical proximity and using the ties of loyalty to fellow unit members. Do this through any means available. **Do not evacuate away from the area of operations or the unit, if possible.**
- ◊ **Simple:** Do not engage in psychotherapy. Address the present stress response and situation only, using rest, limited catharsis, and brief support (physical and psychological).
- ◊ **Or refer:** Must be referred to a facility that is better equipped or staffed for care.

If battlefield casualties do not have physical injuries, DO NOT send them out of the battle area, because this will worsen stress reactions.

Resource Constraints

Triage decisions are influenced by multiple factors. Areas to consider include:

- **External factors:** The surgeon/medic may have limited knowledge of and no control over external issues. Nonetheless, optimal casualty care requires at least an assessment of these factors.
  - **Tactical situation and the mission:** The decision to commit scarce resources cannot be based on the current tactical/medical/logistical situation alone. One severely wounded, resource-consuming casualty may deplete available supplies and thus prevent future, less seriously injured casualties from receiving optimal care. Liaison with the tactical force operating in your area is essential to making sound triage decisions. Operational security may make this kind of information difficult to obtain in a timely fashion. **Education of, and communication with, line commanders about the critical nature of this information is essential.**

- **Resupply:** Having a sense of how and when expended internal resources will be resupplied may prove critical to making the decision to treat or not treat the individual casualty.
- **Time:**
  - **Evacuation to the MTF:** The shorter the time and distance interval from injury to arrival will increase the volume and complexity of triage decisions and increase the risk of the facility to be overwhelmed by the walking wounded. Securing the facility and strictly controlling points of entry are key steps in the execution of a mass casualty response. Longer intervals will result in the opposite, with "autotriage" of the sicker patients from the emergent category to the expectant.
  - **Time spent with the individual casualty:** In a mass casualty situation, time itself is a resource that must be carefully managed. All patients receive an evaluation, but only some receive immediate or operative interventions. Time on the operating room table is usually the choke point. Apply the damage control concepts to minimize the time casualties are required to spend in surgery. On-table triage to the expectant category may be necessary due to deteriorating casualty physiological response and/or the pattern of injury (aorta-vena cava GSW, dual exsanguination sites, extensive pancreatic-duodenal injury, etc).
  - **Evacuation out:** Casualties must move expeditiously to the next level of care, otherwise valuable local resources will be consumed in maintaining patients, thereby preventing additional patients from receiving care.

- **Internal factors:** These issues are known to all medical personnel and should be factored into triage decisions.
  - **Medical supplies:** These supplies include equipment, drugs, oxygen, dressings, sutures, sterilization capability, blood, etc. **Immediate** liaison with the logistics system in the MTF and the theater of operation is essential to ensure the availability and timely resupply of these items, to include "surge" capabilities and local resource availability. Blood products may be scarce in an immature theater

or during accelerated consumption in the case of mass casualty. Hemostatic or damage control resuscitation may be precluded by the availability of hemostatic transfusion components (plasma, platelets, cryoprecipitate). Transfusion medicine in the theater of war has in the past and will likely continue in the future to rely on the "walking blood bank," that is, using uninjured personnel as blood donors. It is crucial that expeditionary medical units have a system in place for effective and expedient execution of a fresh whole blood drive. Early consideration of a fresh whole blood drive should be included in the response to a mass casualty.

- **Space/capability:** This category includes the number of OR tables and intensive care unit (ICU) beds (holding capacity and ward capacity), the available diagnostic equipment—ultrasound, radiograph, computerized tomography (CT)—and laboratory tests. For example, if an MTF has the only CT scanner in theater, evaluation for an increased number of head-injured patients should be anticipated. Early in the mass casualty response, an assessment should be made to clear occupied beds in the hospital, either by discharge or potential transfer of patients to other appropriate treatment facilities within theater. This should be accomplished in coordination with the theater medical regulator and occur as soon as possible following notification.
- **Personnel:** This includes knowing the professional capability (type and experience of individual physician/nurse/medic), and the emotional stability, sleep status, etc, of your personnel. This perishable resource must be preserved; for example, 24 hours of continuous operation may exhaust your only OR crew and may necessitate diversion of casualties to another facility. A response plan should include mechanisms to sustain and refresh the staff with hydration and energy-dense foods during extended periods of high activity. Robust and practical plans for personnel recall must be a component of the mass casualty response plan. Also recognize that medical professionals may possess a range of skill sets that is not reflected in their deployment specialty (eg, the Reserve Component

physician who is a general surgeon in civilian practice, but who is assigned as a general medical officer or flight surgeon). Identifying and including these individuals as appropriate in a mass casualty response is a force multiplier.

- **Stress:** Soldiers, including medical personnel, are affected by the consequences of war; individual and unit capabilities are degraded during sustained operations. The personal impact of military triage on the medical team cannot be overemphasized. It is extremely emotional, and measures should be undertaken to minimize these effects. This is best provided by trained staff. Cohesive groups may tolerate stress better and assist each other in dealing with traumatic events when allowed to process the event in a group format according to their own traditions.

Triage Decision-Making

The complexity of decision-making in triage varies greatly, often depending on the level of training and experience of the triage officer, as well as the location where the triage decision is being made. In the emergent treatment area, the surgeon (ie, surgeon of the day; SOD) must make decisions about whether surgery is needed, the timing of the surgery, and the priority of multiple surgical patients. Regardless of the type of triage decision needed, the following information is of critical importance in reaching that decision:

- **Initial vital signs:** Pulse (rate and quality), mentation, and difficulty breathing (eg, a casualty with normal mentation and radial pulse quality is nonemergent). Respiratory rate alone is not predictive of the appropriate triage category.
- **Pattern of injury:** A historical perspective aids the triage decision-maker in understanding the distribution of wounds encountered on the modern battlefield and the likely mortality associated with those wounds. **The majority of combat wounded will suffer nonfatal extremity injuries**. In general, these will be triaged as nonemergent.
- **Response to initial intervention:** Does the shock state improve, remain unchanged, or worsen with initial resuscitative efforts? A patient who fails to respond rapidly to initial resuscitation

should be triaged ahead of a patient with a good response; alternatively, this nonresponder in a mass casualty situation may need to be placed in the expectant category.

Data from more recent American combat operations in Iraq and Afghanistan, 2007–2017—indicating the spectrum of injury type (Table 3-1), mechanism (Table 3-2), and anatomical location (Table 3-3)—are found in the tables.

Table 3-1. Type of Injury*

Type of Injury	Frequency	Percent
Penetrating	9,791	52.0%
Blunt	8,569	45.5%
Burn	452	2.4%
Other	12	0.1%
TOTAL	**18,824**	**100.0%**

*The data is battle injured patients only.
Data source: Department of Defense Trauma Registry.

Setup, Staffing, and Operation of Triage System

- **Initial triage area.**
  All casualties should flow through a **single triage area** and undergo rapid evaluation by the **initial triage officer**. Casualties will then be directed to separate treatment areas (emergent, nonemergent, and expectant), each with its own triage/team leader. The expectant will have a medical attendant who ensures monitoring and optimal pain control. The dead should be sent to the morgue and must remain separate from all other casualties, especially the expectant. Unidirectional flow of patients is important to prevent clogging the system. Reverse patient flow in any treatment area is highly discouraged.

No significant treatment should occur in the triage area. Casualties should be rapidly sent to the appropriate treatment area for care.

Table 3-2. Mechanism of Injury*

Mechanism of Injury	Frequency	Percent
IED	11,372	60.4%
Bullet/GSW/Firearm	3,608	19.2%
Mortar/Rocket/Artillery Shell	1,461	7.8%
Hand Grenade	874	4.6%
RPG	847	4.5%
Mine/Landmine	269	1.4%
MVC	126	0.7%
Fall	94	0.5%
Helo Crash	31	0.2%
Blunt Object	27	0.1%
Fire/Flame	21	0.1%
Knife/Other Sharp Object	18	0.1%
Other**	15	0.1%
Altered ROM	14	0.1%
Machinery/Equipment	14	0.1%
Inhalation Injury	10	0.1%
Altercation/Fight	8	0.04%
Penetrating NFS	8	0.04%
Pedestrian	7	0.04%
TOTAL	**18,824**	**100%**

*The data is battle injured patients only.
**Includes the following: Building Collapse, Plane Crash, Chemical, Crush, Submersion/Drowning, and unknown.
GSW: gunshot wound
Helo: helicopter
IED: improvised explosive device
MVA: moving vehicle accident
NFS: not further specified
ROM: range of motion
RPG: rocket-propelled grenade
Data source: Department of Defense Trauma Registry.

- Qualities of an ideal initial triage area should include:
  - **Proximity** to the receiving area for casualties—landing zone, ground evacuation, and decontamination area.
  - **One-way flow** both into and out of the triage area through separate routes to **easily identified, marked** (signs, colors, chemical lights, etc) treatment areas.

Table 3-3. Anatomical Location of Injury*

Anatomical Location	Frequency	Percent
Multiple Sites**	13,096	69.6%
Other	2,892	15.4%
Head or Neck	1,435	7.6%
Extremities or Pelvic Girdle	1,019	5.4%
Abdominal or Pelvic Contents	139	0.7%
Face	135	0.7%
Chest	108	0.6%
Total	**18,824**	**100.0%**

*The data is battle injured patients only.
**Casualties with more than one injury location are included in "multiple sites." These numbers are based on 18,824 Role 3 casualties.
Data source: Department of Defense Trauma Registry.

- ♦ **Well-lighted, covered, climate-controlled** (if possible) area with sufficient space for easy access, evaluation, and transport of casualties in and out.
- ♦ Dedicated **casualty recorders** to identify, tag, register, and record initial triage/disposition.
  - ◊ Using an indelible marker to place numbers on the casualty's forehead is an easy, fast way to track patients. Any method that is reproducible and simple will suffice.
  - ◊ If resources allow, casualty tracking may include stationing administrative personnel at every entry/exit.
- ♦ Sufficient **litter bearers** (controlled by an NCO) to ensure continuous casualty flow.

- ○ Initial triage officer.
  - ♦ Ideally, a surgeon experienced in dealing with combat trauma should be used in this capacity.
  - ♦ It is essential that another provider with trauma clinical experience be trained to assume this function, should the primary triage officer become indisposed.
  - ♦ Using mass casualty exercises or limited mass casualties situations is one way to train/identify the right person to fill this role.

- Emergent treatment area.
  - Setup.
    - Close proximity to initial triage area with direct access.
    - Administrative personnel stationed at entry and exit doors to record patient flow. Ideally, a display board or a computer should be used to record patient identity, location, and disposition.
    - Series of resuscitation bays (number depends on available resources/personnel).
      - Allow sufficient room for three-person team to work.
      - Easy access in and out of bay.
      - Availability of equipment needed for damage control/ATLS (Advanced Trauma Life Support)-style resuscitation (Figs. 3-1 and 3-2).
  - Staffing.
    - At Role 1 facilities, the most experienced healthcare provider should serve as the mass casualty Team Leader. At Role 2–4 facilities, the Chief of Trauma (most trauma-experienced surgeon) is responsible for overarching clinical management of the mass casualty response. The Chief of Trauma or a designated surgeon serves as the Chief Surgical Triage Officer at Role 2–4 facilities.
      - Determine priority for operative interventions.
      - Identify patients who require early evacuation.
      - Maintain close communication with the operating surgeon(s).
      - Reassess patients awaiting surgery or evacuation.
    - Security personnel: both for crowd control and to take possession of armaments (weapons, grenades, etc) from incoming patients.
    - Administrative person: Responsible for registering and tracking flow of patients through unit.
    - Resuscitation team: A physician or physician extender, nurse, and medical technician, ideally.
      - Each individual resuscitation treatment team will coordinate movement of its patients with the Chief Surgical Triage Officer.
  - Operation.
    - Manpower team delivers patient.

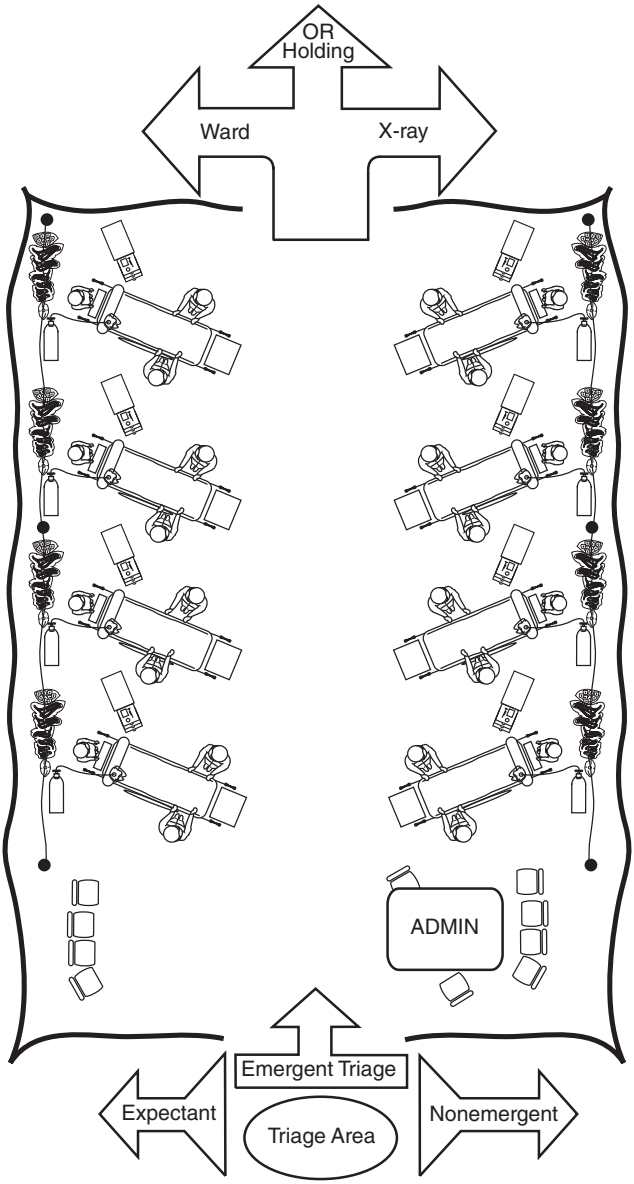

Fig. 3-1. Triage area. ADMIN: administrative personnel; OR: operating room.

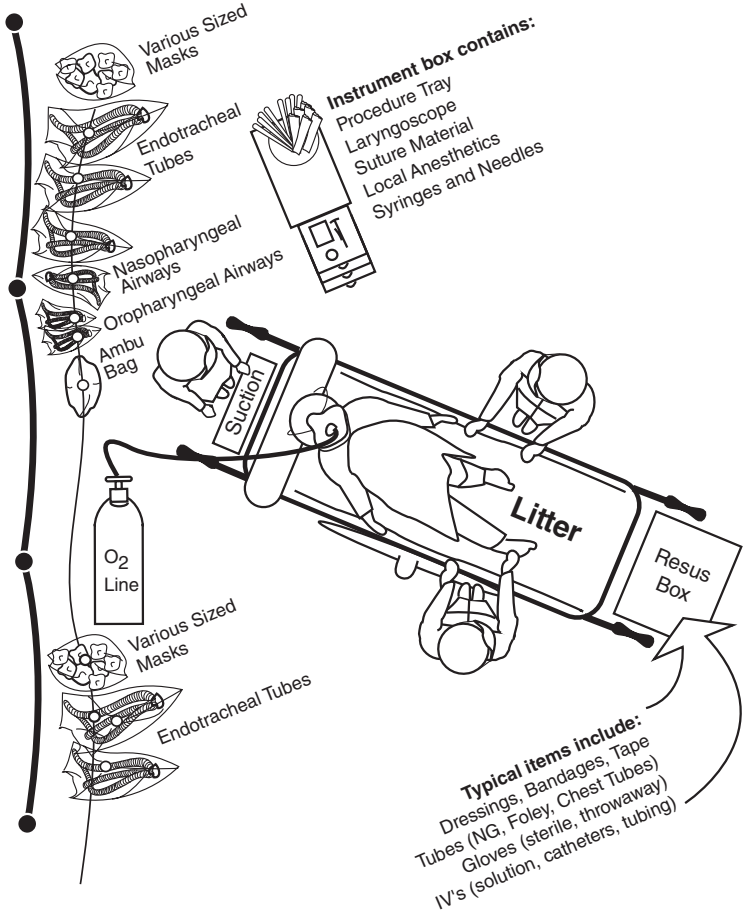

Fig. 3-2. Resuscitation station. IV: intravenous; NG: nasogastric; O_2: oxygen; Resus: resuscitation.

- Chief Surgical Triage Officer retriages patient and assigns resuscitation team to patient.
- Resuscitation team treats patient and coordinates required disposition (radiography, surgery, ICU, ward, and air evacuation).
- Resuscitation team communicates the recommended disposition to Chief Surgical Triage Officer.

- ♦ Chief Surgical Triage Officer coordinates movement of patient to next stop.
- ♦ Administrative person records disposition.

- **Nonemergent treatment area.**
  An empty ward, a cleared out supply area, or other similar space can be utilized. Appropriate medical and surgical supplies should be stockpiled and easily identifiable. A team consisting of a physician or physician extender and several nurses and medical technicians can form the nucleus of the treatment team. Lacerations can be sutured, fractures splinted, IVs placed, and radiographs taken. The team leader should be alert to changing vital signs, mental status changes, and nonrespondents to treatment. Any evidence of deterioration should prompt a retriage decision and a possible transfer to the emergent treatment area.
- **Expectant area.**
  Ideally, expectant casualties should be kept in an area away from all other treatment areas. The team leader can be anyone capable of giving parenteral pain medications and monitoring the patients. The patient should be kept comfortable. **After all other patients have been treated, a retriage of these patients should be done and treatment instituted if appropriate.**

Additional Triage Operation Tips

- Diversion of casualties to another facility should be considered. Triage of inpatients should be done to identify patients who may be discharged or transferred to predetermined facilities.
- As the casualties finally clear the OR suites, the pace will slow for the surgeons. ICU and ward care will supplant operative procedures. Casualties initially undertriaged (~10%) will be discovered and will require care. The recovery room and ICUs will become crowded, nursing shifts will have to be extended, and fatigue will rapidly become a hospital-wide factor.
- Numerous authors have stated that, after the first 24 hours of a mass casualty ordeal, the activities of the care providers must be decreased by 50%, allowing for recovery and rest for the participants. A new rotation must be established to sustain a modified, but continuous, effort. Once the acute phase is over, personnel must be required to rest.

- Prior to an actual mass casualty situation, all deployed or deployable units should exercise the mass casualty response plan to ensure smooth patient flow and identification. These exercises should evaluate patient registry and tracking, personnel, supplies, and equipment. The practical value of exercising and adapting the response plan to the changing facility, personnel, and tactical situation cannot be overstressed.
- Each mass casualty event or exercise requires debriefing, with evaluation of process and action plan to improve future response.
- Given the rotational nature of expeditionary medicine, lessons learned and after-action reports should be reviewed with incoming staff.

Triage remains our most constant and effective method of establishing order in overwhelming chaos. The organic integration of triage principles in tactical, logistical, and clinical decision-making remains the best hope for providing the greatest good to the greatest number.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 4

Aeromedical Evacuation

Introduction

Evacuation of injured personnel using rotary or fixed-wing aircraft has revolutionized the rapid transport of casualties from areas where there is either inadequate or no care available, to medical treatment facilities (MTFs) where essential and/or definitive care can be rendered. Although use of an aircraft can decrease transport time, the aeromedical environment creates unique stresses on the injured patient. The following are terms that describe evacuation of patients using aircraft.

- **Casualty evacuation (CASEVAC)** is the movement of a casualty from the point of injury to medical treatment by nonmedical personnel. Casualties transported under these circumstances may not receive en route medical care. Typically, this involves a helicopter returning from the battlefield.
- **Medical evacuation (MEDEVAC)** is the timely, efficient movement and en route care provided by medical personnel to the wounded being evacuated from the battlefield to MTFs using medically equipped vehicles or aircraft. Examples include civilian aeromedical helicopter services and Army air ambulances. This term also covers the transfer of patients from the battlefield to an MTF or from one MTF to another by medical personnel, such as from ship to shore.
- **Aeromedical evacuation (AE)** generally utilizes US Air Force (USAF) fixed-wing aircraft to move sick or injured personnel within the **theater of operations (intra**theater) or between two theaters (**inter**theater), such as moving a casualty from Afghanistan to Germany. This is a regulated system in which care is provided by AE crewmembers. The AE crews may be augmented with Critical Care Air Transport Teams (CCATTs) to provide intensive care unit level care.

- **En route care** is the maintenance of treatment initiated prior to evacuation and sustainment of the patient's medical condition during evacuation.

Medical Considerations for Patients Entering the Medical Evacuation System

Medical Considerations/Requirements

- Medical evacuation request includes requirement for surgical equipment and/or providers.
- Patient is stabilized for the anticipated mode and duration of travel.
- Patient's airway and breathing are adequate for movement.
- Patient's IV lines; drainage devices; physiologic monitoring devices (arterial catheters, intracranial pressure monitors, EKG leads, pulse oximeter, capnometer); and tubes are fully secured and patent.
- Small pneumothoraces have the potential for expansion at altitude, so early placement of a chest tube should be considered. Any patient with a pneumothorax regardless of the size should have a chest tube before any flight.
- Heimlich valves on chest tubes are functioning.
- Foley catheters and nasogastric tubes are placed and allowed to drain.
- Patient is covered securely with both a woolen blanket, and an aluminized blanket, or other warming system for air transport.
- Three litter straps are used to secure the patient to the litter.
- Earplugs should be provided to patients during flight.
- Personal effects and all medical records accompany the patient.

- Evacuation of a patient is initiated by the originating/sending physician according to established procedures. Patient administration personnel normally provide the administrative details and coordination required to accomplish the evacuation. Due to differences in the type of evacuation assets used and their effect on the patient's medical condition (eg, flying in

the pressurized cabin of an aircraft), requests to transport patients via the USAF AE system must also be validated for evacuation by the theater validating flight surgeon.

- For patients evacuated from Role 2 MTFs or Forward Surgical Teams (FSTs), the brigade surgeon (or designee) determines the evacuation precedence for all patients requiring evacuation from that facility. This is done in consultation with the FST's chief surgeon and/or senior nurse. When a patient is readied for evacuation from the FST by USAF assets, the supporting Patient Movement Requirements Center (PMRC) should be contacted at the earliest possible time. This allows the PMRC sufficient time to coordinate airlift and patient movement item requirements.

Implications of the Aviation Environment

- **General considerations prior to transport.**
  - Due to altitude effects, restricted mobility, limited staffing en route, and unpredictable evacuation times, the referring physician should tailor vital signs monitoring requirements and frequency of wound and neurovascular checks.
  - Some therapies that might not be required in a fixed MTF are appropriate for AE.
    - For example, patients with significant medical or surgical conditions should have Foley catheters, nasogastric tubes, provisions for IV pain medications, extended duration IV antibiotics, and appropriate nutrition.
  - Consider liberal use of fasciotomies/escharotomies.
  - Consider securing the airway with a prophylactic endotracheal tube.
  - Wounds dressed for delayed primary closure. Unless directed otherwise, the AE crew does not routinely redress wounds. However, if a patient develops fever or sepsis en route, wounds must be inspected.
  - The use of splints is preferable. Circumferential casts should be avoided or bivalved. Document neurovascular checks prior to and frequently during flight. Unrecognized extremity compartment syndrome in patients with regional blocks has the potential to be devastating.

- **Decreased barometric pressure.**
  - The volume of a gas bubble in liquid doubles at 18,000 feet above sea level. Cabin pressures in most military aircraft are maintained at altitudes between 8,000 and 10,000 feet. If an aircraft has the capability, the cabin altitude can be maintained at lower levels, but this will significantly increase flight time and fuel consumption.
- **Consider cabin altitude restriction (CAR) for the following:**
  - Penetrating eye injuries with intraocular air.
  - Free air in any body cavity.
  - Severe pulmonary disease.
  - Decompression sickness and arterial gas embolism require CAR at origination field altitude. Destination altitude should not be higher than origination altitude. Transport on 100% oxygen (by aviator's mask if available).
- Pneumothorax: Chest tube should be inserted for all pneumothoraces given the risk of expansion at altitude. All pneumothoraces must be drained prior to strategic air transport. A Heimlich valve or approved collection system must be in place prior to patient transfer to the flight line.
- Air Splints: Should be avoided.
- Ostomy Patients: Vent collection bags to avoid excess gas dislodging the bag from the stoma wafer. Use a straight pin to put two holes in the bag above the wafer ring.
- Decreased Partial Pressure of Oxygen: Ambient partial pressure of oxygen decreases with increasing altitude. At sea level, a healthy person has an oxygen saturation of 98%–100%. At a cabin altitude of 8,000 feet, this drops to 90%, which corrects to 98%–100% with 2 L/min of oxygen.
- Neurosurgical Patients: Hypoxia may worsen neurological injury. Adjust ventilator settings to meet increased oxygen demands at altitude.
- Acceleration Stress: Traumatic brain injury patients can experience transient marked increases in intracranial pressure during takeoff or landing. Patient positioning onboard the aircraft helps minimize this risk (head forward on takeoff, head aft on landing).
- Thermal Stress: Plan for cabin temperature changes from 15°C (59°F) to 25°C (77°F) on winter missions, and from 20°C (68°F)

to 35°C (95°F) on summer missions. Normothermia should be maintained by using approved devices.

- Noise: Exposure to noise can produce problems with communication and patient evaluation (auscultation is impossible—use noninvasive blood pressure monitoring and/or an arterial line). Provide the patient hearing protection. Audible medical equipment alarms are useless.
- Decreased humidity: Airplanes have very low cabin humidity at altitude. Evaporative losses will increase; therefore, patients will require additional fluids, especially those with large burns and those at risk for mucous plugging.
- **Patient movement in nuclear, biological, and chemical (NBC) environments:**
  - Nuclear and chemical casualties must be externally decontaminated and time allowed for off-gassing of residual chemical agent.
  - Movement of biological casualties varies by the nature of the agent, its mechanism of transmission, and the period of communicability during the course of illness.
  - Any NBC AE movement may be delayed due to the following:
    - Aircraft decontamination time.
    - Availability of noncontaminated aircrew.
    - Cohorting of similarly exposed patients.
    - Highly communicable diseases (eg, plague and smallpox) require special approval (command and diplomatic) before AE.
    - Chemically or radiologically contaminated casualties must be decontaminated before entering the AE system unless the theater and USTRANSCOM commanders direct otherwise.

Medical Evacuation Precedences

- Depending on the service, the type of evacuation assets used, and the evacuation environment, the timeframes for effecting evacuation differ. Refer to Table 4-1.
- **The USAF AE system:** The Air Force's AE system requires the availability of a secure landing strip, which can support the fixed-wing platforms that are used to move casualties. AE is a regulated, in-transit visible system utilizing a variety

of opportune aircraft with dedicated medical crews and equipment, primarily C-130, KC-135, and C-17. The medical crews are made up of flight nurses, aeromedical technicians, and medical attendants trained to perform routine care to stable patients during transport. This system is not designed as a primary/scene response team.

- AE personnel and equipment for inflight supportive patient care and flight line support operations.
- Organic communication network for medical facilities and airlift C2 agencies.
  - Aeromedical Evacuation Liaison Team (AELT): 4- to 6-person communication team, usually co-located with an MTF, to coordinate requests with the AE system.

Table 4-1. Evacuation Precedences*

Movement Precedence	Army, Navy, Marines (MEDEVAC)	Air Force (AE)	Description
Urgent	Within 1 h	ASAP	Immediate AE to save life, limb, or eyesight
Priority	Within 4 h	Within 24 h	Prompt medical care not available locally Medical condition could deteriorate and patient cannot wait for routine AE
Routine	Within 24 h	Within 72 h or next available mission	Condition is not expected to deteriorate significantly while awaiting flight

AE: aeromedical evacuation; ASAP: as soon as possible; MEDEVAC: medical evacuation.
*Timeline may vary based on patient requirements and logistical constraints.

- Aeromedical Staging Facilities (ASFs), generally located at major transit points, manage the administrative processing and staging, providing limited medical care of casualties entering or transiting the AE system. Patients are normally held only for 2–6 hours prior to evacuation.

- ASFs range in size/capability from small units deployed in support of Special Operation Forces to 100-bed facilities.

- **Reporting a patient for AE:** Originating physician consults with local flight surgeon to determine the en route care plan and timing of evacuation.

Due to the complexity of the aeromedical evacuation system, physicians must identify points of contact (local flight surgeons, the Aeromedical Evacuation Liaison Team, aeromedical staging elements, and the Patient Movement Requirements Center), verify and test lines of communication, and rehearse patient evacuation drills and procedures before the actual need arises.

- **Patient stability:** Patients validated for transport by AE must be stabilized as completely as possible prior to evacuation (airway secured, hemorrhage controlled, shock treated, and fractures immobilized).
  - Communicate the condition, AE category (ambulatory or litter), and movement precedence (see Table 4-1) of the patient to the PMRC, as communications assets allow (Table 4-2).

Table 4-2. Patient Movement Requirements Center Contact Information

PMRC	Commercial Telephone Number	Military Telephone Number
Global (Scott AFB, Illinois)	1-800-303-9301 or 1-800-874-8966	DSN 779-4200 or 8184
EUCOM Theater (Ramstein Air Force Base, Germany)	011-49-6371-47-2264 or 2235/2243	DSN 314-480-2264 or 2235/2243
PACOM Theater (Hickam AFB Hawaii)	808-448-1602	DSN 315-448-1602

AFB: Air Force Base; DSN: Defense Switched Network; EUCOM: European Command; PACOM: Pacific Command; PMRC: Patient Movement Requirements Center.

- To ensure optimum care, communicate with the accepting physician, and provide diagnosis, care rendered, and subsequent medical care plan (next 24–48 hours).
- Ensure that the patient has adequate quantities of supplies and medications for duration of transfer (at least 24 hours **intra**theater and 48 hours **inter**theater).

- **Local flight surgeon responsibilities.**
  - Authority for determining whether patients are physiologically ready for air transport.
  - Resource for AE system information, communication, and coordination (Table 4-3).
- **Request versus requirement:** AE **requests** and patient movement **requirements** are different. Physicians at originating MTFs submit requests for movement, timing, destination, suggested support therapies, etc. Only the validating flight surgeon (usually located at PMRC; not the local flight surgeon) and the PMRC can validate those requests, which then become AE requirements.

Table 4-3. The Aeromedical Evacuation Process

Activity	Location Where the Activity Occurs
Request for AE mission	Originating physician
Validation for AE	PMRC (establishes AE requirement)
Clearance to move by air	MTF (referring physician and local Flight Surgeon)

AE: aeromedical evacuation; MTF: medical treatment facility; PMRC: Patient Movement Requirements Center.

- **Validation versus clearance for USAF AE.**
  - AE **clearance** is a medical care event; **validation** is a logistical event.
  - **Clearance** is a decision between the referring physician and the local flight surgeon, addressing:
    - Description of the medical condition of the patient.
    - Probability that the patient can survive transit through an aviation environment.
    - What the patient needs to make the trip safely.
    - En route medical capability requirements.

- **Key steps for USAF AE patient request.**
  - Contact local flight surgeon and AE liaison for clearance consultation.
  - Determine the patient's AE category, based on diagnosis and ability to self-help in an emergency during flight.
  - Determine need for CCATT (see next page). The CCATT adds an additional level of support to the AE system for movement of *stabilized* patients who require a higher level of medical therapy or who have the potential to experience significant deterioration during movement. The CCATT physician is the clinical authority and, with the other team members, is responsible for documenting and providing care. CCATT members may be called on to consult and/ or assist in the care of other patients.
  - A five-person burn transport team can augment the AE system as required for inhalation injury and/or severe burns.
  - Determine if special requirements exist for transport (eg, CAR and splinting). Contact the Burn Center at SAMMC (210-233-5815, 210-222-BURN [2876], or DSN 471-2816) prior to initiating movement.
  - Determine patient movement items required (eg, ventilators, pulse oximeters, among others). Flight surgeon must verify that all items accompanying the patient are cleared for in-flight use.
  - Determine the patient's movement precedence.
  - Submit request.

Selection of the CCATT Patient

When deciding if a casualty requires the expertise of a CCATT, the provider needs to assess what requirements the casualty will have during transport.

Basic Definition of a CCATT Patient

Patients requiring CCATT transport include those in need of intensive nursing care, constant hemodynamic monitoring, mechanical ventilation, frequent therapeutic interventions, or other medical or surgical interventions vital to sustain life, limb, and eyesight during movement of the patient through the aeromedical environment.

To ensure mission success, a CCATT should be used to move the patient if any of the criteria listed below are present.

Use a CCATT if the patient:

- is intubated
- requires aggressive fluid administration or has received more than 10 units of blood products in the past 24 hours
- requires blood replacement or vasopressor support
- requires invasive hemodynamic or intracranial monitoring
- requires frequent suctioning or nebulizer treatments
- has an increasing oxygen requirement
- has undergone a vascular reconstruction
- has unstable angina
- has a condition requiring the need to initiate/continue IV drips for pain relief, anticoagulation, etc, while in flight
- has an unstable spine fracture
- requires the Vacuum Spine Board for movement
- has altered mental status
- will require electrolyte replacement and monitoring in flight.

If there is a question about whether a patient without any of the previously described criteria should be moved via CCATT, the sending provider should contact the theater validating flight surgeon. Consultation with all providers involved is fundamental in ensuring that the appropriate resources are used to move the patient safely.

Critical Care Air Transport Teams (CCATTs)

Intensivist Physician
- Capable of providing short-term life support, including advanced airway management, ventilator management, and limited invasive (nonoperative) procedures.
- Trained in critical care medicine, general surgery, anesthesiology, or emergency medicine.

Critical Care Nurse
- Experienced in managing patients requiring mechanical ventilation, invasive monitoring, and hemodynamic support.

Cardiopulmonary Technician
- Experienced in the management of patients requiring mechanical ventilation and invasive monitoring.
- Experienced in troubleshooting ventilatory support, portable laboratory devices, and monitoring systems.

After it is determined that a casualty requires the expertise of a CCATT, the next step lies in the preparation of that casualty for transport. The most important aspect in ensuring that the movement of a critically ill or injured patient is successful lies in the preparatory phase. To accomplish this task, the sending facility must make certain that all aspects of the Intertheater Transport Checklist are followed (see next page).

Upon arrival of the CCATT, a one-on-one report should be given to the team, thus ensuring that any changes of patient condition have been addressed. Whenever possible, it is preferred that the sending physician directly speaks to the CCATT physician prior to departure. This will ensure that a smooth transition of care is accomplished.

Humanitarian Transport Requests
- The process of arranging routine humanitarian evacuations out of theater can take more than 6 months.
- Appropriate patient selection is critical. Ideally, these patients have a single, fixable, stable problem.

Intertheater Transport Checklist

Name_____ DOB_____ SSN_____

Originating Facility_____ Destination Facility_____ Date_____

INTERVENTIONS	Initial
Patient Validated and Manifested for Flight:	
- AF Form 3899, Patient Movement Record completed	_____
- Notify destination facility accepting physician and Burn/Lung Team as appropriate	_____
- Determine need for medical/non-medical attendant or CCATT	_____
- Ensure identification card/passport/orders are with patient	_____
Patient Transport Considerations:	
- Maximize patient pre-flight condition (See AFI 41-307, AE Patient Considerations & Standards of Care)	_____
- Consider special equipment and need for equipment waiver	_____
- Determine need for restraints	_____
- Consider isolation precautions	_____
- Consider need for Over-size Litter (OSL) for patients in excess of 350 lbs (Green/Black DECON litter including patient & equipment)	_____
- Consider need for Stryker Frame bed (spinal stabilization/traction/pronation)	_____
- Determine need for blood product administration in-flight; contact blood bank as appropriate	_____
Patient Preparation:	
- Ensure patient identification and allergy bands are on patient	_____
- Complete patient care orders written for in-flight care	_____
- Pharmacy orders sent for medication preparation	_____
- Recently extubated patients should have been stable for 4 hours since extubation (unless approved by CCATT physician)	_____
- Verify airway patent; insert/secure ETT tube	_____
- Ensure adequate & functional IV access; secure; label IV tubing w/ med/fluid name for easy identification	_____
- Insert and secure arterial line; ensure transducer is correctly positioned and easily accessible	_____
- Insert Foley catheter for patients with difficulty ambulating or who cannot use bedpan/urinal while supine	_____
- Ventilated patients:	_____
1. Switch to transport ventilator at least 2 hrs prior to flight to ensure tolerance	_____
2. Obtain/review pre-flight chest x-ray/ABG	_____
3. Suction immediately prior to transport	_____
- Change dressings as close to patient departure time as possible	_____
- Perform anti-hijacking and complete associated documentation	_____
- Empty Foley and all drains immediately prior to departure	_____
- Obtain and document discharge vital signs/labs/I&Os, etc.	
- Administer pain/sedation medication	
Miscellaneous Preparation:	
- Obtain adequate oxygen supply for transport	_____
- Obtain all transport equipment and supplies	_____
- Obtain blood products	_____
- Obtain medications and IV fluids	_____
- Obtain copy of chart, x-rays, etc.	_____
- Gather personal property and complete associated documentation	_____
- Complete patient education (e.g.: self-administered medication, etc.)	_____
Patient Litter:	_____
- Prepare Green/Black DECON litter with litter pad and clean linens (back rest and IV pole, as applicable)	_____
- Pad patient appropriately; add and secure equipment	_____
- Cover with sheets and blankets	_____
- Apply at least two litter straps	_____
- Place Ambu-bag with face mask at head of litter	_____
Medical/Non-medical Attendant:	_____
- Ensure original deployment and travel orders to return to AOR	_____
- Provide point of contact for arrival and departure; planned itinerary back to AOR	_____

ABG: arterial blood gas; AE: aeromedical evacuation; AF: Air Force; AFI: Air Force Instruction; AOR: area of responsibility; CCATT: Critical Care Air Transport Team; DECON: decontamination; DOB: date of birth; ETT: endotracheal tube; hrs: hours; I&Os: intakes and outputs; IV: intravenous; med: medicine; SSN: Social Security Number; w/: with.

Data source: Joint Theater Trauma System Clinical Practice Guideline for Intratheater Transfer.

- The lack of suitable host nation care must be confirmed and documented. Regional care is preferred over transport to the continental United States (CONUS).
- Individual cases for humanitarian evacuation out of theater are unlikely to be successful without a passionate advocate. Personalizing the case with photos and compelling narrative is crucial for success.
- The approval process is complex and requires coordination with the local US embassy or State Department, host nation medical officials, and transit nations' ministries of foreign affairs or equivalent.
- All evacuated children must have an attendant. Those needing military transport require "Secretary of Defense Designee" status.
- Coordination also includes travel to the receiving medical center once in CONUS, obtaining diplomatic transit clearance while waiting in a third country for ongoing transport, and arrangements for return transport. Clearances must cover both the patient and the nonmedical attendant.
- Contact the servicing Patient Movement Requirements Center early for guidance.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 5

Airway/Breathing

Introduction
Rapid assessment and management of airway and ventilation are critical to preventing morbidity and mortality. Airway compromise can occur rapidly or slowly, and an airway may deteriorate after having been adequate in the initial assessment. Frequent reassessment is necessary. Preventable causes of death from airway problems in trauma include the following:

- Failure to recognize the need for an airway.
- Inability to establish an airway.
- Failure to recognize the incorrect placement of an airway.
- Displacement of a previously established airway.
- Failure to recognize the need for ventilation.
- Aspiration of the gastric contents.

Initial airway management at any level, but especially outside of medical treatment facilities, is crucial for the survival of casualties. The immediate goal is to move the tongue, pharyngeal soft tissues, and secretions out of airway. **Until a formal airway is established, place patients in the lateral or prone position (rescue position), unless cervical spine precautions are appropriate in the particular battlefield situation.**

- Chin-lift and head tilt.
  - Place fingers under the tip of the mandible to lift the chin outward from face.
- Two-handed jaw thrust.
  - Place both hands behind the angles of the mandible and displace forward. This method can be used on the patient with cervical injury.
- Oropharyngeal airway.
  - Estimate airway size by distance from corner of the mouth to the ear lobe.

- Insert oral airway upright if a tongue depressor is used (preferred method).
- Keep the airway inverted past the tongue, then rotate 180°.
- If the oropharyngeal airway is too small, it will not alleviate the obstruction. If the oropharyngeal airway is too long, it may fold the epiglottis caudally, worsening the obstruction.
- **Oral airways are not used in conscious patients.**

- Nasopharyngeal airway.
  - Pass lubricated nasal airway gently through one nostril.
  - Use with caution in significant facial/skull base fractures.
  - Is tolerated by conscious patients.
- Field expedient.
  - Pull tongue forward and safety pin or suture it to the corner of the mouth.
- Endotracheal intubation is preferred for transport in any unconscious/unstable patient.
- Cricothyrotomy.

Ventilation

- Ventilate patient with the bag-valve mask.
  - **Bring the face into the mask rather than pushing the mask onto the face**.
  - The chin lift and head tilt are also used during mask ventilation unless they are contraindicated due to cervical spine precautions.

Assess air movement during mask ventilation by observing the rise and fall of the chest, auscultation, absence of a mask leak, compliant feel of self-inflating bag, and stable oxygen saturation.

  - If air movement is not achieved, use **two-person mask ventilation** (Fig. 5-1).
    - One person lifts the jaw aggressively at the angles of the mandible; the other holds the mask and ventilates. Alternatively, one person may lift and hold the mandible with both hands, while at the same time holding down the mask on both sides. The other person ventilates the patient.

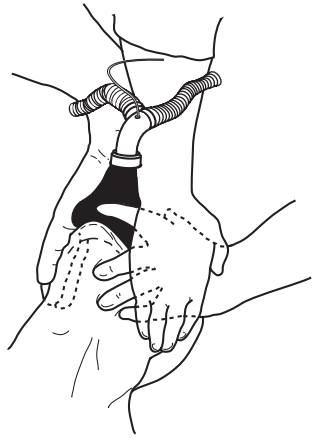

Fig. 5-1. Two-person mask ventilation.

- ♦ If air movement is still not present, obtain a definitive airway.

- ○ Unsuccessful and aggressive attempts at ventilation may result in inflation of the stomach, placing the patient at increased risk for vomiting and aspiration.

Positive pressure ventilation can convert a simple pneumothorax into a tension pneumothorax.

Perform frequent assessment and have equipment available for needle chest decompression.

Orotracheal Intubation

"7-P" Mnemonic for Rapid Sequence Intubation (RSI)

1. **PREPARATION**. Pre-intubation preparation checklist (see RSI checklist in Chapter 8, Anesthesia).
2. **PREOXYGENATE** with 100% oxygen by mask.
3. **PRE-INTUBATION OPTIMZATION.** Initiate appropriate damage control resuscitation (DCR).

4. **PARALYSIS INDUCTION**. Induction agent: ketamine 2 mg/kg IV/IO. Muscle relaxant: succinylcholine 1.0–1.5 mg/kg IV push (avoid in crush/burn injuries >24 h).
5. **PASS THE TUBE.** Laryngoscopy and orotracheal intubation.
6. **POST-PLACEMENT MANAGEMENT.** Verify tube placement.
7. **POST-INTUBATION SEDATION**.

Consider nasogastric (NG) or orogastric (OG) tube placement after securing airway.

- Direct laryngoscopy technique.
  - Ensure optimal "sniffing" position is achieved unless contraindicated by cervical spine injury.
  - Open the mouth by scissoring the right thumb and middle finger.
  - Hold the laryngoscope in the left hand and insert the blade along the right side of the mouth, slightly displacing the tongue to the left.
    - **Macintosh** (curved) blade: Advance the tip of the blade into the space between the base of the tongue and the epiglottis (ie, into the vallecula). Apply force at a 30°–45° angle, lifting the entire laryngoscope/blade without rocking it backward (Fig. 5-2).

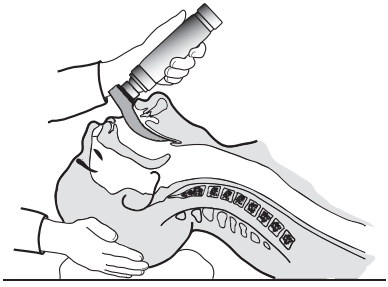

Fig. 5-2. Use of curved blade laryngoscope.

- **Miller** (straight) blade: Advance the tip of the blade into the posterior oropharynx, picking up the epiglottis and tongue base anteriorly and laterally, and apply a force vector like that of the Macintosh blade. Avoid rocking the laryngoscope backward (Fig. 5-3).

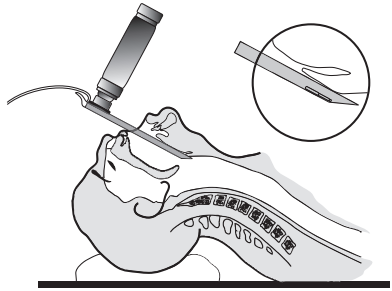

Fig. 5-3. Use of straight blade laryngoscope.

- Visualize the vocal cords.
- Consider the "BURP" (Backward Upward Rightward Pressure) maneuver when the laryngoscopic view is poor (Fig. 5-4).

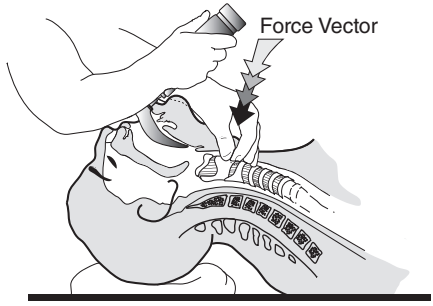

Fig. 5-4. BURP (Backward Upward Rightward Pressure) maneuver.

- "BURP" of the larynx was also referred to as external laryngeal manipulation.
- Place the fingers of an assistant onto the larynx with your right hand and manipulate the glottic opening into the field of view.

- ♦ Assistant then holds the position for intubation.
- ○ **Eschmann stylet** or Gum Elastic Bougie (Fig. 5-5).

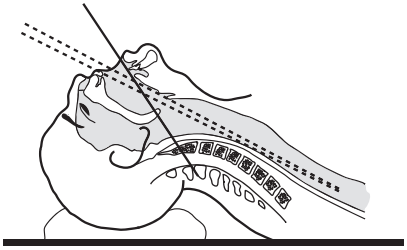

Fig. 5-5. Eschmann stylet in place.

- ♦ Blindly guide the tip of the stylet beneath the epiglottis, then anteriorly through the vocal cords.
- ♦ Advance the bougie deeply. Placement into the trachea results in the sensation of tracheal ring "clicks" and turning of the stylet as it passes airway bifurcations.
- ♦ The patient may cough as the stylet passes through the airway.
- ♦ When passed beyond the trachea, the stylet will stop at a terminal bronchus. If placed into the esophagus, it will pass indefinitely into the stomach without any tactile feedback.
- ♦ The endotracheal tube (ETT) is guided over the stylet into the airway, and tracheal intubation is confirmed.
- ○ Advance the ETT between the vocal cords, withdraw stylet, and advance the ETT to 20–21 cm at the teeth for adult females and 22–23 cm for adult males. Deeper placement may result in right mainstem intubation.
- ○ Confirm placement of the ETT in the trachea.
- ○ Auscultate over the axilla to ensure that breath sounds are equal.

Avoid making more than three attempts at direct laryngoscopy. Excessive attempts may result in airway trauma and swelling, potentially turning a "cannot intubate" urgency into a "cannot intubate–cannot ventilate" emergency.

Difficult Airway

After three unsuccessful attempts at direct laryngoscopy, abandon the technique and try alternatives.

- Alternative intubation techniques.
  - Video-assisted laryngoscopy (GlideScope Ranger) is currently a key tool.
  - Gum elastic bougie. Visualize epiglottis, pass inferior and anterior, feel for tracheal rings, hard stop/diversion at carina. If in esophagus should be bottomless soft feel. Pass tube over bougie once in trachea. If resistance at arytenoids, slightly withdraw, rotate ETT, and pass tube gently.

Do NOT use gum elastic bougie in penetrating upper airway trauma or central airway obstruction (foreign body).

  - Alternative (extraglottic) airways.
    - ♦ May NOT be definitive airways.
    - ♦ Allow for oxygenation and ventilation when standard airways cannot be placed.
    - ♦ Supraglottic airways.
      - ◊ laryngeal mask airway (LMA)
      - ◊ iGEL
    - ♦ Retroglottic airways.
      - ◊ King LT
      - ◊ Combitube
- Perform a surgical airway.

Surgical Cricothyrotomy

- Identify cricothyroid membrane (between cricoid ring and thyroid cartilage [Fig. 5-6a]).
- Prep skin widely.
- Grasp and hold trachea until airway is completely in place.
- Make a **vertical SKIN** incision down to the cricothyroid membrane (a no. 10 or no. 11 blade).
- Bluntly dissect the tissues to expose the membrane.
- Make a **horizontal MEMBRANE** incision (Fig. 5-6b).
- Open the membrane with forceps or the scalpel handle.
- Insert a small, cuffed ETT, 6.0–7.0 inner diameter, to just above the balloon (Fig. 5-6c).

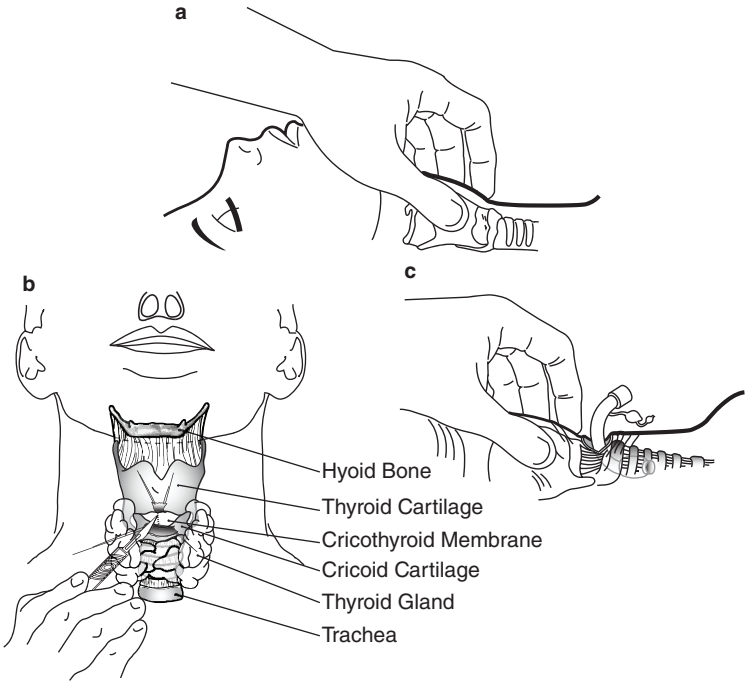

Fig. 5-6. Steps of surgical cricothyrotomy. (**a**) Identify cricothyroid membrane. (**b**) Make a horizontal membrane incision. (**c**) Insert a small, cuffed ETT to just above the balloon.

- Confirm tracheal intubation.
- Suture the ETT in place and secure it with ties that pass around the neck.

Laryngeal Mask Airway

- Insert blindly without a laryngoscope. The laryngeal mask airway (LMA) rests over the laryngeal inlet.
- Compared to an ETT, the LMA supports less airway pressures and offers less aspiration protection.
- Check the LMA cuff, then deflate it until the down side (inner) surface is smooth and flat; lubricate the pharyngeal (upper) side of the LMA.
- The sniffing position works best, but the LMA may be inserted in different patient positions.

- Insert LMA (3–4 for women, 4–5 for men) with upper (pharyngeal) side **gliding along the hard palate, down and around into the posterior pharynx**. This allows proper direction and reduces the chance of cuff folding.
- Do **NOT** push the LMA directly back into the mouth. This folds the cuff and prohibits proper placement.
- Inflate cuff with 20–30 cc of air via syringe. Slight upward movement of the LMA tubing is seen.
- Secure the LMA.

King LT Insertion

- Place patient in sniffing position and introduce the King tube blindly into the corner of the mouth.
- Gently advance the tube until base of connector is aligned with the teeth.
- Inflate the cuff according to the volume noted on tube.
- Attach ambu bag. While gently bagging, slowly withdraw tube until ventilation is easy and free flowing with minimal airway pressure and use tube confirmation measures.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 6

Hemorrhage Control

The hemorrhage that take[s] place when a main artery is divided is usually so rapid and so copious that the wounded man dies before help can reach him.
— Colonel H. M. Gray, 1919

Stop the Bleeding!

- Hemorrhage is the leading cause of preventable death on the battlefield.
  - 90% of combat fatalities occur forward of a medical treatment facility.
  - 75% of combat fatalities have nonsurvivable injury and 25% have potentially survivable injury. Of those with potentially survivable wounds, 90% die from hemorrhage.
  - Although bleeding is a main cause of death, the vast majority of wounds do not have life-threatening bleeding.

CARE UNDER FIRE

- Return fire, find and move to cover.
- Give the casualty directions to move to cover and perform self-aid.
- Get the patient out of the line of fire — prevent further injury.
- Control life-threatening external bleeding once out from effective fire.
- Remove patient from structural harm (burning vehicles, building, etc).
- Do not endanger the casualty or yourself with unnecessary treatment.
- Stay engaged in the firefight if necessary.

KEEP YOUR HEAD DOWN

Sites of Hemorrhage

- External.
  - Extremity injury (most common cause of massive external blood loss in combat), scalp, and torso wounds.
  - Usually associated with an open fracture or amputation.
- Internal.
  - Chest, abdomen, pelvis, and closed extremity fractures.
  - High mortality if the casualty is not expeditiously transported and salvage surgical procedures performed.
  - Controlled (hypotensive) resuscitation should be implemented. (See below; also see Chapter 7, Shock, Damage Control Resuscitation, and Vascular Access.)

Internal Torso Bleeding Requires Surgical Control

Treatment — Tactical Field Care

- External hemorrhage from extremity wounds.
  - Apply a **tourniquet.**
    - Use a tourniquet early, rather than allow ongoing blood loss.
    - Tourniquets should not be removed until the hemorrhage can be reliably controlled by advanced hemostatic agents or until arrival at surgery.

Tourniquet Is the First Choice in Combat

    - Tourniquet placement on the forearm or lower leg might not compress the vessels, which lie between the double long bones. Tourniquets on the upper extremity should be placed on the upper arm. If bleeding from the lower extremity is not controlled by a tourniquet on the leg, it should be moved to the thigh, where the vessel may be more easily compressed.
    - A second tourniquet may need to be added to provide better hemostatic control.
    - Point compression of the proximal artery.
      - May help slow bleeding while attempting to gain better control at the wound site.

◊ Table 6-1 and Figure 6-1 show the recognized pressure points.

Table 6-1. Recognized Pressure Points

Bleeding Site	Hand	Forearm	Arm	Leg	Thigh
Artery	Radial/ulnar	Brachial	Axillary	Popliteal	Femoral
Pressure point	Wrist	Inner upper arm	Axilla	Behind knee	Below groin crease

- Junctional wounds.
  - High femoral/pelvic and axillary wounds.
  - Junctional wounds are not amenable to tourniquets but are compressible.
  - Initial treatment is direct pressure and wound packing with hemostatic agents (which require 3 minutes of direct pressure after application).
  - Transition to a junctional tourniquet (leaving hemostatic agents in place).
- **Clamping vessels:** If there is continued bleeding and a damaged vessel can be readily identified, a hemostat may be used to clamp the visualized vessel.
- **Limb splints** will decrease bleeding associated with fractures and soft-tissue injury by aligning, stabilizing, and returning the limb to length.
- **Scalp bleeding:** Can be significant due to the rich vasculature of the scalp.
  - Responds to direct pressure.
  - However, it is difficult to apply and maintain direct pressure.
  - Compression dressings must be applied if you cannot provide ongoing direct pressure.
  - Requires circumferential head application.
  - Vertical mattress suture closure sometimes is necessary to control bleeding scalp edges.
  - A readily identified bleeding vessel can be clamped, but the wound should generally not be explored.

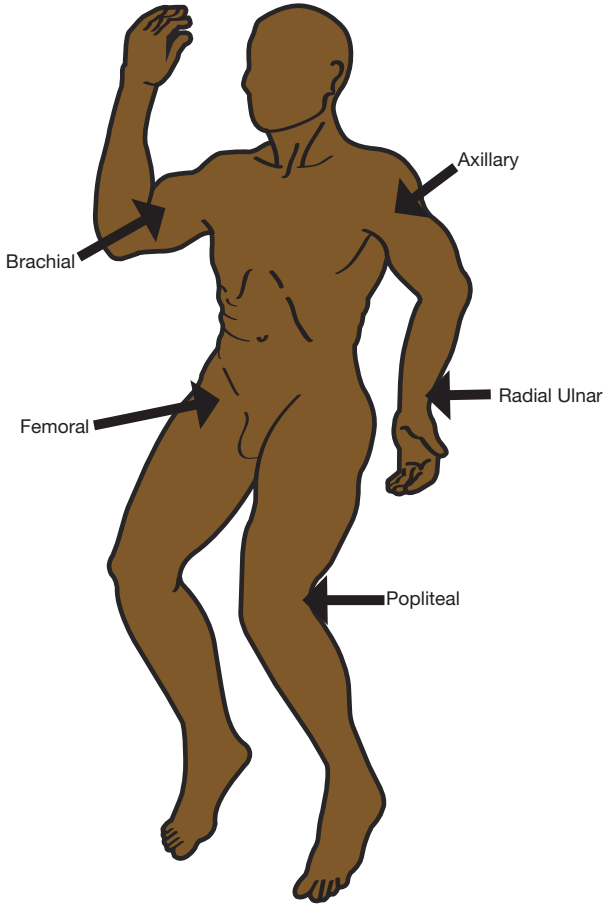

Figure 6-1. Recognized pressure points.

- Avoid pushing fragments into the brain when applying pressure, but control hemorrhage even at the expense of exposed brain.
- Protection of exposed brain with nonadherent gauze or plastic can minimize injury.

- **Internal bleeding.**
  - Blood loss into the abdomen or chest cannot be controlled in the field and requires immediate evacuation for salvage or definitive surgery.

- Stabilize a suspected pelvic fracture with a pelvic binder or by wrapping the pelvis tightly with a wide strap (such as a folded sheet).
- Open torso injuries: If direct pressure does not stop the hemorrhage, consider inserting a tamponade with a balloon (Foley) catheter into the wound. Then, with the balloon inflated, pull back to compress the bleeding site.

Dressings, Bandages, Hemostatic Agents, and Controlled Hypotension

Dressings promote hemostasis, protect wounds from mechanical injury and contamination, immobilize tissues, and provide physical and psychological support to the patient.

- **Application of dressings and bandages.**
  - Control all bleeding.
  - Assess neurological status and circulation of extremity before and after applying a dressing or bandage.
  - Immobilize suspected fractures.
  - Keep dressing as clean as possible.
  - Dressings should cover the entire wound.
  - Bandages should cover the entire dressing.
  - Avoid skin-to-skin contact.
  - Leave fingers and toes exposed.
  - **Reinforcement.**
    - If at all possible, **DO NOT** remove the first dressing.
    - If the dressing becomes thoroughly saturated, reevaluate the wound for a source of bleeding amenable to direct pressure and consider advanced hemostatic agents or a proximal tourniquet. Blood loss into the dressing can be estimated.
  - Coagulopathy: Blood loss, massive fluid resuscitation, and a drop in body temperature may lead to an inability to form clots.
    - Keep patient warm (above 34°C).
    - Use warm fluids.
    - Use crystalloid fluids sparingly.
    - Transfuse with component therapy or fresh whole blood in accordance with current Clinical Practice Guidelines (CPGs).

- Hemostatic agents: New products and bandages are available in several forms:
  - Dressings: Impregnated with hemostatic agents.
  - Injectables.
    - Intravenous: Augment clotting cascade of body.
    - Intracavitary: Through wounds to control internal bleeding.
  - Two-component "glues."
  - If an advanced hemostatic agent is used after a tourniquet has been placed, the tourniquet may be carefully removed after the agent has achieved hemostasis and the wound observed for hemorrhage. If hemorrhage recurs, replace the tourniquet.

- See current TCCC Guidelines/CPGs for a list of hemostatic agents.

Hemostatic Agents

- Blood and clot should be wiped out of the wound prior to application.
- Pressure must be applied for 3–5 minutes at the bleeding site, after application of a hemostatic dressing.

Field Hemostatic Dressings—Considerations

- Do not use on minor injuries.
- Must apply pressure to the bleeding site after application.
- Effectiveness is limited if hemostatic agent is not in contact with the bleeding source in a deep wound.

- **Controlled Resuscitation** (Permissive Hypotension).
  - Resuscitation is a method of hemorrhage control. The needs of organ perfusion must be carefully balanced against the risk of increased bleeding as blood pressure rises. Excessive fluid resuscitation may increase bleeding and rebleeding. Prior to definitive hemorrhage control, a lower than normal blood pressure may be acceptable. Small volumes of resuscitation fluid are still required in those casualties with decreased mentation due to hypotension (ie, decreased or absent radial pulse).

Reference

Gray HMW. *The Early Treatment of War Wounds*. London, UK: Henry Frowde Hodder & Stroughton/Oxford University Press; 1919.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 7

Shock, Damage Control Resuscitation, and Vascular Access

Introduction

The goal of resuscitation is to maintain adequate perfusion. Resuscitation of the wounded combatant remains a formidable challenge on the battlefield. Resuscitation begins with the placement of two large-bore IVs (16 or 18 G). **The vast majority of casualties do not need any IV fluid resuscitation prior to arrival at a forward medical treatment facility**. For the more seriously injured trauma patients in the presurgical setting, the goal is to deliver the patient to a surgical facility expeditiously while maximizing the patient's chances of survival. This is accomplished using damage control resuscitation (DCR) principles at point of injury (POI), Role 1, and Role 2 facilities in order to mitigate the lethal triad of acidosis, hypothermia, and coagulopathy. For the approximately 10% of casualties who constitute the most seriously injured, are in shock and coagulopathic, and represent potentially preventable hemorrhagic deaths, blood products should be part of the initial fluid resuscitation.

This chapter will briefly address shock (including recognition, classification, treatment, definition, and basic pathophysiology), review initial and sustained fluid resuscitation, summarize currently available fluids for resuscitation, and describe vascular access techniques.

Recognition and Classification of Shock

Shock is a clinical condition marked by inadequate organ perfusion and tissue oxygenation, manifested by poor skin turgor, pallor, cool extremities, capillary refill greater than 2 seconds, anxiety/confusion/obtundation, tachycardia, weak or thready pulse, and hypotension. Lab findings include base deficit >5 and lactic acidosis >2 mmol/L.

- **Hypovolemic shock:** Diminished volume resulting in poor perfusion as a result of hemorrhage, diarrhea, dehydration, and burns. **Shock in the setting of trauma is hypovolemic until proven otherwise** (Table 7-1). In the prehospital setting, particularly at POI where laboratory analysis is not available, hypovolemic shock is indicated by altered mental status and a weak thready radial pulse.

Hypotension suggests a profound shock state, occurring after 30%–40% blood volume loss. Earlier signs are tachycardia, decreased pulse pressure, and mental status changes. However, even these earlier signs may not be readily apparent in military casualties who generally have a greater propensity for physiological compensation secondary to physical conditioning.

Table 7-1. Clinical Correlates in Hypovolemic Shock

Size Designation: Blood Loss (mL):	Class I <750	Class II 750–1,500	Class III 1,500–2,000	Class IV >2,000
Blood volume*	<15%	15%–30%	30%–40%	>40%
Pulse	<100	>100	>120	>140
BP	Normal	Normal	↓	↓
Pulse pressure	Normal	↓	↓	↓
RR	14–20	20–30	30–40	>35
UOP (cc/h)	>30	20–30	5–15	Negligible
CNS	Normal	Anxious	Confused	Lethargic

BP: blood pressure; CNS: central nervous system; RR: respiratory rate; UOP: urine output.
*Blood volume is approximately 7% (eg, a 70-kg patient has a blood volume of 4,900 mL).

- **Cardiogenic shock:** Pump failure from intrinsic cardiac failure or obstructive cardiac dysfunction from a tension pneumothorax (unilateral absence of breath sounds + distended neck veins) or cardiac tamponade (distended neck veins).
- **Distributive shock:** Poor perfusion due to loss of vascular tone.

- **Neurogenic shock:** Bradycardia with hypotension, seen with spinal cord injury T6 and above due to loss of sympathetic tone and unopposed parasympathetic stimulation with resultant vasodilation.
- **Septic shock:** Fever, hypotension, tachycardia, and warm extremities from massive vasodilation related to infection.

Treatment of Hypovolemic Shock—Control Bleeding!

The goal in the treatment of shock is to restore tissue perfusion and oxygen delivery (dependent on hemoglobin, cardiac output, and oxygenation).

- Control obvious bleeding and assess for occult hemorrhage.
- Secure the airway and administer oxygen for SaO_2 <92%.
- Diagnose and treat tension pneumothorax.
- Assess circulation and establish IV access.
  - Consider cardiac tamponade, even if there are no distended neck veins.
- Presurgical setting: follow TCCC guidelines (permissive hypotension in the non-head injured patient, Hextend bolus × 2).
- Role 2/3: Resuscitate initially with any fluid available. If patient is received after prior treatment, consider fluids already received in treatment decisions. Strong consideration must be given for early blood product transfusion, particularly in those casualties at risk for a massive transfusion (>10 units of PRBCs [packed red blood cells] in 24 hours).
  - Physiological/laboratory predictors of massive transfusion include:
    - Systolic blood pressure <110.
    - Heart rate >105.
    - Hematocrit <32%.
    - pH <7.25.
    - 3 of 4 risk factors = 70% risk massive transfusion.
    - 4 of 4 risk factors = 85% risk massive transfusion.
  - Injury patterns associated for risk of massive transfusion include:
    - Truncal/axillary/neck/groin bleeding not controlled by tourniquet or hemostatic dressings.
    - Multiple amputations.

- Large soft-tissue injuries with uncontrolled bleeding.
- Large hemothorax.
- Large hemoperitoneum.

These patients should be immediately resuscitated with blood products (PRBCs:fresh frozen plasma [FFP]:platelets) in a 1:1:1 ratio or consider fresh whole blood if full component therapy not available.

- Based on response to fluids, casualties will fall into three groups: responders, transients, and nonresponders.
  - **Responders**: Casualties with a sustained response to fluids may have had significant blood loss, but have stopped bleeding. However, they may still require definitive surgery.
  - **Transient** and **nonresponders** are continuing to bleed. They need immediate surgical intervention.
    - Start blood product transfusion as soon as possible, with a target goal ratio of 1:1:1 (PRBCs:FFP:platelets).
    - For nonresponders, fluids may be given to keep the casualty alive, but you should not attempt to restore pressure to normal. Consideration should be taken into account of the futility of the resuscitation, depending on the tactical scenario.
    - Follow **controlled resuscitation** guidelines as presented in this chapter.

Exsanguinating hemorrhage is the cause of most preventable deaths during war. Combat casualties in shock should be assumed to have hemorrhagic shock until proven otherwise.

- Vasopressors have NO role in the initial treatment of hemorrhagic shock.
- Resuscitation fluid selection.
  - See TCCC guidelines for the most current management (Table 7-2).
  - Blood product transfusions should be considered early in the resuscitation, particularly in patients who have lost 30% or more of their blood volume. Blood products may also be

Table 7-2. Intravascular Resuscitation Fluids

Fluid/Initial Dose	Indication	Advantages	Cautions
Crystalloids	Hypovolemia,	Easy to store, inexpensive,	Weight ratio—requires 3:1 for lost blood,
Saline	hemorrhage, shock,	proven effectiveness,	dilution, edema, coagulopathy
Ringer's lactate	burns	isotonic	
Hypertonic saline	Hemorrhagic shock:	Lighter weight	>500 cc—risk of hypernatremia, seizures
3%–5%	4 cc/kg or 250 cc bolus,	Small volume = large effect	Do not use for dehydration from vomiting,
7.5%*	may repeat once	Increased cardiac contractility	diarrhea or sweating, or heat injuries
HTS–colloid	Burns—only one dose	Longer duration of effect than	Do not repeat without addition of other
combinations*	initially	plain HTS?	fluids
HTS dextran*			Must replace depleted extravascular fluid
HTS Hetastarch*			
Colloids	Hemorrhagic shock	Longer duration	Overuse may lead to "leak" into tissue
Albumin	(500–1,000 mL bolus)	1:1 replacement for blood	Binds immunoglobulins and Ca^{2+}
Artificial colloids	Burns? 3rd day	Raises plasma oncotic pressure	Must replace depleted extravascular fluid
Dextran		Recruits extravascular fluid	Artificial colloids:
6% Hetastarch		Weight/cube better than	coagulopathy, allergic reaction, osmotic
(Hextend, Hespan)		crystalloids	diuresis, interferes with cross-matching
10% Pentastarch*			Hetastarch: ↑ fibrinolysis, ↑ amylase
Gelatin-based colloids*			Maximum dose: 20 mL/kg/d (about 1.5 L)
Oral rehydration fluids	Dehydration-controlled	Fluids of opportunity	Austere option in abdominal wounds and
	hemorrhage	Nonsterile ingredients: 4 tsps	unconscious patients, but use with caution
	Burns	sugar, 1 tsp salt, 1 L water	
Blood	Hemorrhage—type O	Carries oxygen	Storage, type, and cross-match
	universal donor	Autotransfusion	Transfusion reactions, infection,
		Walking blood bank	immunogenic
Artificial blood	Hemorrhage	Easy storage	Experimental only, not yet available for use
Hemoglobin-based		No type and cross-matching	Fluorocarbons require supplemental oxygen
Fluorocarbon-based			Future option?

FDA: Food and Drug Administration; HTS: hypertonic saline. *Not FDA approved.
Data source: *Emergency War Surgery, Third United States Revision*. Washington, DC: Department of the Army, Office of The Surgeon General, Borden Institute; 2004.

necessary in patients who have not reached this threshold, but who have ongoing blood loss or who are at high risk of ongoing bleeding. Fresh whole blood therapy should be considered at levels of care where component blood product therapy (ie, PRBCs, FFP, platelets) is inadequate to meet the target goal ratio of 1:1:1.

Concept of Controlled Hypotensive Resuscitation / Permissive Hypotension

- Raising the blood pressure with fluid resuscitation may dislodge established clots, leading to continued blood loss. Prior to establishing definitive hemorrhage control, use controlled resuscitation to achieve and maintain adequate perfusion as demonstrated by at least one of the following prioritized goals:
  - Regains consciousness (follows commands).
  - Palpable radial pulse.
  - SBP (systolic blood pressure) ~90 mm Hg.
  - MAP (mean arterial pressure) ~60 mm Hg.

Controlled resuscitation (permissive hypotension) is NOT a substitute for definitive surgical control. It is an attempt to keep a critically injured casualty alive until definitive treatment.

- Endpoints of resuscitation.
  - Following definitive hemorrhage control, more traditional endpoints of resuscitation include:
    - Blood pressure: SBP >110–120 mm Hg, MAP >65–70 mm Hg.
    - Urine output: >0.5 mL/kg/h (approximately 30 mL/h).
    - Correction of acidosis by achieving base deficit <2 or serum lactate <2 mmol/L.
  - Hypothermia: It is important to maintain normal body temperature. Fluids, blood products, and casualty care areas must be warmed. Casualties frequently arrive at the facility hypothermic. Keep casualties covered when on litters, radiograph tables, and operating tables. External warmers should be used in all casualty care areas from

initial emergency area through operating room and ICU. Hypothermia is much easier to prevent than it is to treat. See further discussion of hypothermia in Chapter 12, Damage Control Surgery. Also see JTTS (Joint Theater Trauma System) Clinical Practice Guideline "Hypothermia Prevention."

Vascular Access

- Vascular access is a critical early step in the management of trauma.
- Large-bore peripheral access in the antecubital fossa should be attempted first; if unsuccessful, consider intraosseous (IO) device placement for initial resuscitation, followed by alternatives such as percutaneous central line (ie, subclavian, internal jugular, femoral veins) or "cutdowns" (saphenous vein either at the groin or ankle).

Subclavian Vein Access or Internal Jugular Venipuncture

- Place the casualty supine in the Trendelenburg position (15° head down).
- Prep and drape subclavian/jugular area. Sterile gloves must be worn. Use central line access kit.
  - Subclavian line.
    - With an index finger placed at the sternal notch, the thumb is placed at the junction of the medial and middle third of the clavicle.
    - 1% lidocaine is infiltrated into the skin, subcutaneous tissue, and periosteum of the clavicle.
    - Introduce a large caliber needle with an attached 5-mL syringe at the junction of the middle to lateral portion of the clavicle. Insert with the bevel of the needle up, directing the needle toward the contralateral clavicular head. Keep the needle horizontal to avoid a pneumothorax.
    - While aspirating, slowly advance the needle underneath the clavicle.
  - Jugular vein line.
    - Turn the casualty's head 45° toward the contralateral side to expose the neck. Position must be altered to neutral position if concern exists for cervical spine injury.

- Current standard of care is to perform under ultrasound guidance; however, if not available, it can be performed using landmarks as follows:
  - Identify the apex of the anterior cervical triangle formed by the heads of the sternocleidomastoid muscle to locate the carotid artery.
  - Palpate the carotid artery and stay lateral with your venipuncture.
  - Introduce a large-bore needle on a 10-mL syringe at a 45° angle into the apex of the triangle, lateral to the carotid pulse.
  - Advance the needle caudally, parallel to the sagittal plane and at a 30° posterior angle (ie, toward the ipsilateral nipple).
  - When free flow of venous blood appears, advance the needle an additional 4 mm (the length of the needle bevel), then remove the syringe and quickly cover the hub of the needle to prevent air embolism.
    - If air or arterial blood appears, stop immediately. Withdraw needle immediately and place pressure at the site for at least 5 minutes.
  - If no venous blood returns after advancing 5 cm, slowly withdraw the needle while aspirating. If this fails, redirect the needle.
- Subclavian vein or internal jugular vein catheter insertion.
  - Once the needle is in the vein, introduce the "J" wire through the needle (Seldinger technique). The wire should pass with minimal resistance. If the wire does not pass easily, withdraw the entire apparatus and reattempt line placement.
  - Remove the needle.
  - Enlarge the puncture site with a scalpel and dilator.
  - Pass the catheter over the wire while holding the wire in place to a depth of 18 cm on the left and 15 cm on the right for subclavian, and to a depth of 9 cm on the right and 12 cm on the left for jugular vein; then remove the wire.
  - Aspirate from all ports, flush all ports, suture in place, apply antibiotic ointment, dress area, secure tubing, and label date of insertion.

- ♦ Chest radiograph to ensure line position and rule out pneumothorax.

Intraosseous Infusion

- Contraindications.
  - Trauma or infection at insertion site.
  - Excessive tissue or absence/inadequate anatomic landmarks.
  - Recent IO device at the same site.
  - Fracture of insertion bone.
  - Recent sternotomy.
- Devices/procedure.
  - Procedure techniques vary based on model and can be either manual or power-driven.
    - ♦ Manual: Cook, FAST1, sternal EZ-IO, Sur-Fast.
    - ♦ Semiautomatic: Adult and pediatric Bone Injection Gun (B.I.G.)—spring-loaded, adult and pediatric EZ-IO—battery-powered drill.
    - ♦ Adult versus pediatric IO devices and needles are usually specified on the packaging labeling. Pediatric IO devices are only approved for the proximal and distal tibia.
  - Insertion location.
    - ♦ Tibia: B.I.G., Cook, Sur-Fast, EZ-IO.
    - ♦ Proximal humerus: EZ-IO.
    - ♦ Sternum (manubrium): FAST1, sternal EZ-IO.

DO NOT USE HUMERAL OR TIBIAL IO DEVICES ON THE STERNUM.

  - All IV fluids (except hypertonic saline [HTS]) and medications can be administrated via IO in similar rates to IV infusions.
  - Confirm placement of IO by aspirating a small amount of blood and then flush with 10 mL of normal saline.

IO device placement is age and anatomical location specific. Care must be taken to ensure IO device insertion is correlated to the packaging labeling instructions (eg, tibial IO cannot be used on the sternum because of the length of the needle).

- The IO device should be removed as soon as possible after other IV access is established, but definitely before 24 hours.
- **See JTTS Clinical Practice Guideline "Damage Control Resuscitation."**
- Types of IV fluids.
  - Lactated Ringer (LR) solution: 1,000 mL expands intravascular volume by only ~250 mL within 1 hour after infusion. Normal saline should be discouraged.
  - Hextend (500 mL, Hetastarch 6% + a physiological balanced crystalloid carrier, including lactate buffer and glucose) expands intravascular volume by ~800 mL in 1 hour, is functionally equivalent to three bags of LR, and is sustained for at least 8 hours. May repeat once for a total of 1,000 mL.
  - HTS 7.5% results in the same physiological response with one-eighth the volume of LR or saline. Two infusions of 250 mL can be used. Although this recommendation has been made by the Institute of Medicine (in Washington, DC) and two military consensus groups, HTS 7.5% is not commercially available. HTS 3% and HTS 5% can be used instead and are formulary stock items.

Caution: Hextend and HTS are effective primarily by shifting extracellular volume into intravascular space. They may be less effective if administrated in casualties with significant dehydration and require supplementation with judicious use of crystalloid.

- Isolated neurogenic shock.
  - Intravascular resuscitation with crystalloid to maintain systolic mean arterial pressure >90 mm Hg or SBP >110.
    - Crystalloid fluid resuscitation is first line treatment in isolated neurogenic shock.
- Add a vasopressor after appropriate intravascular volume challenge (generally 2–3 L) to address the loss in vascular tone. The type of vasopressor chosen should be based on availability.
- Septic shock.
  - Initial resuscitation (first 12 hours).

- ◊ Targets:
  - ■ Mean arterial pressure ≥65 mm Hg or SBP ≥90.
  - ■ Central venous pressure 8–12 mm Hg.
  - ■ Urine output ≥0.5 mL/kg/h.
  - ■ Central venous or mixed venous oxygen saturation ≥70%.
- ◊ Begin intravenous broad-spectrum coverage within the first hour of recognition of severe sepsis.
- ◊ Add a vasopressor after appropriate intravascular volume challenge (generally up to 5 L crystalloid and/or colloid).
  - ■ Norepinephrine, initial dose 8–12 μg/min, then titrate to effect at 2–4 μg/min. (In a septic patient, use the following formula [weight-based dosing]: 0.01–3 μg/kg/min [could be as much as 0.7–210 μg/min in 70-kg patient].)
  - ■ Vasopressin 0.04 units/min (may titrate down for effect; do not titrate above maximum: 0.04 units/min).
- ◊ Institute early acute lung injury/acute respiratory distress syndrome mechanical ventilation measures with low tidal volumes (4–6 mL/kg lean body mass) and end-inspiratory plateau pressures <30 cm H_2O.

- ○ Subsequent therapy.
  - ♦ Overall fluid balance target after 12 hours of resuscitation is between 3–12 L. More than 12 L positive balance associated with increased mortality.
  - ♦ Consider blood transfusion if hemoglobin <7 to target hemoglobin of 7.0–9.0 g/dL.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 8

Anesthesia

Introduction

Battlefield anesthesia primarily describes a state of balanced anesthesia using **adequate amounts of anesthetic agents** to minimize cardiovascular instability while providing amnesia, analgesia, and a quiescent surgical field in a technologically austere environment. Adapting anesthetic techniques to battlefield conditions requires flexibility and a reliance on fundamental clinical skills. Although modern monitors provide a wealth of data, the stethoscope may be the only tool available in an austere environment. Thus, the value of crisp heart sounds and clear breath sounds when caring for an injured service member should not be underestimated.

In addition, close collaboration and communication with the surgeon are essential to assist with aggressive resuscitation and a team approach to damage control surgery (DCR) decisions.

Airway

Many methods for securing a compromised airway exist, depending on the condition of the airway, the co-morbid state of the patient, and the environment in which care is being rendered. When a definitive airway is required, it is generally best secured with direct laryngoscopy and an endotracheal tube (ETT) firmly secured in the trachea.

Indications for a Definitive Airway

- Apnea/airway obstruction/hypercarbia.
- Impending airway obstruction: facial fractures, retropharyngeal hematoma, and inhalation injury.

- Excessive work of breathing.
- Shock (blood pressure ≤ 80 mm Hg systolic).
- Glasgow Coma Scale ≤8 (see Appendix 2).
- Persistent hypoxia (SaO_2 < 90%/PaO_2 < 60 mm Hg).

Secondary Airway Compromise Can Result From:
- Failure to recognize the need for an airway.
- Inability to establish an airway.
- **Failure to recognize an incorrectly placed airway.**
- Displacement of a previously established airway.
- Failure to recognize the need for ventilation.

Induction of General Anesthesia
- The anesthesia provider must evaluate the patient for:
  - Concurrent illness and current state of resuscitation.
  - Airway—facial trauma, dentition, hyoid-to-mandibular symphysis length, extent of mouth opening.
  - Cervical spine mobility (preexistent and trauma related).
  - Additional difficult airway indicators:
    - Immobilization.
    - Children.
    - Short neck/receding mandible.
    - Facial hair.
    - Obesity.
    - Prominent upper incisors.

Rapid Sequence Intubation (RSI) Checklist
- Equipment.
  - Laryngoscope, blades, and batteries (tested daily).
  - Suction, oxygen setup.
  - ETTs and stylet.
  - Airway adjuncts (oropharyngeal, nasopharyngeal, and LMA [laryngeal mask airway]).
  - IV access items.
  - Monitors—pulse oximeter, ECG, blood pressure, end-tidal CO_2.
  - Positive-pressure ventilation (Ambu bag or anesthesia machine).
- Drugs.
  - Narcotics.
  - Muscle relaxants.

- Anxiolytics and amnestics.
- Induction agents and sedatives.
- Inhalation agents.

- Narcotics.
  - **Fentanyl:** 1.0–2.0 μg/kg IV bolus, then titrate to effect.
  - **Morphine:** 2–5 mg IV bolus to load, then 1–2 mg every 5 minutes to effect.
  - **Dilaudid** (Hydromorphone): 0.4–0.8 mg IV to load, then 0.2–0.4 mg every 5 minutes to effect.
  - Use caution when administering higher doses of opioids to patients with respiratory or hemodynamic compromise or head injury.
- Muscle relaxants.
  - Depolarizing.
    - **Succinylcholine**.
    - 1.0–1.5 mg/kg. (**Note**: Can double the dose to give IM if IV access is not available and it is an emergency.)
    - Onset: 30–60 seconds.
    - Duration: 5–10 minutes.
    - Can cause bradycardia, fasciculations, elevated intragastric pressure, elevated intracranial pressure, potassium release (especially in "chronic" burn or immobile patients), and prolonged duration of action possible with pseudocholinesterase deficiency.
    - Potent trigger of malignant hyperthermia.

Succinylcholine should NOT be used in patients with burns or crush injuries >24 hours old or chronic neuromuscular disorders due to risk for hyperkalemia.

Rocuronium is the next best choice.

  - Nondepolarizing.
    - **Vecuronium:** Induction dose of 0.1 mg/kg, with an onset of 2–3 minutes and a duration of action of 30–40 minutes.
    - **Rocuronium:** Induction dose of 0.6 mg/kg, with an onset of 1.5–2.5 minutes and a duration of action of 35–50 minutes. At 1.2 mg/kg, onset is similar to succinylcholine, with a duration of action that can exceed 60–90 minutes.

- **Pancuronium:** Induction dose of 0.1–0.15 mg/kg (it will cause or exacerbate tachycardia), with an onset of 3.5–6 minutes and a duration of action of 70–120 minutes.
- **Cisatracurium:** Induction dose of 0.15–0.20 mg/kg, with an onset of 2–3 minutes and a duration of action of 30–40 minutes. (Drug of choice for renal or hepatic disease.)

Table 8-1. Induction Agents and Sedatives

Agent	Routine Dose*	Characteristics	Concerns
Ketamine	1.0–2.0 mg/kg IV	Dissociative anesthetic and amnestic Sympathomimetic effects (useful in hypovolemia) Potent bronchodilator	Varying degrees of purposeful skeletal movement despite intense analgesia and amnesia
	4.0–10.0 mg/kg IM	Onset within 30–60 seconds Emergence delirium avoided with concomitant benzodiazepine use	Increased salivation; consider an antisialagogue
Propofol	1.0–2.5 mg/kg IV	Mixed in lipid, strict sterility must be ensured Rapid onset and rapidly metabolized Onset within 30–60 seconds	Contraindicated in acute hypovolemic shock patients
Etomidate	0.2–0.4 mg/kg IV	Onset within 30–60 seconds Duration: 3–10 minutes Minimal cardiac effects Minimal effects on peripheral and pulmonary circulation Maintains cerebral perfusion	May cause clonus May cause adrenal suppression

*All induction agents can be used for induction of severely injured patients if reduced dosages are used (eg, ½ of the lower recommended dose). However, the recommended choice for hypovolemic patients would be ketamine ≥ etomidate >> propofol.

- Anxiolytics and amnestics.
  - **Versed** (midazolam; 0.5–2 mg IV bolus).
  - **Scopolamine:** 0.4 mg IV. (For use in hemodynamically unstable patients.)
- Induction agents and sedatives (Table 8-1).

Rapid Sequence Intubation—5 Steps

1. Preoxygenate with 100% oxygen by mask.
2. Ketamine 2 mg/kg IV/IO (alternate: propofol 2 mg/kg, .5-1.0 mg/kg if hypotensive)
3. Muscle relaxant: succinylcholine 1.0–1.5 mg/kg IV push.
4. Laryngoscopy and orotracheal intubation (after 1 minute or seeing fasciculation).
5. Verify tube placement.

Consider nasogastric or orogastric tube placement after securing airway.

Note: For children, see Table 31-4.

- Endotracheal intubation.
  - Orotracheal.
    - Direct laryngoscopy 60–90 seconds after administration of induction agents and neuromuscular blockade.
    - First attempt is the best chance for success, but have a backup plan:
      - Optimize positioning of patient and anesthesia provider.
      - Have adjuncts readily available (stylet, smaller diameter tubes, alternative laryngoscope blades, suction, LMA, lighted stylet).
  - Nasotracheal intubation should generally not be performed.
  - Other considerations.
    - Hypertension can be managed with short-acting medications, such as beta blockers (labetalol, esmolol).
    - May treat induction-related (transient) hypotension initially with a small dose of ephedrine (5–10 mg), Neo-Synephrine (50 μg), or epinephrine (5–10 μg). But if hypotension persists after induction agents are metabolized, use damage control resuscitation DCR

principles to treat the persistent hypovolemia. The anesthesiologist must convey this situation to the surgeon, because the need to control bleeding becomes urgent.

- ♦ A sensitive airway can be topically anesthetized with lidocaine 1.5 mg/kg 1–2 minutes before laryngoscopy.

- Verify ETT placement.
  - Auscultate the lungs.
  - Measure the end-tidal CO_2.
  - Ensure that the SaO_2 remains high.
  - Palpate cuff of ETT in sternal notch.
  - Place the chemical CO_2 sensors in the airway circuit.

Verification of tube placement is VITAL. Any difficulty with oxygenation/ventilation following RSI should prompt evaluation for immediate reintubation.

The Difficult Airway

(See Chapter 5, Airway/Breathing)

Initially provide airway management with jaw thrust and face mask oxygenation. Assess the situation. Failed RSI may be due to inadequate time for induction agents to work; inadequate time for muscle relaxation to occur; anatomically difficult airway; or obstruction due to secretions, blood, trauma, or foreign material.

- Resume oxygenation; consider placing a temporary oral and/or nasal airway.
- Reposition patient.
- Call for help.
- Consider alternatives to RSI.
  - Awake intubation.
  - LMA.
  - Regional anesthesia (RA) or local anesthesia.
  - Surgical airway.

Maintenance of General Anesthesia

General anesthesia is maintained after intubation with:

- Oxygen. Titrate to maintain SaO_2 >92%.
- Maintain body temperature >36 C.

- Resuscitation according to DCR principles.
  - Consider TXA: 1 g over 10 minutes followed by infusion of 1 g over 3 h.
  - Re-administer antibiotics at decreased intervals with large volume replacement.
  - Consider hydrocortisone: 100 mg in critically ill patients.
- Ventilation.
  - Tidal volume: 6 mL/kg (low lung volume ventilation).
  - Respiratory rate: 12–14/min.
  - Positive end-expiratory pressure: if desired at 5 cm H_2O, titrate as necessary.
- Minimal alveolar concentration (MAC).
  - 0.6 MAC: awareness reliably abolished, although 50% of patients respond to verbal commands.
  - 1 MAC: 50% of patients do not move to surgical stimulus.
  - 1.3 MAC: 95% of patients do not move to surgical stimulus.
  - Common inhalation agent MACs:
    - Halothane: 0.75%.
    - Sevoflurane: 1.8%.
    - Isoflurane: 1.17%.
    - Desflurane: 6.00%.
    - Enflurane: 1.63%.
    - Nitrous oxide: 104%.
    - Additive effects (eg, 60% nitrous oxide mixed with 0.8% sevoflurane yields 1 MAC).
- Total intravenous anesthesia.
  - Mix midazolam 5 mg, vecuronium 10 mg, ketamine 200 mg in 50 mL normal saline and infuse at 0.5 mL/kg/h (stop 10–15 minutes before end of surgery).
  - Mix 50–100 mg of ketamine with 500 mg of propofol (50 mL of 10% propofol) and 250 μg of fentanyl, and administer at 50–100 μg/kg/min of propofol (21–42 mL/h for a 70-kg patient).
- Balanced anesthesia (titration of drugs and gases) combine:
  - 0.4 MAC of inhaled agents.
  - Versed: 1–2 mg/h.
  - Ketamine: 0.5–1 mg/kg/h.
  - Fentanyl: 2–4 μg/kg/h.

Conclusion of General Anesthesia

- If the patient is to **remain intubated**, anesthetics may be terminated, but sedatives and possibly muscle relaxants should be continued.
- If the patient is to be **extubated**, controlled ventilation is decreased to allow the patient to spontaneously breathe.
  - Anesthetic agents are titrated to allow for rapid recovery.
  - Muscle relaxation reversal is accomplished with Neostigmine (0.04–0.08 mg/kg IV over 3–5 minutes and can be mixed in the same syringe as Glycopyrrolate [Robinul 0.01–0.02 mg/kg IV over 3–5 minutes]).
- Extubation criteria include reversal of muscle relaxation, spontaneous ventilation, response to commands, eye opening, and head lifting for 5 seconds. **When in doubt, keep the patient intubated.**
- Amnestic therapy with midazolam and analgesic therapy with a narcotic are appropriate in small amounts so as not to eliminate the spontaneous respiratory drive.

Regional Anesthesia

RA is a "field-friendly" anesthetic requiring minimal logistical support while providing quality anesthesia and analgesia on the battlefield. Advantages of RA on the modern battlefield include the following:

- Excellent operating conditions.
- Profound perioperative analgesia.
- Stable hemodynamics.
- Limb-specific anesthesia.
- Reduced need for other anesthetics.
- Improved postoperative alertness.
- Minimal side effects.
- Rapid recovery from anesthesia.
- Simple, easily transported equipment needed.

Recent conflicts have revealed that the majority of casualties will have superficial wounds or wounds of the extremities. RA is well suited for the management of these injuries either as an adjunct to general anesthesia or as the primary anesthetic. The use of basic RA blocks (listed below) is encouraged when time and resources are available.

- Superficial cervical plexus block.
- Axillary brachial plexus block.
- Intravenous RA.
- Wrist block.
- Digital nerve block.
- Intercostobrachial nerve block.
- Saphenous nerve block.
- Ankle block.
- Spinal anesthesia.
- Lumbar epidural anesthesia.
- Combined spinal-epidural anesthesia.
- Femoral nerve block.

Prior training in basic block techniques is implied, and use of a nerve stimulator or ultrasound, when appropriate, is encouraged to enhance block success. More advanced blocks and continuous peripheral nerve blocks are typically not available until the patient arrives at a Role 3 or higher level healthcare facility where personnel trained in these techniques are available. A long-acting local anesthetic, such as 0.5% ropivacaine, is used for most single-injection peripheral nerve blocks. Peripheral nerve blocks can often be used to treat pain (without the respiratory depression of narcotics) while patients are waiting for surgery. Do not perform a peripheral nerve block for an injured extremity without consulting an orthopedic or general surgeon regarding the risk of compartment syndrome and the potential to obscure its diagnosis.

- **Neuraxial anesthesia.**
  - Subarachnoid block.
  - Epidural block.

When the patient's physical condition allows the use of spinal or epidural anesthesia, those techniques are encouraged. The sympathectomy that results is often poorly tolerated in a trauma patient, and this must be factored into any decision to use those techniques. Peripheral nerve blocks do not have this limitation.

Local Anesthesia

When local anesthesia would suffice, such as in certain wound debridements and wound closures, it should be the technique of choice.

Field Anesthesia Equipment

There are two anesthesia apparatuses currently fielded in the forward surgical environment: (1) the drawover vaporizer and (2) a conventional portable ventilator machine. A schematic of the drawover system is shown in Fig. 8-1.

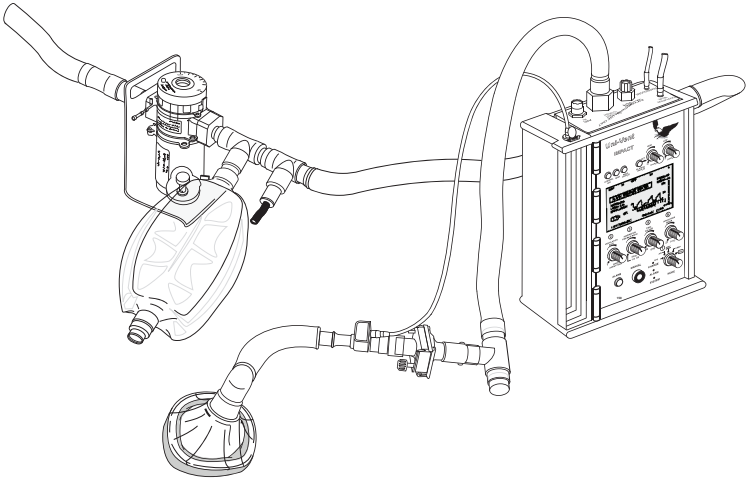

Fig. 8-1. Drawover apparatus in combination with the ventilator.

- **Drawover vaporizer.**
  - Currently fielded model: Ohmeda Universal Portable Anesthesia Complete (UPAC).
  - Demand-type system (unlike the plenum systems in hospital-based ORs).
    - When the patient does not initiate a breath or the self-inflating bag is not squeezed, there is **no flow of gas**. No demand equals no flow.
  - Temperature-compensated, flow-over inline vaporizer.
  - Optimal oxygen conservation requires a larger reservoir (oxygen economizer tube) than is described in the operator's manual—a 3.5-foot oxygen economizer tube optimizes Fio_2.
  - May be used with spontaneous or controlled ventilations.
  - Bolted-on performance chart outlines dial positions for some commonly used anesthetics (eg, halothane and isoflurane).

Ohmeda UPAC Drawover Apparatus in Combination With the Impact Uni-Vent Eagle Model 754 Portable Ventilator

- Currently, there is no mechanical ventilator specifically designed for use with the UPAC drawover apparatus, but use with various portable ventilators has been studied in both the drawover and pushover configurations.
  - Adding the ventilator frees the anesthesia provider's hands while providing more uniform ventilation and more consistent concentrations of the inhalational anesthetic agent.
  - The **drawover** configuration places the ventilator distal to the vaporizer, entraining ambient air and vapor across the vaporizer in the same manner as the spontaneously breathing patient. Do not attach a compressed source of air to the Impact Uni-Vent Eagle Model 754 in this configuration because it will preferentially deliver the compressed gases and will not entrain air/ anesthetic gases from the UPAC drawover.
  - The **pushover** configuration places the ventilator proximal to the vaporizer, effectively pushing entrained ambient air across the vaporizer and then to the patient.
- The Impact Uni-Vent Eagle Model 754 portable ventilator (Fig. 8-1) is not part of the UPAC apparatus, but is standard equipment for the US military. It has been used in combination with the Ohmeda UPAC drawover apparatus.
  - The air entrainment (side intake) port is used to create the drawover/ventilator combination.
    - The side intake port of the ventilator contains a nonreturn valve, preventing back pressure on the vaporizer that could result in erratic and inconsistent anesthetic agent concentrations.
  - The patient air-outlet port on the ventilator also contains a nonreturn valve, preventing backflow into the ventilator from the patient side.
  - Scavenging of waste gases can be accomplished by attaching corrugated anesthesia tubing to either the outlet port of the Ambu E-valve (induction circuit) or the exhalation port of the ventilator tubing (ventilator circuit) venting to the outside atmosphere.

- The following items are added to the circuit to improve this UPAC/Impact Uni-Vent Eagle Model 754 ventilator combination:
  - Small and large circuit adapters to aid in attachment of various pieces.
  - Pall Heat and Moisture Exchange Filter to conserve heat and limit patient contact with the circuit.
  - Accordion circuit extender to move the weight of the circuit away from the patient connection.
  - Oxygen extension tubing to attach supplemental oxygen.
- Two separate circuits should be constructed for use with the UPAC/Uni-Vent Eagle Model 754 combination: for induction and spontaneous ventilation and for controlled ventilation using the portable ventilator.
  - This process can be complicated because switching circuit components requires several disconnections and reconnections, creating the potential for error. (Practice.)

- **Conventional plenum anesthesia machine.**
  - Currently fielded models: Drager Narkomed and Fabius Tiro M.
  - Compact version of standard OR machines, with comparable capabilities.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 9

Soft-Tissue and Open Joint Injuries

All war wounds are contaminated and should not be closed primarily.

Introduction

The goals in the treatment of soft-tissue wounds are to save lives, preserve function, minimize morbidity, and prevent infection through early and aggressive surgical wound care far forward on the battlefield.

Presurgical Care

- Prevent infection.
  - Antibiotics.
    - **Antibiotics are not a replacement for surgical treatment.**
    - Antibiotics are therapeutic, not prophylactic, in war wounds.
    - Give antibiotics for **all** penetrating wounds as soon as possible. Less than 1 hours from injury is ideal.
  - Sterile dressing.
    - Place a sterile field dressing as soon as possible.
    - Leave dressing undisturbed until surgery. A **one-look** soft-tissue examination may be performed on initial presentation. Infection rate increases with multiple examinations prior to surgery. Initial wound cultures are unnecessary.

Surgical Wound Management Priorities

- Lifesaving procedures have priority over limb and soft-tissue wound care.
- Save limbs.
  - Vascular shunt, bypass, or repair.

- Compartment release (see Chapter 34, Compartment Syndrome).

- Prevent infection.
  - Early antibiotic administration (<1 hour).
  - Wound debridement as early as possible, preferably within 6 hours of wounding (infection is increased 3% per hour when debridement is delayed).
  - Sterile dressing.
  - Fracture immobilization = soft tissue stabilization.
- Superficial penetrating fragment (single or multiple) injuries usually do not require surgical exploration.
  - Wounds should be assessed for the presence of pressurized dirt/debris along with fragments.
  - Limited wound extension may be reasonable to remove deep wound contamination.
  - If there is no significant deep contamination, superficial wounds and skin can be cleansed with antiseptic and scrub brush.
  - Avoid "Swiss cheese" surgery—connection of multiple small wounds into a single surgical wound is preferred over the creation of multiple large wounds that will result in prolonged healing or may limit the ability to accomplish a delayed repair.
  - Maintain high suspicion for vascular injury and concurrent fragment wounding to head, chest, abdomen, and pelvis.

Wound Care

Primary Surgical Wound Care

- **Limited longitudinal incisions.**
- **Excision of foreign material and devitalized tissue.**
- **Irrigation.**
- **Leave wound open—no primary closure.**
- **Antibiotics and tetanus prophylaxis.**
- **Splint for transport (improves pain control).**

- Longitudinal incisions.
  - Extend wounds parallel to the longitudinal axis of the extremity to facilitate deep exposure.

- Longitudinal incisions allow for proximal and distal extension for more thorough visualization and debridement.
- Avoid transverse incisions; they do not facilitate subsequent extension if needed.
- Incise obliquely across flexion creases to prevent flexion contracture.

- Wound excision (current use of the term **debridement**).
  - Skin.
    - Perform conservative excision (1–2 mm) of damaged skin edges (Fig. 9-1a).
    - Questionable areas can be assessed at the next debridement.

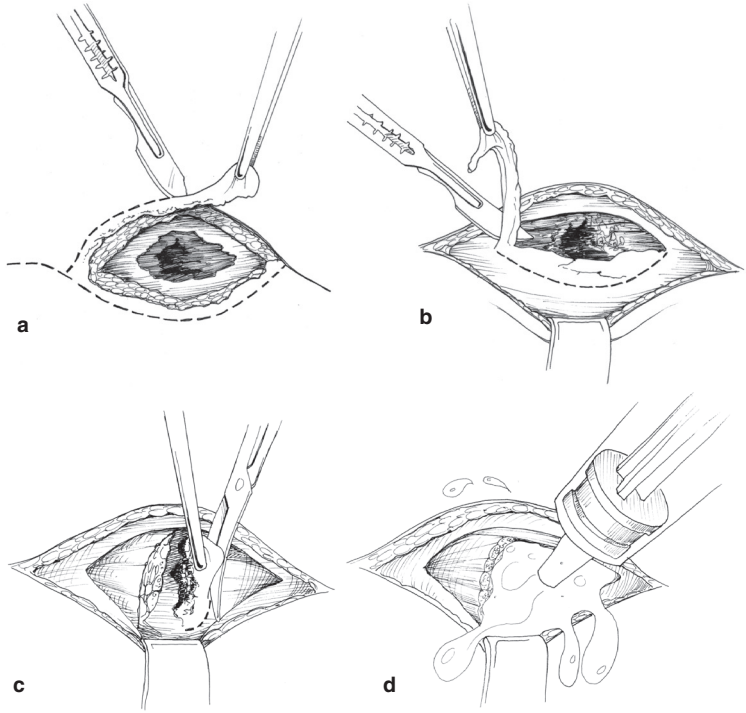

Fig. 9-1. (**a**) Skin excision, (**b**) removal of fascia, (**c**) removal of avascular tissue, and (**d**) irrigation.

- Fat.
  - Damaged, contaminated fat should be generously excised.
- Fascia.
  - Damage to the fascia is often minimal relative to the magnitude of destruction beneath it (Fig. 9-1b).
  - Shredded, torn portions of fascia are excised, and the fascia is widely opened through a longitudinal incision to expose the entire zone of injury beneath.
  - Complete fasciotomy should be performed for compartment syndrome.
  - Limited fasciotomy is reserved for localized fascial injury without evidence of compartment syndrome.
- Muscle.
  - Sharply excise all nonviable, severely damaged avascular muscle (Fig. 9-1c).

Removal of dead muscle is important to prevent infection. Accurate initial assessment of muscle viability is difficult. Tissue-sparing debridement is acceptable if follow-on wound surgery will occur within 24 hours. More aggressive debridement is required if subsequent surgery will be delayed for more than 24 hours.

  - The "4 Cs" (**color**, **contraction**, **consistency**, and **circulation**) may be **unreliable** for initial assessment of muscle viability. They should be used together to assist in determining the extent of muscle damage.
    - **Color**—Assessment may be unreliable when used independently. Surface muscle may be discolored due to blood under the myomysium, contusion, or local vasoconstriction. Muscle at the wound margin may also be transiently hypoperfused in an incompletely resuscitated patient.
    - **Contraction**—Assessed by observing the retraction of the muscle with the gentle pinch of forceps or a response to electrocautery.

- ◊ **Consistency**—May be the best predictor of viability. In general, viable muscle will rebound to its original shape when grasped by forceps, whereas muscle that retains indentation from the forceps has questionable viability.
- ◊ **Circulation**—Assessment via bleeding tissue from a fresh wound. Transient vasospasm, common with war wounds, may not allow for otherwise healthy tissue to bleed.

o Bone.
- ♦ Fragments of bone with vascularized soft tissue attachments and large free articular fragments are preserved.
- ♦ Remove all devitalized, avascular pieces of bone smaller than thumbnail size that have no soft-tissue attachment.
- ♦ Remove large fragments of diaphyseal and metadiaphyseal bone that have no soft-tissue attachments, but consider retention of osteoarticular fragments after thorough debridement if they were not grossly contaminated from the wounding mechanism.
- ♦ Deliver each of the bone ends of any fracture independently, clean the surface, and clean out the ends of the medullary canal.

o Nerves and tendons.
- ♦ Debridement—Not normally required except frayed edges and resecting grossly destroyed portions.
- ♦ **Primary repair is not performed**. To prevent desiccation, use soft-tissue or moist dressings for coverage. Mark the ends of the nerve or tendon with a suture (Prolene or other monofilament/nonabsorbable) to facilitate reidentification at later operations.

o Vessels.

(Refer to Chapter 25, Vascular Injuries, for a discussion of considerations in vascular shunting, bypass, and repair.)
- ♦ Debridement—Generally only a minimal debridement of the vessel is recommended for purposes of decreased infection risk. Priority should be given to restoration of flow to minimize distal tissue ischemia at the time of initial debridement.

- Irrigation.
  - Irrigation should begin after thorough surgical debridement has been accomplished.
  - Irrigation should be performed until the wound is visibly clean (Fig. 9-1d).
  - Irrigation volume between 6 and 12 L should be utilized for large, significantly contaminated open wounds.
  - Low-pressure irrigation is preferred for acute wounds. High pressure may force wound contaminants deeper into soft tissues. Mechanical irrigation may be necessary if wounds have been chronically contaminated.
  - Sterile physiological fluid (0.9% normal saline) may be used as an alternative when resources are scarce. May consider terminal irrigation with sterile solution (1–2 L).
  - A sterile, loose, bulky dry dressing is most appropriate for patients being transported through and out of the battlefield.
- Negative pressure wound therapy (NPWT).
  - NPWT devices may be helpful in maintaining an isolated wound environment.
  - NPWT devices may enhance the local wound environment and vascular permeability for wound healing.
  - NPWT devices may be placed over split-thickness skin grafts to facilitate graft adherence.
  - Malfunction of NPWT devices can create an environment with a higher risk of infection. When utilized, NPWT devices need to be checked frequently to ensure operational performance.
  - Makeshift and improvised NPWT devices should not be used in a combat theater or during aeromedical transport.
- Antibiotic beads.
  - Antibiotic beads are not used for the majority of open wounds.
  - Antibiotic beads may be helpful in delaying the period of bacterial regrowth after initial debridement.
  - Antibiotic beads are normally made using 1 g of vancomycin/1.2 g of tobramycin per 40 g of polymethylmethacrylate (PMMA) cement.

- ♦ May consider use of PMMA antibiotic beads beneath NPWT devices.

- o Local soft-tissue coverage.
  - ♦ The development and rotation of flaps for this purpose should not be done during primary surgical wound debridement.
  - ♦ Local soft-tissue coverage through the gentle mobilization of adjacent healthy tissue to prevent drying, necrosis, and infection is recommended. Saline-soaked gauze is an alternative.

No Primary Closure of War Wounds

- o Dressing.
  - ♦ Cavitary wounds—Wound may be gently packed with gauze to serve as a wick for fluid egress. **Do not plug the wound** with packing because this prevents wound drainage and creates an anaerobic environment.
  - ♦ Loosely apply circumferential bandages in anticipation of swelling during initial 72 hours postoperative.

Wound Management After Initial Surgery

- The wound undergoes a planned second debridement and irrigation in 24–48 hours, and subsequent procedures until a clean wound is achieved.
- The time interval between debridements may be extended to 48–72 hours if NPWT devices are utilized, provided all nonviable tissue and gross contamination has been removed.
- Between procedures, there may be better demarcation of nonviable tissue or the development of local infection.
- Early soft-tissue coverage is desirable within 3–5 days, when the wound is clean, to prevent secondary infection.
- Delayed primary closure (3–5 days) requires a clean wound that can be closed without undue tension. This state may be difficult to achieve in war wounds.
- Soft-tissue war wounds heal well through secondary intention. This is especially true of simple soft-tissue wounds.

- Definitive closure with skin grafts and muscle flaps should not be done in theater when evacuation is possible. These techniques may be required, however, for injured host nation casualties.

Crush Syndrome

- When a victim is crushed or trapped with compression on the extremities for a prolonged time, there is the possibility for crush syndrome, characterized by ischemia and muscle damage or death (rhabdomyolysis).
  - With rhabdomyolysis, there is an efflux of potassium, nephrotoxic metabolites, myoglobin, purines, and phosphorous into the circulation, thus resulting in cardiac and renal dysfunction.
  - Reperfusion injury can cause up to 10 L of third-space fluid loss per limb that can precipitate hypovolemic shock.
  - Acute renal failure (ARF) can result from the combination of nephrotoxic substances from muscle death (myoglobin, uric acid) and hypovolemia, resulting in a renal low-flow state.
- Recognition.
  - History.
    - Suspect in patients in whom there is a history of being trapped (eg, urban operations, mountain operations, earthquakes, or bombings) for a prolonged period (from hours to days).
    - A clear history is not always available in combat, and the syndrome may appear insidiously in patients who initially appear well.
  - Physical findings.
    - A thorough examination must be done with attention to the extremities, trunk, and buttocks.
    - Physical findings depend on the duration of entrapment, treatment rendered, and time since the victim's release.
    - Extremities.
      - May initially appear normal just after extrication.
      - Edema develops and the extremity becomes swollen, cool, and tense.
      - May have severe pain out of proportion with examination.

        - ◊ Anesthesia and paralysis of the extremities, which can mimic a spinal cord injury with flaccid paralysis, but there will be normal bowel and bladder function.
      - ♦ Trunk/buttocks: May have severe pain out of proportion with examination in tense compartments.
    - o Laboratory findings.
      - ♦ Creatinine phosphokinase (CPK) is elevated with values usually >100,000 IU/mL.
      - ♦ The urine may initially appear concentrated and later change color to a typical reddish-brown color—the so-called "port wine" or "iced tea" urine. Urine output decreases in volume over time.
      - ♦ Due to myoglobin, urine dipstick is positive for blood but microscopy will not demonstrate red blood cells. The urine may be sent to check for myoglobin, but results take days and should not delay therapy.
      - ♦ Hematocrit/hemoglobin (H/H) can vary, depending on blood loss, but in isolated crush syndrome, H/H is elevated due to hemoconcentration from third-spacing fluid losses.
      - ♦ With progression, serum potassium and CPK increase further with a worsening metabolic acidosis. Creatinine and BUN will rise as renal failure ensues. Hyperkalemia is typically the ultimate cause of death from cardiac arrhythmia.
- Therapy.
  - o On scene while still trapped.
    - ♦ The primary goal of therapy is to prevent ARF in crush syndrome. Suspect, recognize, and treat rhabdomyolysis early in victims of entrapment.
    - ♦ Therapy should be initiated as soon as possible, preferably in the field, while the casualty is still trapped. Ideally, it is recommended to establish IV access in a free arm or leg vein.
      - ◊ Avoid potassium- and lactate-containing IV solutions.
      - ◊ At least 1 L should be given prior to extrication and up to 1 L/h (for short extrication times) to a maximum of 6–10 L/d in prolonged entrapments.

- As a last resort, amputation **may** be necessary for rescue of entrapped casualties (ketamine 2 mg/kg IV for anesthesia and use of proximal tourniquet). "Skin to skin" technique with Gigli saw works quickly in this situation.

- Hospital care.
  - Other injuries and electrolyte anomalies must be treated while continuing fluid resuscitation, as given previously, to protect renal function.
  - Foley catheter for urine output monitoring.
  - Establish and maintain urine output >100 mL/h until pigments have cleared from the urine. If necessary, also:
    - Add sodium bicarbonate to the IV fluid (1 amp/L D5W) to alkalinize the urine above a pH of 6.5. If unable to monitor urine pH, put 1 amp in every other IV liter.
    - Administer mannitol, 20% solution 1–2 g/kg over 4 hours (up to 200 g/d), in addition to the IV fluids.
  - Central venous monitoring may be needed with the larger volumes (may exceed 12 L/d to achieve necessary urine output) of fluid given.
  - Electrolyte abnormalities.
    - Hyperkalemia, hyperphosphatemia, hypocalcemia, and hyperuricemia must be addressed.
  - Dialysis.
    - ARF requiring dialysis occurs in 50%–100% of those with severe rhabdomyolysis.
  - Surgical management centers on diagnosis and treatment of **compartment syndrome**—remember to check torso and buttocks as well.
    - Amputation: Consider in casualties with irreversible muscle necrosis/necrotic extremity.
  - Hyperbaric oxygen therapy: May be useful after surgical therapy to improve limb survival.

Compartment Syndrome

(See Chapter 25, Vascular Injuries, and Chapter 34, Compartment Syndrome)

- Compartment syndrome is an urgent surgical condition.

- Combat extremity injuries are at an elevated risk of developing a compartment syndrome within 48–72 hours postinjury.
- Compartment syndrome may occur with an injury to any fascial compartment: extremities, buttocks, or trunk.
- Compartment syndrome may occur with fascial defects or open wounds. The defect may not be adequate to fully decompress the compartment.
- Compartment syndrome is a clinical diagnosis. Pressure measurement is not necessary or advised in a combat setting.
- All compartments within a surgical-treated extremity should be released. Do not perform single or selective compartment release, especially in the lower leg and forearm.
- Mechanisms of injuries associated with compartment syndrome include the following:
  - Open fractures.
  - Closed fractures.
  - Penetrating wounds.
  - Crush injuries.
  - Vascular injuries.
  - Reperfusion following vascular repairs.
  - Burns/electrical shock.
- Early clinical diagnosis of compartment syndrome.
  - Pain out of proportion with injury and treatment.
  - Tense, swollen compartment.
  - Pain with passive stretch.
- Late clinical diagnosis.
  - Paresthesia.
  - Pulselessness and pallor.
  - Paralysis.
- Treatment: Emergent fasciotomy.
- Measurement of compartment pressures.
  - Not indicated for patients with a clear examination.
  - May be considered for patients who cannot be accurately assessed (obtunded, intubated, sedated, body habitus), with low clinical suspicion, but entering prolonged transport.
- **Consider prophylactic fasciotomy for high index of suspicion and limited capacity for serial examination.**
  - Intubated, comatose, sedated.
  - Closed head injuries.

- Vascular repair independent of ischemia time.
- Prolonged transport.

Fasciotomy Technique

(See Chapter 34, Compartment Syndrome)

- **Use full-length incisions to ensure that skin and subcutaneous tissues do not constrict the underlying muscle tissue.**
- **Keep fasciotomy wounds covered with moist dressing or an NPWT device. Do not use closure/approximation techniques during the initial fasciotomy if being transported. These may be appropriate to consider if the patient is not transported and can be adequately monitored.**

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 10

Infections

Introduction

All wounds incurred on the battlefield are grossly contaminated with bacteria. Most will become infected unless appropriate treatment is initiated quickly.

The battlefield environment is conducive to wound infection due to the:

- Absence of "sterile" wounding agents on the battlefield. All foreign bodies (wounding projectile fragments, clothing, dirt) are contaminated with bacteria.
- High-energy projectile wounding, which causes:
  - devitalized tissue,
  - hematoma, and
  - tissue ischemia.
- Delay in casualty evacuation.

Diagnosis of a Wound Infection

- The four "-**or**'s": dolor, rubor, calor, and tumor—**pain** and **tenderness**, **redness**, **warmth**, and **swelling**.
- Drainage or discharge, ranging from frank pus to the foul "dishwater" discharge of clostridial infection.
- Crepitus, radiographic evidence of soft-tissue gas, epidermal blistering, and/or epidermal necrosis are the hallmarks of necrotizing soft-tissue infection (eg, clostridial gas gangrene or necrotizing fasciitis).
- Systemic effects: fever, leukocytosis, unexplained tachycardia, or hypotension.
- Confirm diagnosis by Gram stain and culture, if available, and/or tissue biopsy.

Common Microorganisms Causing Battlefield Infections

- Gram-positive cocci:
  - staphylococci,
  - streptococci, and
  - enterococci.
- Gram-negative rods:
  - *Escherichia coli*, *Proteus*, and *Klebsiella*.
  - *Pseudomonas*, *Enterobacter*, *Acinetobacter*, and *Serratia* are common nosocomial pathogens usually expected among casualties who have been hospitalized for an extended period, not those fresh off the battlefield.
- *Salmonella*, *Shigella*, and *Vibrio* should be suspected in cases of bacterial dysentery.
- Anaerobic gram-positive and gram-negative rods:
  - *Clostridia*,
  - *Bacteroides*, and
  - *Prevotella* species.
- Fungal species: *Candida* species should be suspected in casualties hospitalized for prolonged periods, those malnourished or immunosuppressed, or those who have received broad-spectrum antibiotics, adrenocortical steroids, or parenteral nutrition. Empiric therapy should be considered in appropriate patients with presumptive evidence of fungal infection.

Common Patterns of Infection

- **Skin, soft tissue, muscle, and bone**: Primarily due to staphylococcal, streptococcal, and clostridial species. These infections include:
  - wound abscess,
  - cellulitis,
  - septic arthritis,
  - osteomyelitis,
  - necrotizing fasciitis, and
  - gas gangrene.
- **Intracranial:** Meningitis, encephalitis, and abscess—commonly from staphylococci and gram-negative rods—are difficult to treat due to the impervious nature of the meninges to common antibiotics.

- **Orofacial and neck:** Gram-positive cocci and mouth anaerobes are generally responsive to surgery and clindamycin.
- **Thoracic cavity:** Empyema (usually staphylococcal) and pneumonia (*Staphylococcus*, *Streptococcus*, and *Pseudomonas*), especially among those on prolonged mechanical ventilation or those casualties prone to aspiration (polymicrobial).
- **Intraabdominal:** Include posttraumatic or postoperative abscess and peritonitis due to *Enterococcus*, gram-negative rods, and anaerobic bacilli. *Clostridium difficile* is often responsible for a potentially severe diarrheal colitis that occurs following the administration of even one dose of antibiotic.
- **Systemic sepsis:** A syndrome caused by a bloodborne or severe regional infection resulting in a global inflammatory response (fever, leukocytosis, tachycardia, tachypnea, and possibly hypotension).
  - A similar inflammatory response without infection can be caused by a focus of retained necrotic tissue or the mere act of sustaining severe trauma.
  - Culprit microorganisms will not be recovered in all cases of sepsis syndrome.
  - Although typically associated with gram-negative organisms, any bacterial or fungal agent can cause sepsis.

Prompt surgical source control consisting of copious irrigation and thorough debridement are the cornerstones of prevention and treatment of all war wound infections.

Treatment

General Principles

- Antibiotic treatment should begin as early as possible, ideally within an hour after injury, and be repeated in the prophylaxis of war wound infection.
- Optimally, surgical debridement should be achieved within 6 hours of injury.
- Following initial exploration and debridement, the wound should be sufficiently irrigated to ensure that all dead material, bacterial contamination, and foreign material have been washed from the wound.

- To minimize gross contamination, wounds should be irrigated with saline or sterile water by bulb syringe or gravity flow from irrigant bag.
- The skin is left open, and a lightly moistened sterile gauze dressing is applied.
- For larger wounds, placement of a vacuum-assisted closure device may be indicated.
- Ballistic wounds should NEVER be closed in theater. Multiple irrigations and debridements are required to remove all ischemic and contaminated tissue.
- Antibiotics should be started as soon as possible after wounding, then continued for 24 hours, depending on the size, extent of destruction, and degree of contamination of the wound.
  - If time from wounding to initiation of antibiotics is >6 hours, or time from wounding to surgery is >12 hours, begin an antibiotics regimen for established infection.
- The choice of empiric antibiotic is dependent on the part of the body injured (Tables 10-1 and 10-2).
- Once a battlefield wound has become infected, treatment is two-fold: surgical and medical.
  - Surgical strategy remains the same: Open the wound, remove infected and necrotic tissue, and inspect for foreign material.
  - Drainage is generally used in abscess cavities to prevent premature closure and reformation.
  - Empiric broad-spectrum antibiotic therapy is initiated against likely pathogens per current CPG guidelines.
  - Ideally, obtain cultures and tailor therapy to cover the actual pathogens recovered on Gram stain and culture. However, routine bacteriology is often not available in forward medical facilities.
  - The patient is returned to the operating room every 1–2 days for serial irrigation and debridement.

Specific Infections

- Tetanus.
  - Battlefield wounds are "tetanus-prone" due to high levels of contamination with *Clostridium tetani*.

Table 10-1. Recommendations to Prevent Infections Associated With Combat-Related Injuries Based on Level of Care

Level of Care	Care Category	Recommendations
Role 1 (Prehospital)	Initial care in the field	● Bandage wounds with sterile dressings (avoid pressure over eye wounds) ● Stabilize fractures ● Transfer to surgical support as soon as feasible
	Post-injury antimicrobials	● Provide single dose point of injury antimicrobials (Appendix B) if evacuation is delayed or expected to be delayed
Role 1 and Role 2 without surgical support (IIa)	Post-injury antimicrobials	● Provide IV antimicrobials for open wounds (Appendix B) as soon as possible (within 3 h) ● Provide tetanus toxoid and immune globulin as appropriate ● Gram-negative coverage with aminoglycoside or fluoroquinolone not recommended ● Addition of penicillin to prevent clostridial gangrene or streptococcal infection not recommended ● Redose antimicrobials if large volume blood product resuscitation ● Use only topical antimicrobials for burns
	Debridement and irrigation	● Irrigate wounds to remove gross contamination with normal saline, sterile, or potable water; add middle point without additives ● Do not attempt to remove retained deep soft-tissue fragments if criteria met;[†] provide Cefazolin 2 g IV × 1 dose
Role 2 with surgical support and Role 3	Post-injury antimicrobials	● Provide intravenous antimicrobials (Appendix B) as soon as possible (within 3 hours). ● Provide tetanus toxoid and immune globulin as appropriate. ● Gram-negative coverage with aminoglycoside or Fluroquinolone not recommended.

(Table 10-1 *continues***)**

Table 10-1 *continued*

Level of Care	Care Category	Recommendations
		● Addition of penicillin to prevent clostridia gangrene or streptococcal infection is not recommended. ● Redose antimicrobials if large volume blood product resuscitation. ● Use only topical antimicrobials for burns ● Antimicrobial beads or pouches may be used. ● Provide post splenectomy immunizations if indicated.
	Debridement and irrigation	● Irrigate wounds to remove contamination with normal saline or sterile water using bulb irrigation, gravity irrigation, or pulse lavage without additives. For open fractures, use 3 L for each type I, 6 L for each type II, and 9 L for each type III extremity fractures. ● Repeat debridement and irrigation every 24-48 hours until wound is clean and all devitalized tissue is removed. ● Do not attempt to remove retained deep soft tissue fragments if criteria met. Provide Cefazolin 2 gm IV x 1 dose. ● Do not obtain cultures unless infection is suspected.
	Other surgical management	● Surgical evaluation as soon as possible. ● Only dural and facial wounds should undergo primary closure. ● Negative pressure wound therapy (NPWT) can be used. ● External fixation (temporary spanning) of femur/tibia fractures. ● External fixation (temporary spanning) OR splint immobilization of open humerus/forearm fractures.
Role 4	Post-injury antimicrobials	● Complete course of post-injury antimicrobials (Appendix B) ● Antimicrobial beads or pouches may be used ● Provide post splenectomy immunizations if indicated

(Table 10-1 *continues***)**

Table 10-1 *continued*

Level of Care	Care Category	Recommendations
	Debridement and irrigation	• Irrigate wounds to remove contamination with normal saline or sterile water using bulb • Irrigation, gravity irrigation, or pulse lavage without additives. For open fractures, use 3 L for each type I, 6 L for each type II, and 9 L for each type III extremity fractures. • Repeat debridement and irrigation every 24-48 hours until wound is clean and all devitalized tissue is removed. • Do not attempt to remove retained deep soft tissue fragments if criteria met.[†] Provide Cefazolin 2 gm IV x 1 dose • Do not obtain cultures unless infection is suspected
	Other surgical management	• Wounds should not be closed until 3-5 d post-injury when wound is clean and all devitalized tissue is removed. • Only dural and facial wounds should undergo primary closure. • Negative pressure wound therapy (NPWT) can be used. • External fixation (temporary spanning) of femur/tibia fractures. • External fixation (temporary spanning) OR splint immobilization of open humerus/forearm fractures.

Criteria for allowing retained fragments to remain behind: entry/exit wounds < 2 cm; no bone, joint, vascular, body cavity involvement; no high-risk etiology (e.g., mine); no obvious infection; assessable by x-ray.
Reproduced from: Joint Trauma System Clinical Practice Guideline: Infections Prevention in Combat-Related Injuries. August 8, 2016. CPG ID: 24. Appendix A.

Table 10-2. Postinjury Antimicrobial Agent Selection and Duration Based Upon Injury Pattern*

Injury	Preferred Agent(s)	Alternate Agent(s)	Duration
Extremity wounds (include skin, soft tissue, and bone)			
Skin, soft tissue, no open fractures	Cefazolin 2 gm IV q6–8h†,‡	Clindamycin (300–450 mg PO TID or 600 mg IV q8h)	1–3 days
Skin, soft tissue, with open fractures, exposed bone, or open joints	Cefazolin 2 gm IV q6–8h†,‡,§	Clindamycin 600 mg IV q8h	1–3 days
Thoracic wounds			
Penetrating chest injury without esophageal disruption	Cefazolin 2 gm IV q6–8h†,‡	Clindamycin (300–450 mg PO TID or 600 mg IV q8h)	1 day
Penetrating chest injury with esophageal disruption	Cefazolin 2 gm IV q6–8h†,‡ PLUS metronidazole 500 mg IV q8–12h	Ertapenem 1 g IV × 1 dose OR moxifloxacin 400 mg IV × 1 dose	1 day after definitive washout
Abdominal wounds			
Penetrating abdominal injury with suspected/known hollow viscus injury and soilage; may apply to rectal/perineal injuries as well	Cefazolin 2 gm IV q6–8h†,‡ PLUS metronidazole 500 mg IV q8–12h	Ertapenem 1 gm IV × 1 dose or moxifloxacin 400 mg IV × 1 dose	1 day after definitive washout
Maxillofacial and Neck Wounds			
Open maxillofacial fractures, or maxillofacial fractures with foreign body or fixation device	Cefazolin 2 gm IV q6-8h†‡	Clindamycin 600 mg IV q8h	1 day

(Table 10-2 *continues***)**

Table 10-2 *continued*

Injury	Preferred Agent(s)	Alternate Agent(s)	Duration
Central nervous system wounds			
Penetrating brain injury	Cefazolin 2 gm IV q6–8h.[†,‡] Consider adding metronidazole 500 mg IV q8–12h if gross contamination with organic debris	Ceftriaxone 2 gm IV q24h if gross contamination with organic debris. For penicillin allergic patients, Vancomycin 1 gm IV q12h PLUS ciprofloxacin 400 mg IV q8–12h	5 days or until CSF leak is closed, whichever is longer
Penetrating spinal cord injury	Cefazolin 2 gm IV q6–8h[†,‡]; ADD metronidazole 500 mg IV q8–12h if abdominal cavity is involved	As above. ADD metronidazole 500 mg IV q8–12h if abdominal cavity is involved	5 days or until CSF leak is closed, whichever is longer
Eye wounds			
Eye injury, burn, or abrasion	Topical: Erythromycin or Bacitracin ophthalmic ointment QID and PRN for symptomatic relief Systemic: No systemic treatment required	Fluoroquinolone 1 drop QID	Until epithelium healed (no fluorescein staining)
Eye injury, penetrating	Levofloxacin 500 mg IV/PO once daily. Prior to primary repair, no topical agents should be used unless directed by ophthalmology		7 days or until evaluated by an ophthalmologist

(Table 10-2 *continues***)**

Table 10-2 *continued*

Injury	Preferred Agent(s)	Alternate Agent(s)	Duration
Burns			
Superficial burns	Topical antimicrobials with twice daily dressing changes (include mafenide acetate[**] or silver sulfadiazine; may alternate between the two), OR silver-impregnated dressing changed q3–5d, OR Biobrane	Silver nitrate solution applied to dressings	Until healed
Deep partial thickness burns	Topical antimicrobials with twice daily dressing changes, OR silver impregnated dressing changed q3–5d PLUS excision and grafting	Silver nitrate solution applied to dressings PLUS excision and grafting	Until healed or grafted
Full thickness burns	Topical antimicrobials with twice daily dressing changes PLUS excision and grafting	Silver nitrate solution applied to dressings PLUS excision and grafting	Until healed or grafted
Point-of-injury/delayed evacuation[††]			
Expected delay to reach surgical care	Moxifloxacin 400 mg PO ×1 dose; ertapenem 1 g IV or IM if penetrating abdominal injury, shock, or unable to tolerate PO medications	Levofloxacin 500 mg PO × 1 dose. Cefotetan 2 g IV or IM q12h if penetrating abdominal injury, shock, or unable to tolerate PO medications	Single dose therapy

(Table 10-2 *continues***)**

Table 10-2 *continued*

*Post-injury antimicrobial agents are recommended to prevent early post-traumatic infectious complications, including sepsis, secondary to common bacterial flora. Selection is based on narrowest spectrum and duration required to prevent early infections prior to adequate surgical wound management. This narrow spectrum is selected to avoid selection of resistant bacteria. The antimicrobials listed are not intended for use in established infections, where multidrug-resistant (MDR) or other nosocomial pathogens may be causing infection.
†Cefazolin may be dosed based on body mass: 1 gram if weight < 80 kg (176 lbs), 2 grams if weight 81-160 kg (177-352 lbs), 3 grams if weight > 160 kg (>352 lbs); doses up to 12 grams daily are supported by FDA-approved package insert.
‡Pediatric dosing: cefazolin, 20-30 mg/kg IV q6-8h (maximum, 100 mg/kg/day); metronidazole, 7.5 mg/kg IV q6h; clindamycin 25-40mg/kg/day IV divided q6-8h; ertapenem, 15 mg/kg IV or IM q12 (children up to 12 years) or 20 mg/kg IV or IM once daily (children over 12 years; maximum, 1 gm/day); ceftriaxone, 100 mg/kg/day IV divided q12-24h (dosing for CNS injury); levofloxacin, 8 mg/kg IV or PO q12h (levofloxacin is only FDA-approved in children for prophylaxis of inhalational anthrax in children > 6 months of age, but this dose is commonly used for other indications); vancomycin 60 mg/kg/day IV divided q6h (dosing for CNS injury); ciprofloxacin, 10mg/kg IV (or 10-20mg/kg PO) q12h.
§These guidelines do not advocate adding enhanced Gram-negative bacteria coverage (i.e., addition of fluoroquinolone or aminoglycoside antimicrobials) in type III fractures.
**Mafenide acetate is contraindicated in infants less than 2 months of age.
††Post-injury antimicrobial therapy as suggested by the Committee on Tactical Combat Casualty Care (CoTCCC).
Reproduced from: Joint Trauma System Clinical Practice Guideline: Infections Prevention in Combat-Related Injuries. August 8, 2016. CPG ID: 24. Appendix B.

- Bacteria grow anaerobically and release a central nervous system (CNS) toxin that results in muscle spasm, trismus, neck rigidity, and back arching.
- **In addition to surgical debridement of war wounds, additional prophylactic measures for tetanus-prone wounds include:**
  - Administration of 0.5 mL intramuscular (IM) of **tetanus toxoid** if prior tetanus immunization is uncertain, if the patient received less than three doses of tetanus vaccine or it has been >5 years since the last dose.
  - Administration of 250–500 U IM of **tetanus immune globulin** in a separate syringe and at a separate site from the toxoid if prior tetanus immunization is uncertain or less than three doses.

- Treatment for established tetanus includes:
  - IV antibiotics (penicillin G, 24 million U/d; or doxycycline, 100 mg bid; or metronidazole, 500 mg q6h for 7 days).
  - Tetanus immune globulin.
  - Wound debridement as needed.
  - IV diazepam to ameliorate the muscle spasm.
  - Place patient in a dark, quiet room free of extraneous stimulation.
  - May warrant endotracheal intubation, mechanical ventilation, and neuromuscular blockade.

- **Soft-tissue infections.**
  - **Cellulitis** is manifested by localized skin erythema, heat, tenderness, and swelling or induration.
    - Treatment: IV antibiotics against streptococcal and staphylococcal species (IV nafcillin, Cefazolin, or, in the penicillin-allergic patient, clindamycin or vancomycin).
  - **Postoperative wound infections** become evident by wound pain, redness, swelling, warmth, and/or foul or purulent discharge, with fever and/or leukocytosis.
    - Treatment: **Open the wound**, drain the infected fluid, and debride any necrotic tissue present.
    - The wound is left open and allowed to close via secondary intention.
  - **Necrotizing soft-tissue infections** are the most dreaded infections resulting from battlefield wounding. These include **clostridial myonecrosis (gas gangrene)** and **polymicrobial infections** caused by *Streptococcus*, *Staphylococcus*, *Enterococcus*, *Enterobacteriaceae*, *Bacteroides*, and *Clostridia*.
    - The organisms create a rapidly advancing infection within the **subcutaneous tissues** and/or **muscle** by producing exotoxins that lead to bacteremia, toxemia, and septic shock.
    - **All layers of soft tissue can be involved**, including skin (blistering and necrosis), subcutaneous tissue (panniculitis), fascia (fasciitis), and muscle.
    - Clinical manifestations begin locally with severe pain, crepitus, and with *Clostridia,* a thin, brown, foul-smelling discharge.

- ♦ The skin may be tense and shiny, showing pallor or a bronze color.
- ♦ Systemic signs include fever, leukocytosis, mental obtundation, hemolytic anemia, and hypotension, progressing rapidly to multiple organ failure and death in untreated or undertreated cases.
- ♦ The diagnosis is made by a history that seems out of proportion to the extent of injury combined with palpable or radiographic soft-tissue gas (air in subcutaneous tissue and/or muscle).
- ♦ Absence of soft-tissue gas does not exclude diagnosis of necrotizing infection.
- ♦ **Treatment is surgical**, including early, comprehensive, and repeated (every 12–24 hours) debridement of all dead and infected tissue, combined with broad-spectrum **antibiotics**.
- ♦ **Excision** of affected tissue must be as radical as necessary (including amputation or disarticulation) to remove all non-viable tissue (discolored, noncontractile, or nonbleeding). **Clinical judgment is paramount.**
- ♦ Identification of causative organisms is often problematic; treatment must be aimed at all possible organisms.
- ♦ **IV antibiotic** therapy.
  - ◊ **Clindamycin,** 900 mg q8h; **plus penicillin G**, 4 million U q4h; **plus gentamicin,** 5–7 mg/kg qd.
  - ◊ As a **substitute for clindamycin**: Metronidazole, 500 mg q6h.
  - ◊ As a **substitute for penicillin**: Ceftriaxone, 2.0 g q12h, or erythromycin, 1.0 g q6h.
  - ◊ As a **substitute for gentamicin**: Ciprofloxacin, 400 mg q12h.
- ♦ Alternative regimen: Imipenem, 1 g IV q6h.

- **Intraabdominal infections.**
  - o Regimens (start as soon as possible and continue for **24 hours** post-op):
    - ♦ **Single agent: cefotetan, 1.0 g q12h**; or ampicillin/sulbactam, 3 g q6h; or cefoxitin, 1.0 g q8h.
    - ♦ **Triple agent:** ampicillin, 2 g q6h; **plus** anaerobic coverage (metronidazole, 500 mg q6h; or clindamycin, 900 mg every 8 hours); **plus** gentamicin, 5–7 mg/kg/day.

- **Established** intraabdominal infection (peritonitis or abscess).
  - Same regimen as above, except continue for 7–10 days.
  - Drain all abscesses.

- **Pulmonary infections.**
  - **Empyema** (generally streptococcal) following penetrating thoracic trauma is typically due to contamination from the projectile, chest tubes, or thoracotomy.
  - Diagnosis: loculations, air/fluid levels on radiograph, pleural aspirate.
  - Treatment.
    - Initial treatment is prevention during all interventions. Once confirmed, a video-assisted thoracostomy (VATS) or formal thoracotomy in indicated. **Chest tubes are not adequate treatment.**
    - Cefotaxime, or ceftriaxone, or cefoxitin, or imipenem.
  - **Pneumonia** is most frequently due to prolonged mechanical ventilation or aspiration in patients with severe traumatic brain injury (TBI).
  - The diagnosis is clinical and supported through radiographical findings of a new pulmonary infiltrate combined with:
    - Fever or leukocytosis.
    - Thick secretions
    - Sputum analysis showing copious bacteria and leukocytes.
  - Empiric therapy is directed toward likely pathogens.
    - **Aspiration**: Streptococcal pneumonia, coliforms, and oral anaerobes are likely. IV antibiotics—such as ampicillin/sulbactam, clindamycin, or cefoxitin—have been proven effective.
    - **Ventilator-associated pneumonia**: *Staphylococcus*, *Pseudomonas*, and other nosocomial *Enterobacteriaceae*. Broad coverage is best with such agents as imipenem, ceftazidime, or piperacillin/tazobactam plus vancomycin for methicillin-resistant *Staphylococcus aureus*. Ciprofloxacin can be considered for double-coverage against *Pseudomonas* if sufficient concern exists.

Systemic Sepsis

Sepsis can be defined as infection combined with a prolonged systemic inflammatory response that includes two or more of the following conditions:

- Tachycardia.
- Fever or hypothermia.
- Tachypnea or hyperventilation.
- Leukocytosis or acute leukopenia.

Progression to septic shock is manifested by systemic hypoperfusion: profound hypotension, mental obtundation, or lactic acidosis.

It is often difficult to identify the source of sepsis, but it is **an important factor** in determining the outcome. Potential sources of occult infection include:

- An undrained collection of pus, such as a wound infection, intraabdominal abscess, sinusitis, or perianal abscess.
- Ventilator-associated pneumonia.
- Urinary tract infection.
- Disseminated fungal infection.
- Central intravenous catheter infection.
- Acalculous cholecystitis.

The newly revised Surviving Sepsis Campaign (2016) recommends:

- Empiric broad-spectrum therapy with one or more antimicrobials to cover all likely pathogens. IV administration should be initiated within one hour of presentation.
- Treatment of sepsis-induced shock with at least 30 mL/kg of IV crystalloid fluid within the first 3 hours.
- Fluid resuscitation should be guided by frequent reassessment of hemodynamics.
- If goal mean arterial pressure (MAP) >65 is not attained with fluid resuscitation, the initiation of vasopressors is indicated.
  - First line agent: norepinephrine.
  - Second line agents: Addition of vasopressin (.03 U/min) or epinephrine.

Table 10-3. Spectrum and Dosage of Selected Antibiotic Agents

Agent	Antibacterial Spectrum	Dosage
Penicillin G	*Streptococcus pyogenes*, penicillin-sensitive *Streptococcus pneumoniae*, clostridial spp.	4 mU IV q4h
Ampicillin	Enterococcal spp., streptococcal spp., *Proteus*, some *Escherichia coli*, *Klebsiella*	1–2 g IV q6h
Ampicillin/ sulbactam	Enterococcal spp., streptococcal spp., *Staphylococcus*,* *E coli*, *Proteus*, *Klebsiella*, clostridial spp., *Bacteroides/Prevotella* spp.	3 g IV q6h
Nafcillin	Staphylcoccal spp.,* streptococcal spp.	1 g IV q4h
Piperacillin/ clavulanate	Enterococcal spp., streptococcal spp., *Staphylococcus*,* *E coli*, *Pseudomonas*, and other enterobacteriaceae, clostridial spp., *Bacteroides/Prevotella* spp.	3.375 g IV q6h
Imipenem	Enterococcal spp., streptococcal spp., *Staphylococcus*,* *E coli*, *Pseudomonas*, and other enterobacteriaceae, clostridial spp., *Bacteroides/Prevotella* spp.	1 g IV q6h
Cefazolin	Staphylococcal spp.,* streptococcal spp., *E coli*, *Klebsiella*, *Proteus*	2 g IV q8h
Cefoxitin	Staphylococcal spp.,* streptococcal spp., *E coli* and similar enterobacteriaceae, clostridial spp., *Bacteroides/Prevotella* spp.	1–2 g IV q6h
Ceftazidime	Streptococcal spp., *E coli*, *Pseudomonas*, and other enterobacteriaceae	2.0 g IV q8h
Ceftriaxone	Streptococcal spp., staphylococcal spp.,* *Neisseria* spp., *E coli*, and most enterobacteriaceae (**NOT** *Pseudomonas*), clostridial spp.	1 g qd
Ciprofloxacin	*E coli, Pseudomonas,* and other enterobacteriaceae	400 mg q12h
Gentamicin	*E coli, Pseudomonas,* and other enterobacteriaceae	5–7 mg/kg qd (based on once-daily dosing strategy and no renal impairment)
Vancomycin	Streptococcal, enterococcal, and staphylococcal spp. (including MRSA, not VRE) q12h	15 mg/kg q12h
Erthromycin	Streptococcal spp., clostridial spp.	0.5–1.0 g q6h
Clindamycin	*Streptococcus* spp., *Staphylococcus* spp.,* clostridial spp., *Bacteroides*, and *Prevotella* spp.	900 mg q8h
Metronidazole	Clostridial spp., *Bacteroides*, and *Prevotella* spp.	500 mg q6h

MRSA: methicillin-resistant *Staphylococcus aureus*; spp.: species; VRE: vancomycin-resistant enterococci.

Note: Dosage and dosage intervals are average recommendations. Individual dosing may vary.

*Not MRSA.

Suitable antibiotic regimens include the following:

- Imipenem, 1 g IV q6h.
- Piperacillin and clavulanate (Zosyn), 3.375 g q6h; or ceftazidime, 2.0 g q8h; or cefepime, 2.0 g q12h; **plus** gentamicin, 5–7 mg/kg qd. (based on a once-daily dosing strategy and no renal impairment); or ciprofloxacin, 400 mg q12h.
- Addition of vancomycin, 15 mg/kg q12h, if methicillin-resistant *Staphylococcus aureus* is a likely pathogen.
- Addition of linezolid, 600 mg q12h, if vancomycin-resistant enterococcus is a likely pathogen.

Battlefield casualties are at high risk for infection. In particular, war wounds are predisposed to infection due to environmental conditions on the battlefield, devitalized tissue, and foreign bodies. The key to minimizing wound infection is prompt and adequate exploration and debridement of devitalized tissue and removal of all foreign material. All wounds, including amputations, should be left open. Antibiotics are an adjunct to the prophylaxis of wound infections in the tactical setting. Knowledge of likely pathogens for particular infections and sites, as well as optimal antibiotics to eradicate those pathogens (Table 10-3), will aid the battlefield clinician in averting and treating infections.

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For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 11

Critical Care

Introduction

The effective application of basic critical care concepts in a timely fashion is vital to the survival of the wounded warrior. At a fundamental level, most of the care required by patients in the combat care environment after a traumatic injury centers around the adequate delivery and utilization of oxygen. An organized system-based approach to care in the intensive care unit should focus on goals of resuscitation and the identification of factors that can threaten these efforts.

Shock/Endpoints of Resuscitation

Shock is an acute physiological state characterized by inadequate oxygen availability to support cellular metabolic needs. **Uncompensated shock** is easily identified at the bedside and is characterized by decreased urine output, altered mental status, hypotension, poor capillary refill, and tachycardia. **Compensated shock** is much more difficult to discern clinically because patients may look normal on examination, but may have organ hypoperfusion that is not appreciated. (See chapter 7 for further information on shock.) Resuscitation is not complete until oxygen delivery (DO_2) and uptake are adequate.

$$\mathbf{DO_2 = CO \times 1.34 \times Hgb \times SaO_2 + 0.0031 \times PaO_2,}$$

where CO = cardiac output, Hgb = hemoglobin, SaO_2 = percentage of oxygen saturation of hemoglobin, and PaO_2 = partial pressure of oxygen in the blood.

Hypovolemic shock is the most common form of shock in the combat casualty care setting and is characterized by decreased intravascular volume (IVV) as its primary abnormality. The resulting decrease in cardiac output leads to diminished DO_2. In

the case of hemorrhage, there is a concomitant decrease in red cell volume that further contributes to inadequate DO_2.

Distributive shock is produced by an inappropriate decrease in systemic vascular tone, leading to an abrupt decrease in mean arterial blood pressure (MAP) to a level that impairs adequate organ perfusion. Neurogenic shock, septic shock, and anaphylactic shock are examples of this process that may be encountered in the combat setting.

Cardiogenic shock results from a primary defect in cardiac output. Myocardial infarction leading to heart wall or valve function abnormalities and cardiac tamponade are classic causes.

Obstructive shock is a process that ultimately results in inadequate cardiac output. Pulmonary embolism (PE) and tension pneumothorax are two common etiologies.

Define Goals of Shock Resuscitation

- MAP > 65 mm Hg.
- Urine output > 0.5 mL/kg/h (in adults).
- Serum lactate <2.

Management of Uncompensated Shock

- Define the type of shock and its etiology; eliminate the cause of the shock if possible.
- Vigorously replete the IVV if MAP or urine output is inadequate.
- Use vasopressor agents to support the MAP after adequate volume restoration.
  - Norepinephrine is the first line agent in most nonhemorrhagic situations.
  - Administer epinephrine in anaphylaxis.
  - Consider dopamine in cardiogenic shock associated with low blood pressure.

Detection of Compensated Shock and Subsequent Management

- Inadequate DO_2 relative to oxygen uptake (VO_2) leads to **increased anaerobic metabolism**.
- Anaerobic metabolism leads to **increased lactate production**.
- Increased lactate may lead to the development of **anion gap metabolic acidosis**.

- An **increased base deficit > 10 mEq/L** suggests inadequate resuscitation.
- Central venous oxygen saturation ($ScvO_2$) **< 65% suggests inadequate resuscitation**.
  - The body should use <25%–35% of oxygen delivered.
  - Increased utilization by cells suggests inadequate DO_2.
  - $ScvO_2$ < 65% suggests inadequate DO_2 and an implied need to optimize SaO_2, hemoglobin, or cardiac output.
    - Optimize SaO_2 and IVV.
    - Consider transfusion > 10 mg/dL.
    - Consider inotropic therapy.

Fluid Management

Intravenous fluids are given to patients to either replete a deficit in IVV or prevent the development of such a deficit in a patient unable to accomplish these goals without assistance. The choice of fluid depends on which of these goals is being addressed and the overall clinical context.

- Total body sodium is directly proportional to extracellular fluid volume (ECFV).
- IVV generally represents 15%–20% of ECFV.
- IVV repletion, therefore, is dependent on sodium infusion.
  - **Lactated Ringer (LR) solution: 130 mEq/L sodium, pH** 5.5–6.0.
  - **0.9% normal saline (NS): 154 mEq/L sodium and chloride, pH 4.5–5.5.**
- In most clinical contexts, colloid infusion confers no benefit during resuscitation relative to isotonic crystalloid solutions, such as LR and NS.
  - However, equivalent IVV repletion can be accomplished using lower volumes of colloid solutions.
- A nonanion gap metabolic acidosis frequently results from the use of large volumes of NS during resuscitation; continued resuscitation can be then accomplished using other isotonic fluid combinations.
  - 0.5 L of ½ NS with 75 mEq sodium bicarbonate ($NaHCO_3$): approximately 152 mEq/L sodium.
  - 1 L of D5W (5% dextrose in water) with 150 mEq $NaHCO_3$: approximately 150 mEq/L sodium.

Special Fluid Considerations

- **Hypertonic saline** should be considered in patients with traumatic brain injury (TBI).
- ½ NS (±D5 [or 5% dextrose]) should be used for maintenance of IVV to counteract insensible losses.
- ½ NS (±D5) can be used to replete IVV for the rare patient with both hypernatremia and IVV depletion (postosmotic diuresis, etc).
- **Albumin** should be considered in the following patients:
  - Complicated burn resuscitation expected to result in hourly IV fluid rate exceeding 1,500 mL/h or if the projected 24-h total fluid volume approaches 250 mL/kg (see Burn CPG, March 2016).
    - ♦ Refer to Chapter 26, Burns, for further guidance.
  - Severely malnourished patients with serum albumin concentration <1.0.
  - Cirrhotic patients who present with spontaneous bacterial peritonitis.

Serum Electrolyte Management

Serum sodium management depends primarily on the recognition that the serum sodium concentration is not necessarily indicative of IVV status. Although IVV is directly proportional to ECFV and, therefore, total body sodium, abnormal serum sodium concentrations usually represent abnormalities in free water handling. Notable exceptions include hypovolemic hyponatremia (diuretics, etc) and hypervolemic hypernatremia (hypertonic saline administration, etc). Two key questions are important to consider in all patients with an abnormal serum sodium:

- **What is the IVV status of the patient?**
- **Is there free water excess (hyponatremia) or deficit (hypernatremia)?**

Hyponatremia (Na < 135 mEq/L)

- Euvolemic hyponatremia.
  - **Differential diagnosis (Ddx):** Antidiuretic hormone (ADH) release (syndrome of inappropriate ADH, pain, anxiety), adrenal insufficiency, hypothyroidism, and severe polydipsia.

- **Management:** Free water restriction, correct underlying cause.

- Hypovolemic hyponatremia.
  - **Ddx:** Diuretic use, cerebral salt wasting.
  - **Management:** IVV repletion with NS.
- Hypervolemic hyponatremia.
  - **Ddx:** Severe congestive heart failure (CHF), cirrhosis, or renal failure.
  - **Management:** Treat underlying condition; consider diuretic use.
- Relative "salt deficit" (mEq Na) = 0.6 × weight in kg × (140 – Na). Free water restriction for euvolemic and hypervolemic hyponatremia. 3% saline (5-6 mL/kg) infusion for central nervous system (CNS) symptoms (mental status changes, seizures, etc).

Rate of serum sodium correction should be <0.5 mEq/L/h and <10 mEq/L/24 h to prevent osmotic demyelination syndrome (formerly known as central pontine myelinolysis).

Hypernatremia (Na > 145 mEq/L)

- Euvolemic hypernatremia.
  - **Ddx:** Same as hypovolemic hypernatremia.
  - **Management:** Treat underlying cause, free water repletion.
- Hypovolemic hypernatremia.
  - **Ddx:** Renal water loss (osmotic diuresis [mannitol, hyperglycemia, etc]), impaired thirst/water intake, and central/nephrogenic diabetes insipidus.
  - **Management:** Treat underlying cause, replete IVV, and free water repletion.
- Hypervolemic hypernatremia.
  - **Ddx:** Iatrogenic (hypertonic saline administration).
  - **Management:** Discontinue NS infusion; free water repletion.
- Relative "free water excess" (in liters) = 0.6 × weight in kg × (Na – 140)/140.
  - Rate of serum sodium correction should be <0.5 mEq/L/h and <10 mEq/L/24 h.

Serum potassium concentration is frequently abnormal in critically ill patients. Similar to the case with serum sodium concentration disorders, the serum potassium level may not be indicative of total body potassium stores. In the case of potassium, the vast majority is contained in the intracellular fluid volume (ICFV) space, and only a small portion is found in the ECFV or intravascular spaces. Potassium shifts back and forth between the ECFV and ICFV with relative ease, leading to potentially large swings in serum concentrations. Total body potassium may be quickly depleted if lost through renal or nonrenal (diarrhea, sweat, and fasting) excretion.

Hypokalemia (K < 3.5 mEq/L)

Serum hypokalemia may be secondary to **redistribution of potassium** from the ECFV to the ICFV, as is commonly seen with significant alkalemia or increased beta-2 agonist utilization. Total body potassium **depletion** may also lead to a decrease in serum potassium concentration through increased renal losses (diuretic use, postobstructive diuresis, osmotic diuresis, alkalosis, and proximal/distal renal tubular acidoses) and nonrenal mechanisms.

- EKG changes consistent with hypokalemia include prominent U waves and T-wave flattening.
  - Clinically this can manifest as paralysis, respiratory muscle dysfunction, and rhabdomyolysis.
- Enteral supplementation is preferred when the patient is clinically stable because it is both safer and results in faster repletion relative to IV infusion.
- IV infusion rates are limited to 10 mEq/h through a peripheral IV and 20–40 mEq/h through a central line. In general, 10 mEq of potassium repletion increases serum levels by 0.1 mEq. **IV potassium replacement at rate >10 mEq/L/h requires continuous cardiovascular monitoring.**
- Use KCl for replacement in most situations; potassium citrate or potassium bicarbonate is more appropriate when hypokalemia is associated with metabolic acidosis (especially renal tubular acidosis).
- Oral repletion: KCl elixir or tablet 30–60 mEq qid until serum potassium concentration is normal.

- Emergent IV repletion: KCl via a central line 20–40 mEq/h until potassium > 3.0 mEq/L, then switch to oral as above or a lower infusion rate of 10–20 mEq/h until serum concentration is normal.
  - Avoid dextrose-containing solutions because the subsequent insulin release will cause intracellular redistribution of potassium (K), further complicating repletion efforts.
- If adequate potassium replacement does not result in appropriate rise in serum potassium, serum magnesium levels should be assessed and repleted

Hyperkalemia (K > 5.5 mEq/L)

- Hyperkalemia may present as a result of several different mechanisms. **Pseudohyperkalemia, or falsely elevated K,** is iatrogenic, arising from improper venipuncture (drawing directly from the IV line with LR) or hemolysis of specimen. The draw should be repeated if the lab value is not clinically correlated. An EKG should be obtained to assess for evidence of myocardial excitation, which may manifest in the following sequence:
  - Peaked T waves, flattened P waves, and prolonged PR interval.
- In more severe cases, this sequence may be followed by:
  - Idioventricular rhythm, widened QRS interval, sine wave pattern, and ventricular fibrillation.

Redistribution hyperkalemia is seen in the trauma critical care setting most frequently as a result of acidemia, succinylcholine utilization, or hypertonic states (hypertonic saline or mannitol use). Finally, hyperkalemia may result from **renal failure, hypoaldosteronism, and medications (salt substitutes and exogenous potassium supplementation).**

- Chronic hyperkalemia is better tolerated than the acute condition.
- Acute hyperkalemia should be regarded as a life-threatening medical emergency.
- Treatment options for hyperkalemia include:
  - 10 mL of 10% calcium chloride if central venous access is available (standard calcium chloride ampule) over 1–3 minutes; can repeat every 5 minutes, as long as severe EKG

changes persist. If peripheral access only, infuse 10 mL of 10% calcium gluconate over 1–3 minutes. **Remember, this will not alter the serum potassium level but will stabilize the myocardium and should be performed immediately upon recognition.**
  - 50 mEq of $NaHCO_3$ (1 standard ampule of a 7.5% $NaHCO_3$ solution). Repeat every 30 minutes until QRS is improved; often ineffective in renal failure.
  - Consider dialysis if QRS widening is present.
- Treatment with mild EKG changes (no evidence of QRS widening):
  - Beta-2 agonists (albuterol) 20 mg in 4 mL of saline nebulizer.
  - 50 mL of 50% dextrose/glucose, 10 U of regular insulin; follow glucose, repeat until EKG returns to baseline.
  - Loop or thiazide diuretic—use only in patients known to be intravascularly replete; will be ineffective in anuric renal failure.
  - Sodium polystyrene sulfonate (Kayexalate) 20 g orally every 6 hours or 50 g as an enema every 2–4 hours.
- Treatment with normal EKG consists of identification and correction of the cause, as well as 15 g of sodium polystyrene sulfonate (Kayexalate) orally every 6 hours or 30–60 g as an enema every 2–4 hours.
  - Intestinal necrosis can result, especially when given orally within a week of major surgery.

Serum magnesium is often not given significant priority in the care of the critical care patient. Similar to K, serum magnesium represents only a fraction of the total body stores. **Low serum magnesium levels indicate severe total body magnesium deficits. Normal serum magnesium levels do not correlate reliably with total body magnesium stores.**

Hypomagnesemia (Mg < 2.0 mEq/L)
Hypomagnesemia usually results from **inadequate intake (NPO status, malnutrition prior to admission)** or **excessive loss, usually via renal mechanisms (diuretics, osmotic diuresis).**
- Magnesium < 1.0 mEq/L may be associated with CNS excitability and torsades de pointes on EKG.

- Establishing and correcting the cause of hypomagnesemia is the ultimate key to the management of this disorder.
- Total body magnesium depletion (with or without serum hypomagnesemia) is frequently associated with both hypokalemia and hypocalcemia.
  - Successful repletion of potassium and calcium will not generally be possible until total body magnesium stores have been normalized.
- In the absence of CNS excitability or life-threatening hypokalemia or hypocalcemia, magnesium repletion should be given as 4 g magnesium sulfate IV every 24 hours for 72 hours before serum magnesium levels are rechecked.
- If CNS excitability or life-threatening hypokalemia or hypocalcemia is present, 2 g of magnesium should be given as an immediate IV push, followed by 4–6 g in 6 hours, and followed by 4–6 g IV each day for the next 2–3 days.
- Checking serum magnesium levels during repletion is not useful because mildly elevated magnesium levels do not indicate successful total body repletion, and clinically significant hypermagnesemia is not seen with the aforementioned rates of repletion unless severe renal failure exists.

Serum calcium disorders are seen frequently in the combat critical care setting. Hypocalcemia is seen with much greater frequency than hypercalcemia and will be given greater emphasis here. Serum calcium levels are often corrected for serum albumin levels because negatively charged proteins, such as albumin, bind positively charged calcium cations. Ionized calcium is the physiologically relevant portion of total calcium. Adjusting total calcium for measured albumin values is useful only if a measurement of ionized calcium is not available. In the combat casualty care setting, ionized calcium measurements can be obtained quickly using handheld point-of-care testing devices, such as the i-STAT Blood Gas Analyzer (with an EG7+ or EG8+ cartridge).

Hypocalcemia (iCa < 1.10)
Hypocalcemia in the combat setting is seen most frequently **after massive blood product transfusion** (calcium is bound by citrate used as an anticoagulant) or as a result of **associated total body hypomagnesemia**. QT interval prolongation can result from severe hypocalcemia, and its presence dictates the pace of repletion.

- 10% calcium chloride 10 mL vial contains 272 mg of elemental calcium.
- 10% calcium gluconate 10 mL vial contains 93 mg of elemental calcium.
- Administer one 10 mL vial of 10% calcium chloride in 50–100 mL of D5 in water for >10–15 minutes if QT prolongation is noted.
  - Follow this with 1–2 mEq/h of elemental calcium infusion until QT prolongation has been resolved or >1.00–1.10 g of calcium are corrected to within normal range. Supplementation should be performed via a central line, given the risk of venous thrombosis and subsequent tissue necrosis.
- Hypocalcemic patients without QT prolongation can be repleted as follows:
  - Oral supplementation of 1.5–2.5 g of elemental calcium per day.
  - If oral supplementation is not possible, initiate an infusion of 0.5 mg/kg/h of elemental calcium >1.10.
- If hypocalcemia is difficult to correct, consider total body magnesium depletion (with or without serum hypomagnesemia).

Pulmonary Medicine

Basics of Mechanical Ventilation
Patients are placed on invasive mechanical ventilation most commonly for airway protection, respiratory failure (hypoxemia), or ventilatory failure (hypercapnia leading to acidemia). Another relatively common indication is in the setting of shock to optimize DO_2. **Compliance** of the chest wall/lung unit is defined by the change in volume resulting from a change in pressure.

Volume control modes of ventilation (assist-control [A/C], synchronized intermittent mandatory ventilation [SIMV]) provide mandatory breaths at a specified volume.

Pressure control modes of ventilation (pressure control ventilation) provide mandatory breaths to a set pressure.

Ventilation (elimination of CO_2) is necessary to achieve a target $PaCO_2$ of 35–45.

- **$PaCO_2$ is regulated by altering respiratory rate (RR) or tidal volume (V_T) in order to change the minute volume (Ve).**

Oxygenation/respiration is necessary to support adequate DO_2 to the patient. Goal SaO_2 is 92%. **There is generally little physiological benefit from attempting to manipulate the ventilator to achieve values higher than 92%.**

Using positive pressure ventilation, increased oxygenation/respiration occurs by increasing the fraction of inspired oxygen (FiO_2) or increasing the mean airway pressure (positive end-expiratory pressure [PEEP]).

- A low PaO_2/FiO_2 (<300), in the absence of very severe hypercapnia, suggests shunt physiology as the most likely cause of hypoxemia in a patient.
- Increased mean airway pressure may be a useful adjunct (increase the PEEP).
- FiO_2 manipulation alone will be unlikely to correct hypoxemia in this setting.

Initial ventilator settings for most patients should **strive to optimize oxygenation and ventilation while at the same time serve to minimize barotrauma** (pneumothorax, subcutaneous emphysema, etc, due to excessive transalveolar pressures); **volutrauma** (lung damage due to excessive stretch); **atelectotrauma** (lung damage due to repetitive opening and closing of alveoli); and **biotrauma** (release of cytokines related to the application of positive pressure ventilation).

Mode: Volume Cycled (A/C or SIMV)

- SIMV is not recommended in the acute setting because it is associated with increased work of breathing when used for prolonged periods.

- When SIMV is used, it is best to use pressure support ventilation to augment any spontaneous breaths.
  - The standard military transport ventilator (Impact 754) does not allow pressure support ventilation to be used when the SIMV mode is used.
- FiO_2 = 100%; titrate down to lowest amount to keep SpO_2 or SaO_2 > 92%.
  - SaO_2 = saturation of hemoglobin as measured by arterial blood gas sampling.
  - SpO_2 = noninvasive pulse oximetry; a rough estimate of SaO_2.
- V_T = 5–7 mL/kg ideal body weight.
  - Ideal predicted body weight in kilograms in males = 50 + 2.3 × (height in inches – 60).
  - Ideal predicted body weight in females = 45.5 + 2.3 × (height in inches – 60).
  - Adjust to keep <8 mL/kg and plateau pressures < 30 cm H_2O.
- RR = 16.
  - Adjust to keep RR × V_T adequate to manipulate $PaCO_2$ to achieve goal pH.
- Inspiration:expiration (I:E) ratio = 1:2 to 1:3.
- PEEP = 5 cm H_2O.
  - Increase PEEP if PaO_2/FiO_2 < 300 (shunt physiology expected).
  - Increase PEEP to 10–12 cm H_2O if shunt physiology present.
    - Increase as necessary above this level to keep SpO_2 > 92%.
    - With increased PEEP, V_T may need to be decreased to keep plateau pressures < 30 cm H_2O.

Acute Respiratory Distress Syndrome

Acute respiratory distress syndrome (ARDS) can be caused by direct (inhaled toxins, aspiration) or indirect (trauma, burns, any cause of systemic inflammatory response syndrome) mechanisms, but the basic management is similar. To meet the definition, the following criteria must be met:

- Acute presentation of hypoxemic respiratory failure.
- Bilateral infiltrates on chest radiography.

- No clinical evidence of left heart volume overload; pulmonary capillary wedge pressure < 18 mm Hg if measured.

The severity of ARDS is determined by the PaO_2/FiO_2 (Berlin definition):

- **Mild ARDS**. The PaO_2/FiO_2 is >200 mm Hg, but ≤300 mm Hg, on ventilator settings that include PEEP or continuous positive airway pressure (CPAP) ≥5 cm H_2O.
- **Moderate ARDS.** The PaO_2/FiO_2 is >100 mm Hg, but ≤200 mm Hg, on ventilator settings that include PEEP ≥5 cm H_2O.
- **Severe ARDS.** The PaO_2/FiO_2 is ≤100 mm Hg on ventilator settings that include PEEP ≥5 cm H_2O.

Basic ventilatory strategies are designed to minimize barotrauma by avoiding excessive alveolar pressures, volutrauma by limiting delivered V_T, and atelectotrauma by keeping alveoli open using increased mean airway pressure ventilator strategies. A ventilator strategy encompassing these features was found by the ARDSNet investigators to lead to an improved mortality and should be followed where possible (Table 11-1).

Table 11-1. Mechanical Ventilation Protocol Summary

INCLUSION CRITERIA
Acute onset of the following:
1. PaO_2/FiO_2 ≤ 300 (corrected for altitude).
2. Bilateral (patchy, diffuse, or homogeneous) infiltrates consistent with pulmonary edema.
3. No clinical evidence of left atrial hypertension.

PART I: VENTILATOR SETUP AND ADJUSTMENT
1. Calculate Ideal Body Weight (IBW).
   Males = 50 + 2.3 (height [inches] – 60).
   Females = 45.5 + 2.3 (height [inches] – 60).
2. Select any ventilator mode.
3. Set ventilator settings to achieve initial V_T = 8 mL/kg IBW.
4. Reduce V_T by 1 mL/kg at intervals ≤2 hours until V_T = 6 mL/kg IBW.
5. Set initial rate to approximate baseline minute ventilation (not >35 bpm).
6. Adjust V_T and RR to achieve pH and plateau pressure goals below.

(**Table 11-1** *continues*)

(**Table 11-1** *continued*)

Oxygenation Goal: PaO_2, 55–80 mm Hg or SaO_2, 88%–95%
Use a minimum PEEP of 5 cm H_2O. Consider use of incremental FiO_2/PEEP combinations, such as shown below (not required) to achieve goal.

Lower PEEP/Higher FiO_2

FiO_2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7
PEEP	5	5	8	8	10	10	10	12
FiO_2	0.7	0.8	0.9	0.9	0.9	1.0		
PEEP	14	14	14	16	18	18–24		

Higher PEEP/Lower FiO_2

FiO_2	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.4**	**0.4**	**0.5**
PEEP	**5**	**8**	**10**	**12**	**14**	**14**	**16**	**16**
FiO_2	**0.5**	**0.5–0.8**	**0.8**	**0.9**	**1.0**	**1.0**		
PEEP	**18**	**20**	**22**	**22**	**22**	**24**		

Plateau Pressure Goal: ≤30 cm H_2O
Check Pplat (0.5-second inspiratory pause), at least q4h and after each change in PEEP or V_T.
- **If Pplat > 30 cm H_2O:** decrease V_T by 1 mL/kg steps (minimum = 4 mL/kg).
- **If Pplat < 25 cm H_2O and V_T < 6 mL/kg,** increase V_T by 1 mL/kg until Pplat > 23 cm H_2O or V_T = 6 mL/kg.
- **If Pplat < 30 and breath stacking or dyssynchrony occurs:** may increase V_T in 1 mL/kg increments to 7 or 8 mL/kg if Pplat remains ≤30 cm H_2O.

pH Goal: 7.30–7.45

Acidosis management: pH < 7.30.
(Consider other causes of acidemia, eg, hemorrhage).
- **If pH 7.15–7.30:** Increase RR until pH > 7.30 or $PaCO_2$ < 25.
  - Maximum set RR = 35.
- **If pH < 7.15:** Increase RR to 35.
  - If pH remains <7.15, V_T may be increased in 1 mL/kg steps until pH >7.15 (Pplat target of 30 may be exceeded).
  - May give $NaHCO_3$.

Alkalosis management: pH > 7.45 (decrease vent rate, if possible)

I:E: Ratio Goal
Recommend I:E = 1:2–1: 3

(**Table 11-1** *continues*)

(**Table 11-1** *continued*)

PART II: WEANING

A. Conduct a Daily Spontaneous Breathing Trial When:

- The cause of the respiratory failure has improved.
- The patient is oxygenating adequately.
- The arterial pH is >7.25.
- The patient is able to initiate an inspiratory effort.
- The patient is hemodynamically stable, without myocardial ischemia.

B. Spontaneous Breathing Trial

If all of the above criteria are met and the subject has been in the study for at least 12 hours, initiate a trial of UP TO 120 minutes of spontaneous breathing with $FiO_2 \leq 0.5$ and PEEP ≤ 5:

1. Place on T-piece, trach collar, or CPAP ≤ 5 cm H_2O with PS ≤ 5.
2. Assess for tolerance as below for up to 2 hours.
   a. $SpO_2 \geq 90$; and/or $PaO_2 \geq 60$ mm Hg.
   b. Spontaneous $V_T \geq 4$ mL/kg IBW.
   c. RR < 35/min.
   d. pH ≥ 7.3.
   e. No respiratory distress (distress = 2 or more).
      i. HR > 120% of baseline.
      ii. Marked accessory muscle use.
      iii. Abdominal paradox.
      iv. Diaphoresis.
      v. Marked dyspnea.
3. If tolerated for at least 30 minutes, consider extubation. A rapid shallow breathing index (RSBI = RR/ TV in liters) <105 has been proven to correlate with successful extubation.
4. If not tolerated, resume preweaning settings.

ARDS: acute respiratory distress syndrome; BP: blood pressure; bpm: breaths per minute; CPAP: continuous positive airway pressure; FiO_2: inspired oxygen; HR: heart rate; I:E: inspiration:expiration; IMV: intermittent mandatory ventilation; $NaHCO_3$: sodium bicarbonate; $PaCO_2$: partial arterial gas pressure (tension) of carbon dioxide; PaO_2: partial pressure of oxygen in the blood; PBW: predicted body weight; PEEP: positive end-expiratory pressure; Pplat: plateau pressure; PS: pressure support; q4h: every 4 hours; RR: respiratory rate; SpO_2: noninvasive pulse oximetry; trach collar: tracheostomy collar; V_T: tidal volume. Reprinted with permission and with minor changes from the ARDS Clinical Network website (www.ardsnet.org) and the National Institutes of Health and the National Heart, Lung, and Blood Institute.

Adjunctive therapies for ARDS have been studied for decades and have been demonstrated to have variable clinical benefit. Each can be considered in a given patient depending on the clinical scenario and availability of resources.

- High (>16 cm H_2O) vs moderate (10–16 cm H_2O) PEEP.
  - Possible benefit using higher levels in patients with more severe hypoxemia.
- Prone positioning.
  - Improves oxygenation in patients with severe hypoxemia.
  - No definitive mortality benefit.
  - Can be accomplished with a Stryker frame in the combat support setting.
- Conservative IVV management.
  - Improved outcomes relative to liberal strategy, as tolerated by physiology and injury pattern of the patient in question.
- Pulmonary artery catheter vs central venous pressure monitoring.
  - No benefit to using a pulmonary artery catheter to guide fluid management.
- Special dietary formulations.
  - No single proprietary formula has been demonstrated to improve outcomes.
- Corticosteroids.
  - Not recommended at this time
- Inhaled nitric oxide (if available).
  - Improved oxygenation noted.
  - No mortality benefit.
- Pressure control ventilation.
  - No significant outcomes benefit relative to volume control A/C mode.
  - If used, efforts must be made to continue to limit V_T as outlined in the ARDSNet protocol.
- Airway pressure release ventilation.
  - No significant outcomes benefit relative to volume control A/C mode.
  - Equivalent mean airway pressures can be obtained using lower amounts of sedation, and patients are less likely to require neuromuscular blockade.
  - If used, efforts must be made to continue to limit V_T as outlined in the ARDSNet protocol.
- High-frequency oscillatory ventilation.
  - No benefit to standard of care demonstrated in the 1990s.

  - Has not been directly compared with ARDSNet low V_T strategy.
  - Technology and expertise unlikely to be available in combat support operations.
- Extracorporeal membrane oxygenation.
  - Improved oxygenation.
  - No mortality benefit.
  - Technology and expertise unlikely to be available in combat support operations.
- Extracorporeal carbon dioxide removal.
  - Maybe a useful adjunct when carbon dioxide elimination is severely limited.
  - Has not been directly compared with ARDSNet low V_T strategy.

Pulmonary Contusion

Pulmonary contusion is frequently seen in the combat setting, most commonly associated with blunt trauma with or without rib fractures. The disorder is similar to ARDS, in that it may present with a significant degree of hypoxemia and decreased compliance. A significant distinction between the two clinical syndromes is the profoundly asymmetric nature of pulmonary contusion. **Excessive mean airway pressure delivery may lead to overdistension of healthy lung, which has the effect of shunting blood away from well-ventilated alveoli (increasing dead space fraction) and toward poorly ventilated contused regions (increasing shunt). If an increase in PEEP is associated with a significant fall in oxygen saturation, an increase in shunt physiology due to excessive mean airway pressure should be suspected, and PEEP should be decreased to its previous level.** Pulmonary contusion is generally managed in a supportive fashion using a low V_T strategy combined with aggressive pulmonary toilet.

Pulmonary Embolism

PE is part of a broader disease process known as venous thromboembolic disease that includes deep venous thrombosis (DVT). DVT is very common in the trauma setting, and may be a life-threatening if accompanied by PE.

Diagnosis of DVT

- Determine pretest clinical suspicion.
- If low, do not work up further.
- If moderate or high, perform duplex ultrasonography.
- If clinical suspicion is high, but ultrasonography is negative, consider empiric treatment with further testing at a higher level of care.
- **Treatment of DVT.**
  - Low molecular weight heparin (Lovenox, 1 mg/kg subcutaneously bid) or unfractionated heparin (initial bolus, 80 units/kg; followed by 18 units/kg/h with goal PTT 55–85).
  - Consider removable inferior vena cava filter placement if there is a contraindication to anticoagulation. Examples of contraindications to anticoagulation common to the combat casualty include TBI, solid visceral injury, and pelvic fracture.

Hemodynamically Significant PE

The majority of patients who die from PE die of right heart failure associated with acute pulmonary hypertension rather than hypoxemia. A high pretest clinical suspicion for PE in the setting of hypotension and evidence of right heart failure on exam should be considered a medical emergency. Patient instability may preclude making a formal diagnosis. In this case a bedside transthoracic echocardiogram can be obtained to assess for right heart failure. If present, the following should be considered:

- Start therapy immediately with low molecular weight heparin or unfractionated heparin.
  - The risks of starting anticoagulation should be carefully weighed in the multisystem trauma patient.
  - Protamine (1–1.5 mg protamine per 100 units heparin) can be used to reverse the effects of low molecular weight heparin, although dosing may be more difficult to predict than when used to reverse the effects of unfractionated heparin. **Note:** When heparin is given as a continuous IV infusion, only heparin given in the preceding 2 to 3 hours should be considered when administering protamine.
  - Do not give fluid boluses for hypotension if significant evidence of right heart failure exists.

- Support blood pressure (MAP > 60 mm Hg, DBP > 40–45 mm Hg) using epinephrine or dopamine.
- Norepinephrine is also acceptable, although reflex bradycardia may be seen.
- Consider the addition of Milrinone or Dobutamine if persistent shock noted.
  - Milrinone may be a superior choice due to an improved ability to directly lower pulmonary vascular resistance.
  - Consider the use of thrombolytic therapy if hypotension is persistent or cardiopulmonary arrest develops.

Prevention of Venous Thromboembolism

Given the high risk of venous thromboembolism complications associated with multisystem trauma patients (especially those with orthopedic and spine injuries), prevention remains the key to avoiding adverse consequences.

- All trauma patients should receive chemical prophylaxis for venous thromboembolism disease unless contraindicated (eg, TBI).
  - Low molecular weight heparin (Lovenox 30 mg subcutaneously bid) should be administered.
  - Highest-risk patients (spine injury, expected prolonged immobilization, and orthopedic injury) should also have intermittent pneumatic compression device therapy initiated.
- Trauma patients with clinical contraindications to chemical prophylaxis should be considered for IVC filter placement

Aspiration Pneumonitis

Patients with compromised pulmonary status secondary to aspiration should be managed supportively, with positive pressure ventilation and a lung protective strategy as described previously in this chapter. **Empiric antibiotics are NOT indicated for isolated aspiration.** Witnessed or clinically suspected aspiration usually results in a chemical pneumonitis and does not commonly lead to an infectious pneumonia. Aspiration pneumonitis generally presents with an infiltrate in a dependent portion of the lungs (especially the right lower lobe, left lower lobe, or the superior segments of the right or left upper lobes) and may be associated with a fever, moderate leukocytosis, worsening

oxygenation, and evidence of consolidation on physical exam. Failure to improve after 24–48 hours should initiate investigation for a secondary bacterial pneumonia infectious process. Cultures should be obtained before initiating empiric therapy with broad-spectrum antibiotics (see Chapter 10, Infections). Antibiotics should be stopped at 72 hours if cultures do not demonstrate a dominant organism. Duration of antibiotic therapy should be limited to 5–7 days. Bronchoscopy should be performed in cases of suspected foreign body aspiration (teeth, etc).

Combat-Associated Healthcare Pneumonia

Combat-associated healthcare pneumonia denotes a hospital-acquired pneumonia that is contracted while being treated in a combat medical facility. The distinction is important, because many combat medical facilities in Iraq and Afghanistan are associated with increased rates of patient colonization with multidrug-resistant bacteria. Patients who develop pneumonia after being in the combat medical system for at least 72 hours should be considered to be colonized with multidrug-resistant organisms, and empiric therapy should include vancomycin plus meropenem, doripenem, piperacillin/tazobactam, or cefepime. Ertapenem is not recommended due to poor coverage of *Pseudomonas aeruginosa*.

Cardiac Considerations

Cardiac Tamponade

Acute cardiac tamponade may occur as a result of either blunt or penetrating thoracic trauma and is a surgical emergency. Hemodynamically significant pericardial effusions may result from small volume collections of blood that result in a decreased ejection fraction. **Pericardial fluid in the setting of trauma requires immediate surgical evaluation**. Tamponade may be subtle, but cardiovascular collapse can quickly develop.

- Beck's Triad suggests the diagnosis of cardiac tamponade.
  - Hypotension, jugular venous distention, muffled heart sounds.
- The diagnosis can be confirmed with transthoracic echocardiogram.

- Assessment of cardiac enzymes has no role in the diagnosis of cardiac tamponade.
- Urgent pericardial drainage is necessary. In the setting of trauma, emergent pericardiocentesis may be performed as a temporizing measure in the absence of immediately available surgical care.
  - A needle is inserted subxyphoid at an angle of 20–30 degrees, and directed toward the left nipple. The needle should be aspirated as it is advanced. Ultrasound can be used to assist, if available.
- IVV may need to be aggressively supported to ensure adequate cardiac filling.
- Proximal aortic dissection should be strongly considered in patients with blunt trauma who develop acute cardiac tamponade.

Blunt Cardiac Injury

Blunt cardiac injury presents as a clinical consequence of blunt thoracic trauma in the combat setting. It is likely underdiagnosed because the vast majority of patients are asyptomatic, and significant consequences are uncommon. Diagnosis is suspected with PVCs or sinus tachycardia. If EKG abnormalities exist, cardiac enzymes are drawn to confirm the diagnosis. The patient should be managed in a monitored setting. A transthoracic echocardiogram should be obtained to assess for mechanical dysfunction (severe acute valve regurgitation, free wall rupture, and ventricular septal wall rupture).

Acute Coronary Syndrome

ST elevation myocardial infarction (STEMI) results from the occlusion of coronary vessels by an unstable plaque. This results in transmural cardiac muscle death. Management centers on revascularization, decreasing cardiac oxygen requirements, and monitoring closely for the development of mechanical complications, CHF, and potentially lethal arrhythmias such as ventricular tachycardia and fibrillation.

- Aspirin 81 mg PO, chewed as quickly as possible and daily thereafter.

- Beta blocker (Lopressor 5 mg IV initially) if no evidence of acute CHF. American Heart Association guidelines (Lopressor 5 mg IV incrementally or Esmolol drip) to target heart rate < 60–70 and SBP < 110.
- If heart rate target met with beta blocker, but SBP is >110, consider the following adjuncts:
  - Nitroglycerin gtt (dose may be limited by headache or the presence of right-sided disease).
  - Nicardipine gtt.
  - Nitroprusside gtt.
- Plavix 300 mg load followed by 75 mg PO daily.
- A glycoprotein 2B/3A inhibitor (Eptifibatide) should be considered.
- Supplemental oxygen to maintain SpO_2 > 96%–98%.
- Sublingual nitroglycerin (spray or tablet) as necessary for pain.
  - Rapid hypotension development with nitroglycerin suggests right-sided disease.
- Morphine IV as necessary for pain.
- Thrombolytic therapy (Tenecteplase, Reteplase) should be given ideally within 3 hours; 12 hours is acceptable.
- Cardiac catheterization is favored over thrombolytic therapy if available.
- **If evidence of CHF:**
  - Start nitroglycerin gtt.
  - Lasix q6h IV versus gtt to affect diuresis/preload reduction.
  - Consider nicardipine versus nitroprusside gtt to titrate blood pressure/afterload reduction, except in the setting of preload dependent inferior wall myocardial infarction.
  - Dopamine or Milrinone can be considered if SBP < 90.
  - Dobutamine can be considered; however, this agent will increase myocardial oxygen demand.
  - Aortic balloon pump is favored in this setting, if available.
- Continuous cardiac and hemodynamic monitoring (arterial line, central venous catheter with central venous pressure monitoring) should be continued until transfer to a higher level of care.
- An ACE (angiotensin-converting enzyme) inhibitor should be started within 24 hours of the index symptoms.
- A statin medication should be started as soon as possible.

Non-STEMI (NSTEMI) and unstable angina are closely related processes when cardiac demand exceeds oxygen supply. It should be regarded as a medical emergency. NSTEMI and unstable angina are physiologically the same process and are only distinguished by the presence of myocardial damage, as evidenced by cardiac enzyme elevation, in the setting of NSTEMI. Management is similar to STEMI; however, fibrinolytics play a less prominent role, and antiplatelet therapy plays a more prominent role due to the relative predominance of platelets over fibrin in coronary vessel clot associated with NSTEMI/unstable angina. Goals remain to improve coronary blood flow, decrease myocardial oxygen demand, and monitor for complications of the disease process. Progression to STEMI needs to be carefully monitored. Therapy should be directed as outlined for STEMI (see above).

Congestive Heart Failure

CHF is a clinical diagnosis in which cardiac output is inadequate relative to preload. Clinical signs and symptoms reflect left-sided heart failure (pulmonary edema, pleural effusions), as well as right-sided failure (jugular venous distention, dependent edema, liver and spleen engorgement). Systolic and diastolic dysfunction can both cause CHF when IVV is excessive (eg, acute or chronic valvular dysfunction). Goals of CHF management include **preload reduction, afterload reduction, and improved inotropic function**.

Preload Reduction

- Diuretic therapy.
  - Loop diuretic (Furosemide, Bumetanide).
    - Consider IV therapy for severe CHF; continuous gtt for refractory CHF.
  - Minimize salt intake (extracellular fluid volume is directly proportional to total body salt).
  - Total salt intake should be <1.5–2.0 g/d.
- Nitroglycerin drip.
  - Vasodilates venous system.
- Nitroprusside drip.
  - Relatively balanced arterial and venodilator.
- Atrial natriuretic peptide therapy (Nesiritide).

- Vasodilates arteries, but also affects significant natriuresis.
- For refractory CHF, no mortality benefit.

Afterload Reduction

- Goal SBP < 100–110 mm Hg.
- Beta-blocker therapy:
  - Carvediolol favored.
  - Lopressor, a longer acting agent, can also be considered.
  - Do not start a new beta blocker in the setting of acute CHF.
    - Patients already on a beta blocker who develop new CHF should have the dose dropped in half, **BUT NOT COMPLETELY DISCONTINUED**.
- Nicardipine gtt in the acute setting.
- ACE inhibitor therapy should be started early and titrated aggressively.
- Consider the addition of hydralazine, clonidine, or minoxidil if blood pressure is difficult to control.
- Nitroprusside or Nesiritide can be used transiently in the acute setting as described in the section on Preload Reduction.

Inotropic Therapy

- There is no mortality benefit to using inotropic therapy in the setting of acute CHF when complicating underlying systolic dysfunction exists.
  - However, it can be considered as a temporizing measure until more definite evaluation and care are available.
- Dobutamine or milrinone can be considered in acute CHF with SBP > 100 mm Hg.
- Dopamine should be considered if SBP < 90 mm Hg.
- An aortic balloon pump should be used, if available, when CHF complicates the period surrounding the presentation of an acute myocardial infarction or when aortic or mitral valve dysfunction is the cause of the CHF.

Other Aspects of Therapy

- Follow electrolytes closely.
  - Normalize serum magnesium and potassium.
  - Phosphorous levels below 1.0 mg/dL should be repleted.
  - Hyponatremia is a marker for increased mortality in the setting of CHF, but there is no benefit in correcting the hyponatremia as a specific therapeutic aim.

- ♦ It will correct on its own as CHF improves; the kidney sees better forward flow, and free water retention decreases.

- Watch for evidence of arrhythmias.
  - Patients with an ejection fraction < 30%–35% should be considered candidates for automated implantable cardioverter defibrillator placement unless life expectancy is <6–12 months.

Neurological Considerations

Traumatic Brain Injury

The medical management of TBI will be briefly reviewed in greater detail in Chapter 15, Head Injuries. Treatment is centered on the prevention of secondary brain injury resulting from hypotension and hypoxia.

Cerebrovascular Accident/Stroke Management

Two questions are vital to answer immediately when a patient presents with symptoms suggestive of a cerebrovascular accident (CVA), because they dictate the therapeutic approach:

- **When did the stroke occur?**
  - If fibrinolytic therapy is going to be considered, it should be delivered within 6 hours of symptom onset (better outcomes associated with early [<3 hour] therapy).
- **Is the stroke hemorrhagic or nonhemorrhagic**?
  - There is a risk of hemorrhagic conversion (may be seen in up to 10%–15% of patients with middle cerebral artery territory strokes). Document and follow serial neurological exams closely.
- Assess airway patency serially and have a low threshold for intubation.
- AVOID HYPOXEMIA (keep SpO_2 > 90% and PaO_2 > 60 mm Hg).
- Avoid hyperglycemia and hypoglycemia (keep glucose 90–140 mg/dL).
  - Utilize insulin drip if necessary.
- Keep head of bed flat unless aspiration risk is present, patient has been placed on mechanical ventilation, stroke territory is large, or there is evidence of elevated intracranial hypertension.

- If such relative contraindications to flat positioning exist, place patient in 30° head-of-bed elevation.

- Start therapy with aspirin within 24 hours if no evidence of intracranial hemorrhage.
- **<u>CAUTION</u>: THROMBOLYTICS SHOULD ONLY BE GIVEN IN ACCORDANCE WITH CURRENT AMERICAN HEART ASSOCIATION GUIDELINES REGARDING TIMING FROM THE ONSET OF SYMPTOMS AND STROKE SEVERITY.**
- Thrombolytics (Tenecteplase, Alteplase, Reteplase) should be given if no significant contraindications exist, the stroke is associated with significant clinical deficits, and there is no evidence of intracranial hemorrhage.
- Ensure that it is possible to lower SBP < 185 mm Hg and DBP < 110 mm Hg.
- Hypertension management.
  - Hypertension in the setting of CVA usually reflects either baseline blood pressure levels or a reaction to the stroke itself and may be dangerous to normalize in the acute setting.
    - SBP > 220 mm Hg or DBP > 140 mm Hg should be treated using short-acting, titratable IV medications, such as Labetalol or Nicardipine, with a goal of producing a 15% drop in blood pressure values.
    - Previously used outpatient antihypertensives should be initiated within 24–48 hours of the CVA, and goal blood pressures of SBP < 130 mm Hg and DBP < 80 mm Hg should be achieved slowly over days to weeks.
  - Other conditions that may coexist with the CVA and may dictate a more aggressive approach to rapid blood pressure titration (even normalization of blood pressure) using short-acting IV agents include:
    - Unclipped cerebral aneurysms associated with subarachnoid hemorrhage.
    - Aortic dissection.
    - Acute myocardial infarction.
- Body temperature regulation: MAINTAIN NORMOTHERMIA.
  - Efforts to normalize body temperature are appropriate.
  - Temperature regulation by the patients may not be normal.

- Hyperthermia is associated with worse outcomes and should be avoided.
- Acetaminophen PO or per rectum may be beneficial in this setting.
- Therapeutic hypothermia in the setting of CVA is not supported by the literature at this time outside of clinical research protocols.
- Other adjunctive agents.
  - Nimodipine has been associated with improved clinical outcomes when used in the management of acute subarachnoid hemorrhage.
  - Free radical scavengers have been suggested to have some benefit in CVA, but are not recommended for routine care at this time.

Gastrointestinal Considerations

Stress Gastritis

Indications for stress gastritis prophylaxis include several factors common in the combat critical care setting that predispose patients to develop stress gastritis. Of particular note are **coagulopathy, mechanical ventilation longer than 48 hours, shock, multisystem trauma, and burn >35% of the total body surface area.** Since most patients in the combat setting who need critical care support have at least one of these risk factors, **prophylaxis against stress gastritis should be considered** in all such patients.

- Suggested agents include pantoprazole 40 mg IV daily or ranitidine 50 mg IV or SQ every 8 hours.
- Sucralfate is not recommended in this setting.

Acalculous Cholecystitis

Trauma patients have several potential risk factors for the development of acalculous cholecystitis, significantly, multisystem trauma, hypotension, and burns. The diagnosis can be elusive but should be made in a timely fashion.

- Diagnosis suspected with new fever, vague abdominal discomfort, and leukocytosis.
  - Liver function tests are often normal

- Confirmation of the diagnosis can be made with RUQ (right upper quadrant) ultrasound.
- Empiric antibiotic therapy should be started when the diagnosis is suspected.
  - Imipenem, pipericillin/tazobactam, ampicillin/sulbactam, or a third-generation cephalosporin with metronidazole are all reasonable choices.
  - Vancomycin or Linezolid should be added only if the patient is known to be colonized with MRSA.
- Urgent percutaneous decompression should be considered in the unstable patient.

Renal Considerations

The most relevant forms of renal abnormalities in the combat setting include **prerenal azotemia, acute tubular necrosis (ATN), rhabdomyolysis, nephrolithiasis, and iatrogenic complications of medications.** Most of these entities are temporary if recognized and managed appropriately. For those that do develop significant azotemia, there usually exists a window of at least 24–36 hours to facilitate evacuation out of the theater of operation, because mechanisms to provide dialysis do not exist in the theater. **Early recognition of renal complications and appropriate early medical management are key to avoiding significant life-threatening complications**.

Prerenal Azotemia and Acute Tubular Necrosis

Although these two entities are separate clinical conditions, they are commonly related in the combat patient. **Prerenal azotemia represents the development of renal failure** (marked by a decreased CrCl and complications such as elevated BUN, acid-base abnormalities, hypervolemia, and electrolyte disturbances such as hyperkalemia) due to hypoperfusion of the kidneys. **ATN usually develops as a result of hypoperfusion with subsequent damage to renal tubule cells, especially in the region of the thick ascending loop of Henle.** Damaged tubule cells may form "muddy brown casts" that can be seen on urine microscopy and may obstruct tubules.

- **Prerenal azotemia diagnosis.**
  - Decreased urine output, elevated Cre, BUN/Cre > 20, UNa < 10 mg/dL.

- FeNa (%) = (UNa/SNa)/(SCre/UCre) × 100.
  - FeNa < 1% is consistent with a prerenal etiology of renal failure
    (where BUN = blood urea nitrogen, Cre = creatinine, UNa = urine sodium, FeNa = fractional excretion of sodium, SNa = serum sodium, SCre = serum creatinine, and UCre = urine creatinine).

- ATN diagnosis.
  - Decreased urine output, elevated creatinine, BUN/Cre 10–20, UNa >20 mg/dL.
  - Muddy brown casts on urine microscopy.
- Prerenal azotemia and ATN management.
  - Ensure adequate IVV.
  - There is no significant clinical benefit to converting anuric renal failure to oliguric failure, although patients who present with anuria generally do worse.
  - If IVV repletion is ensured and urine output is low, diuretic use can be considered in the patient with low urine output if IVV overload is a concern.
  - In the case of ATN, a period of 1–3 weeks may pass before renal recovery is noted.
    - An increase in urine volume occurs that precedes any true improvement in CrCl.
  - Watch closely for the development of hyperkalemia, acidemia due to anion gap metabolic acidosis, IVV overload, pericardial rubs, and extreme uremia.
    - These are indications for emergent hemodialysis.

Rhabdomyolysis

Rhabdomyolysis results in the setting of crush injury that causes significant destruction of skeletal muscle. CK_T (creatinine kinase), heme-pigmented myoglobin, and phosphate elevations are all released in significant amounts. **Heme-pigmented proteins may result in an ATN**. One unique feature of this form of renal failure is that it is associated with hypocalcemia. **Prevention of renal failure and its consequences is one of the fundamental priorities of the management of rhabdomyolysis**.

- Diagnosis: Red/brown low-volume urine, positive urine dipstick for myoglobin in the absence of red blood cells on urine microscopy, and CK_T elevation (may be >50,000–100,000).

- Aggressively ensure adequate IVV repletion.
  - Replete with isotonic crystalloid. (LR should be used with caution due to concern of hyperkalemia.)
- Goal urine output 150–300 mL/h; consider diuretic if IVV has been repleted.
- Bicarbonate therapy can be considered—titrate to a urine pH of 6.5–7.
  - Dose: 150 mEq $NaHCO_3$ (3 standard amps) in 1 L D5W at 100 mL/h initially.
  - No definite clinical benefit to this approach has been demonstrated.
- Mannitol diuresis is not recommended in the peritrauma setting due to possible IVV depletion.
- Follow serum electrolytes closely, especially potassium, phosphorous, and ionized calcium.

Nephrolithiasis

Nephrolithiasis represented one of the most common reasons for soldiers to be evacuated from the combat theater in both Operation Iraqi Freedom and Operation Enduring Freedom, and surgery of renal stones was the most common elective surgery performed in theater. Risk factors related to the combat environment include **low urine volume due to IVV depletion, as well as a high-protein diet.** The majority of stones are calcium based (approximately 80%) and are therefore easy to visualize with radiographic studies. The majority pass spontaneously, but patients with a history of recurrent stones, family history of stones, or complicating anatomical features leading to renal failure may necessitate surgical therapy by a urologist.

- Diagnosis of nephrolithiasis suggested by waxing/waning pain (radiating to the flank or scrotum, generally depending on level of obstruction) and microscopic hematuria.
- The stone may be visualized on KUB, CT/nephrolithiasis protocol, or ultrasound.
  - Start with KUB; subsequent studies based on availability.
- Adequate intravascular hydration is extremely important.
- Parenteral medications are frequently needed for pain control.
- Medical therapy can be considered with an alpha-blocking medication, such as Tamsulosin (0.4 mg PO daily).

- Consultation with a urologist early is important. Evacuation to a medical treatment facility for refractory symptoms should be considered.

Iatrogenic Complications of Therapy (Medications, Contrast Dye)

Several medications may cause or contribute to the worsening of renal function in the multisystem trauma patient. The most common offenders are medications such as diuretics that may be used before IVV repletion has been ensured, resulting in prerenal azotemia or even ATN. Nonsteroidal antiinflammatory medications used for pain management may result in renal failure by altering local glomerular perfusion pressure. Penicillin medications may be associated with acute interstitial nephritis. **The most important single agent to be aware of with respect to the kidneys is intravenous contrast dye, which may cause an associated ATN (contrast dye-associated nephropathy)**. These agents are iodinated and either ionic or nonionic. Most contrast dyes used currently are nonionic, which has decreased the rate of renal failure.

- ATN resulting from intravenous contrast dye generally resolves within days, in contrast to the 1–3 week recovery expected from other causes of ATN.
- Assurance of adequate IVV is most important for the prevention of contrast dye nephropathy.
- The most important aspect of contrast dye-associated nephropathy is aimed at prevention with precontrast hydration. No benefit has been shown with either bicarbonate therapy of *N*-acetylcysteine (Mucomyst).

Disseminated Intravascular Coagulation/Thrombotic Thrombocytopenic Purpura

Disseminated intravascular coagulation (DIC) usually identifies patients with a higher likely mortality due both to underlying injury and possibly DIC itself. The process results from a prothrombotic state wherein fibrin is deposited throughout the body, resulting in the **consumption of coagulation factors, hemolytic anemia, and thrombocytopenia**. This leads to an inability to clot blood effectively, and patients are noted to have petechiae and frank bleeding from IV sites, surgical wounds, and

mucosal barriers of the body. **Thrombotic thrombocytopenic purpura (TTP)** is caused by abnormal activity of von Willebrand's factor, resulting in activation and aggravation of platelets. Laboratory abnormalities include **thrombocytopenia and hemolytic anemia**. The classic clinical pentad includes **fever, anemia, renal failure, thrombocytopenia, and neurological abnormalities (especially seizures)**.

- DIC diagnosis:
  - Hemolytic anemia, thrombocytopenia, and fibrinogen decrease (usually <100).
  - INR elevation (KEY DISTINCTION FROM TTP—THERE IS NO INR ELEVATION WITH TTP).
- DIC management:
  - Largely supportive; correct the cause of DIC.
  - Cryoprecipitate, fresh frozen plasma, platelet, and red blood cell transfusion IF CORRECTABLE ETIOLOGY FOR DIC IS IDENTIFIED.
- TTP diagnosis:
  - Hemolytic anemia, thrombocytopenia, and fibrinogen decrease.
  - INR IS USUALLY NORMAL.
  - Clinical pentad of fever, anemia, thrombocytopenia, renal failure, and neurological abnormalities.
- TTP management:
  - Blood products are largely without benefit.
  - High-dose corticosteroids.
  - Plasma exchange transfusions.
- Unrecognized and untreated TTP can have an extremely high mortality.

Heparin-Induced Thrombocytopenia

Heparin-induced thrombocytopenia (HIT) is caused by antibodies directed at the heparin-platelet factor 4 complex. It usually presents approximately 4–5 days after the initiation of heparin products, but can present suddenly in susceptible patients who have received heparin within the previous 3 months. The risk of the development is 1%–5% with unfractionated heparin and <1% with low molecular weight heparin. **The diagnosis is suspected when the platelet count suddenly drops by 50% or to a value <100,000 (if platelet count was normal initially)**.

Confirmation of the diagnosis will generally not be possible in the combat care setting, but higher-level medical treatment facilities can confirm the diagnosis by sending HIT antibody studies in the appropriate clinical context.

- Suspected HIT should prompt immediate discontinuation of all heparin products (including low molecular weight heparin).
- Therapeutic anticoagulation should be initiated in full anticoagulation doses, if possible.
  - Thrombosis occurs in >50% of HIT patients.
  - Antithrombin agents that can be used in the combat environment require titration based on activated partial thomboplastin time levels:
    - Argatroban.
    - Hirudin.
  - Fondaparinux is an anti-Xa inhibitor that can be considered at Role 4 facilities that have access to onsite anti-Xa level measurement capability.
- Warfarin should NOT BE USED in the management of HIT patients unless an antithrombin agent is in use at full therapeutic anticoagulation doses.

Endocrine Considerations

The majority of endocrine emergencies that happen in the combat setting occur in patients with preexisting conditions (known or not) who undergo a clinical decompensation related to either a stress in the environment or lack of access to maintenance medical care (insulin in the case of the diabetic patient). While infrequently seen, the most likely endocrine emergencies to be aware of are diabetic ketoacidosis, hyperglycemic hyperosmolar syndrome, and adrenal insufficiency.

Diabetic Ketoacidosis/Hyperglycemic Hyperosmolar Syndrome

- Diagnosis of diabetic ketoacidosis (DKA):
  - Elevated glucose (200–600); long-standing DKA may have normal glucose.
  - Anion gap metabolic acidosis; elevated serum and urine ketoacidosis.
  - Glucosuria if serum glucose is elevated.
  - Dehydration (generally <6–8 L of total body water deficit).

- Diagnosis of hyperglycemic hyperosmolar syndrome (HHS):
  - Severely elevated glucose (600–1,500).
  - Severe intracellular dehydration due to extreme osmotic shifts.
  - Mild anion gap metabolic acidosis may be present, but is not a dominant clinical feature.
  - Severe glucosuria.
  - Severe dehydration (>8–10 L of total body water deficit).
- Management of DKA and HHS:
  - Correct the cause of DKA/HHS development (infection, trauma, etc).
  - Management is similar in many ways; differences will be highlighted.
  - Bolus 10 units of regular insulin IV; start insulin drip at 5 units of regular insulin IV per hour.
    - Hold on bolus if potassium < 3.0; do not give insulin until serum potassium > 3.0.
    - Do not correct glucose > 100 per hour or 1,200 in 24 hours.
  - Bolus 2 L of 0.9 NS in the first hour.
    - Repletion of volume is vital for both conditions; HHS will require substantially more isotonic crystalloid to accomplish this.
    - Give 4–6 L of 0.9 NS in the first 6 hours for DKA.
    - Give 6–8 L of 0.9 NS in the first 6 hours for HHS.
    - Subsequent 0.9 NS requirements will be determined by assessment of the adequacy of the IVV status.
  - After repletion of the IVV, change base fluid from isotonic crystalloid (0.9 NS) to hypotonic crystalloid (1/2 NS).
  - Check glucose hourly using point-of-care testing while adjusting insulin drip.
  - Measure serum electrolytes every 1–2 hours until potassium stable for >4 hours and glucose stable for >4 hours.
  - When potassium < 4.5 mg/dL, add 20 mEq KCl/L to current intravenous fluid.
    - Additional supplementation will be needed (orally as a KCl elixir) as well.
    - Potassium replacement needs are usually profound due to total body loss of potassium and magnesium due to diuresis, as well as transcellular shifts associated with insulin utilization.

- When serum glucose drops below 250 mg/dL, add D5 to whatever fluid is being utilized.
- **WHEN TREATING DKA, DO NOT STOP INSULIN INFUSION UNTIL THE ANION GAP IS CLOSED—HYPOGLYCEMIA IS TREATED WITH THE ADDITION OF DEXTROSE AND A DECREASE IN INSULIN DOSE, BUT CESSATION OF INSULIN WILL RESULT IN THE RETURN OF DKA.**

Adrenal Insufficiency

Adrenal insufficiency should be anticipated in patients requiring surgery who are taking corticosteroids at doses in excess of the equivalent of prednisone 10–20 mg daily. It is also seen clinically in patients who have taken such doses for more than 5–7 days at any point in the previous year. Rarely, adrenal insufficiency results from infarction of the bilateral adrenal glands associated with hypovolemic shock states. Unfortunately, there is no universal agreement on the laboratory diagnosis of adrenal insufficiency, so a high index of clinical suspicion should be present in patients with a known history of steroid use. **One clinical scenario that can be suggestive of adrenal insufficiency is a patient with a history of steroid use who is hypotensive (sepsis, hemorrhage, etc), who is not responsive to pressor therapy, and who does not have an appropriate tachycardia. The presence of hyponatremia and/or hyperkalemia may also suggest adrenal insufficiency**.

- Treatment of acute adrenal insufficiency: Hydrocortisone 200 mg IV, then 100 mg IV q8h.
- If hyponatremia and/or hyperkalemia persists despite hydrocortisone therapy, add fludrocortisone 0.1 mg PO every morning.

ICU Prophylaxis

Ventilator-Associated Pneumonia/Combat-Related Ventilator-Associated Pneumonia

- Assess daily the need for continued mechanical ventilation and discontinue as quickly as possible.
- Use a Hi-Lo Tracheal Tube to allow removal of subglottic secretions that collect above the endotracheal tube cuff in all patients expected to be intubated >96 hours.

- Provide oral care with chlorhexidine solution q4h.
- Do not routinely change out ventilator circuitry unless mechanical failure is present or visible contamination is noted.
- Keep head of bed 30°–45° at all times while intubated (unless absolute contraindication exists).
- Perform regular surveillance cultures of respiratory secretions in the ICU and regularly update the biogram describing organisms/susceptibilities that have been isolated.
- Minimize the empiric use of antibiotics.
- When treating a suspected combat-related ventilator-associated pneumonia (CRVAP):
  - Treat aggressively with broad-spectrum antibiotics based on local biogram (see section on Pulmonary Medicine).
  - Culture respiratory secretions, as well as blood; tailor antibiotic regimen based on culture results.
  - Discontinue all antibiotics if cultures are negative at 72 hours and patient is improving.
  - Continue CRVAP therapy for 7 days total if cultures demonstrate a dominant organism, and a Gram stain showed a significant number of leukocytes.
- When a multidrug-resistant organism is isolated, consider cohorting patients with similar isolates to one area of the ICU away from other patients.
- Consider terminal cleaning of a part of the ICU after a multidrug-resistant organism has been isolated and the patient treated.

Deep Venous Thrombosis Prophylaxis

See previous content within this chapter.

Glucose Control

- Most critical care patients in the combat setting should have glucose targeted between 140–200 mg/dL.
- Insulin drips should be initiated in any critically injured patient who has two or more consecutive glucose readings >180 mg/dL.

Nutrition

- Enteral nutrition is favored over venous routes, if possible.

- Duodenal tube placement is favored over gastric tube placement, but gastric is acceptable as long as residuals remain <500 mL/4 h.
  - Total parenteral nutrition may be available at some Role 3 facilities if full-dose enteral nutrition cannot be used by 72 hours.
  - The risk of infection related to total parenteral nutrition use may be driven more by the duration of central venous access and number of times the port is accessed than the actual content of total parenteral nutrition.
- Glutamine can be added to trauma patient nutrition regimens.
- Albumin should be given if the serum album is <1.
- Specialty formulas with specific additives generally offer little benefit in the acute setting.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 12

Damage Control Surgery

Introduction

Historically, the approach to the victim of severe trauma from combat wounding was surgical exploration with definitive repair of all injuries. This approach is successful when there are a limited number of injuries, the patient is not physiologically impaired, and if there are adequate resources. Extensive experience in both civilian and military trauma dictates an abbreviated surgical approach in patients with extensive injuries directed at control of hemorrhage and contamination, followed by resuscitation to normal physiology with definitive repair in a delayed fashion. This approach, termed damage control surgery (DCS), is designed to restore normal physiology prior to normal anatomy. It is well established that patients who develop the lethal triad of coagulopathy, acidosis, and hypothermia have significantly increased mortality. DCS is designed to prevent or limit this process through rapid control of bleeding and contamination in the shortest amount of time.

Damage control surgery is defined as the rapid initial control of hemorrhage and contamination, temporary abdominal closure, resuscitation to normal physiology in the ICU, and subsequent reexploration and definitive repair after normal physiology has been restored. Damage control techniques can also be applied in vascular, thoracic, orthopedic, and neurosurgical procedures.

A **decision to apply damage control techniques should be made early**, and, in many circumstances, even before the operation is begun.

General Considerations

- Philosophy of damage control is "a live patient above all else."
  - Avoid hypothermia.
  - Rapidly achieve hemostasis.
  - Perform initial bowel resections without anastamosis. Control contamination and reconstruct at the second operation after the patient has been stabilized and can tolerate a prolonged operation.
- **When to employ damage control.**
  - Use damage control in patients who present with or are at risk for developing:
    - Multiple life-threatening injuries.
    - Acidosis (pH <7.25).
    - Hypothermia (temperature <34°C).
    - Shock on presentation.
    - Combined hollow viscus and vascular or vascularized organ injury.
    - Coagulopathy (INR >1.4).
    - Mass casualty situation.

The use of specific physiological criteria/lab values to determine when to employ damage control is of questionable utility because these represent borderline physiological states in which the patient may already be unsalvageable. The earlier DCS is applied in patients at risk, the better the outcomes.

  - Take into account ability to control hemorrhage, severity of liver injury, and associated injuries.
  - Pack **before** massive blood loss (10–15 units of packed red blood cells) has occurred.
  - Injuries that typically require damage control techniques:
    - Upper abdominal injuries that are not isolated spleen injuries (duodenal, large liver injuries, pancreas, etc).
    - Penetrating pelvic injury with vascular involvement.
    - Any retroperitoneal vascular injury.

The goal of damage control is to restore normal physiology rather than normal anatomy. It is used for the multiply injured casualty, with combinations of abdominal, vascular, genitourinary, neurological, orthopedic, and/or thoracic injury in **four separate and distinct phases.**

Phase 0 (Ground 0): Prehospital and Early Resuscitation

The emphasis of Phase 0 is the early recognition of patients who are at risk of developing the lethal triad and those in whom damage control techniques may be indicated. Phase 0 includes the following steps:

- Stop bleeding using tourniquets or direct pressure.
- If the patient has noncompressible bleeding, practice permissive hypotension.
- Rapid transfer to the medical treatment facility.
- Initiate damage control resuscitation.
- Prevent hypothermia.
- Measure blood gases.
- Rapid transfer to the OR.
- Consider resuscitative balloon occlusion of the aorta(REBOA)—if appropriately trained and available. (Only if proper surgical service available within 10-15 minutes) REBOA is a bridge to surgical control of hemorrhage in the OR.

Phase 1: Primary Damage Control Operation

- Control of hemorrhage.
- Exploration to determine extent of injury.
- Control of contamination.
- Therapeutic packing.
- Temporary abdominal closure.

General Points

- Control of hemorrhage.
  - Hemorrhage from blood vessels can be controlled by ligation, shunting, or repair of injured vessels as they are encountered.
  - The initial goal is hemorrhage control, not maintenance of blood flow.
  - For the patient in extremis, clamping or shunting of major vessels is recommended over repair.
    - THINK: ⇒ fasciotomy.
  - Additional methods of hemorrhage control include balloon catheter tamponade of vascular or solid viscus injuries.

- Exploration to determine extent of injury.
  - Damage control laparotomy.
    - Perform only essential resections or pack solid organs to diminish blood loss.
    - Rapidly terminate the procedure to minimize hypovolemia, hypothermia, acidosis, and coagulopathy.
    - Perform definitive reconstruction only during subsequent operation(s) after the patient has stabilized and can tolerate a prolonged operation.
  - Assessment and stabilization/external fixation of major extremity and pelvic fractures.
    - Including vascular injuries and fasciotomy.
- Control of contamination.
  - Contamination control also proceeds as injuries are encountered, utilizing clamps, primary repair, or resection without reanastomosis.
  - With multiple enterotomies, if the area of injury represents <50% of the length of the small bowel, a single resection can be undertaken.
  - Alternatively, enterotomies can be excluded in continuity with umbilical tapes and left in situ if the patient remains in extremis.
- Temporary packing.
  - Temporary packing provides tamponade of liver, pelvic, and retroperitoneal bleeding.
  - Do not use the "pack-and-peek" technique. Once packed and bleeding controlled, leave alone until second-look operation.
  - Definitive packing is based on two basic principles:
    - Pressure stops bleeding.
    - Pressure vectors should re-create tissue planes (attempt to re-create the pressure vectors created by the capsule of a solid organ or fill the space of that organ, not random pack placement).
  - Laparotomy pads are the best commonly available packing material.
  - An intervening layer—such as a bowel bag, sterile drape, absorbable mesh, or omentum—can be placed between packs and the tissue to aid in easy pack removal at relaparotomy.

- Temporary abdominal closure.
  - Multiple techniques employed:
    - Bogotá bag—sterile IV bag (3 liters) sewn to skin.
    - Vacuum pack—constructed from available materials in OR (see below) and therefore commonly used in current combat casualties.
    - Wound VAC—commercial device not universally available in deployed setting.
    - Towel clip closure—of historical interest only; NOT RECOMMENDED because there is a high incidence of associated abdominal compartment syndrome (ACS).
    - Skin closure alone is NOT RECOMMENDED for the same concerns as ACS.
  - Key concepts for temporary abdominal closure.
    - Must have a nonadherent layer (eg, IV bag, sterile X-ray cover, Mayo stand cover, bowel bag) on top of the bowel and tucked under the peritoneum as far lateral as possible.
    - Perforate or "pie crust" the above layer prior to placement to allow fluid to drain out.
    - Adequate drainage tubes (eg, chest tube, Jackson-Pratt) that are interposed between gauze or towels and brought out through the top of the wound.
    - Water-tight seal over the top adherent to the skin.
    - Do not sew to the fascia.
    - Use adequate sedation.
    - Be aware that ACS can occur even if the abdomen is left open.
  - The vacuum pack technique (easy, keeps patient dry, allows for expansion):
    - With fascia open, place an OR towel that is fully plastic-covered with a bowel bag, X-ray cassette bag, or Ioban drape, etc, well under the peritoneum to cover the viscera. Place a small number of central perforations to allow fluid to egress to the drains. Alternatively, place a sterile, nonadherent, perforated plastic drape (as above) completely over the viscera and under the peritoneum and cover this with a sterile OR towel.

- Place closed-suction drains (Jackson-Pratt, modified Foley, small chest tube) above the towel at the level of the subcutaneous tissue brought out through separate stab wounds or the inferior or superior portion of the wound.
- Place lap sponges or another sterile towel to fill in the wound and sandwich the drain(s).
- Cover the entire wound with a large sticky (Ioban) drape.
- Place drains on low suction.

Phase 2: Critical Care

- Physiological support in the post-op DCS patient is paramount to survival.
  - **Core rewarming**: Warmed resuscitative fluids, blankets, ventilator air, and environment, or commercially available products, such as Bair Hugger, ChillBuster.
  - **Reversal of acidosis**: Appropriate resuscitation with blood products, colloids, and/or crystalloid.
  - **Reversal of coagulopathy**: Factor replacement.
  - **Ventilatory support: Using ARDSNet low tidal volume support, avoiding barotrauma.**
  - **Injury identification**: Perform a tertiary survey of the patient, obtain CT scans and angiography as indicated.
  - **Monitor for ACS (see below).**
- ACS.
  - ACS is a condition in which **increased intraabdominal pressure adversely affects the circulation/ventilation, and threatens the function and viability of the viscera**. Any patient who has undergone a massive transfusion, major resuscitation for severe trauma or large body surface area burn, or prolonged trauma laparotomy is at risk for development of ACS. A high index of suspicion must be maintained, even in postoperative patients with open abdomen.
  - Measurement is performed using urinary bladder pressure (normal = 0).
    - Measurement of bladder pressure is a good variable to test and follow; however, intervention for ACS should occur when suspected or clinically indicated.

- Occurs in abdominal trauma accompanied by visceral swelling, hematoma, or abdominal pack use.
- Physiology of ACS.
  - Cardiac output and venous return are decreased.
  - Reduction in blood flow to the liver, intestines, and kidneys can result in anuria.
  - The two hemidiaphragms push upward, decreasing thoracic volume and compliance, leading to elevated peak airway pressures.
  - Central venous, pulmonary capillary wedge, and right atrial pressures increase with intraabdominal pressure (can lead to false pulmonary artery catheter pressures).
  - PO_2 is decreased due to increases in airway pressures and ventilation/perfusion abnormalities that worsen with positive end-expiratory pressure.

Abdominal Pressure	Degree of Elevation	Clinical Effect
10–20 mm Hg	Mild	Insignificant
20–30 mm Hg	Moderate	Oliguria and organ dysfunction
>30 mm Hg	Severe	Requires immediate attention

Phase 3: Planned Reoperation

- Packs should be left in place until the patient's hemodynamics are stable and all major sites of hemorrhage have had time to clot. When removed, packs should be taken out slowly with plans for vascular control.
- Reoperation should be scheduled when the probability of achieving definitive organ repair and complete fascial closure are highest, although an estimation that the fascia cannot be closed should not preclude initial reexploration(s).
- Reexploration must occur after correction of hypotension, acidosis, hypothermia, and coagulopathy. It typically occurs 24–48 hours following the initial operation.
- Timing can, however, be dictated by other pressing clinical concerns, such as ACS, limb ischemia, and suboptimal control of spillage at primary operation.
- In cases of a packed and drained duodenum, pancreas, kidney, bladder, or liver injuries with gross bowel contamination, packs should be retrieved within 36–48 hours.

- **This surgery may occur (and in many cases should occur) at the next echelon of care.**
  - STRATEVAC (strategic evacuation) should be weighed carefully because surgery is not available in transit.

Conduct of Relaparotomy

- It is to be presumed that injuries were unrecognized.
- **A complete exploration must be performed.**
- Feeding tube placement, either transabdominal or nasoenteric, should be performed at this time.
- Repacking may be reemployed if other measures fail to control hemorrhage.
- Radiographic images should be obtained that visualize nipples to mid-thigh to ensure that all packs have been removed from the abdomen.
  - Sponge counts are unreliable in this situation.
- **Unplanned reexploration.**
  - Emergent, unplanned reexploration should be considered in any patient who remains unstable, persistently coagulopathic, or acidotic despite continued resuscitation or evidence of ACS.

Damage Control in the Chest

Thoracic Injuries

- **The goal of abbreviated thoracotomy is to stop the bleeding and restore a survivable physiology; contamination is usually not a problem.**
- In the exsanguinating patient, nonanatomical wedge resection to rapidly achieve hemostasis and control of air leaks using a large stapler is preferred over formal lung resection.
- In pulmonary tractotomy, the lung bridging the wound tract is opened between long clamps or with a linear stapler, allowing direct inspection and selective control of bleeding points and air leaks.
- Great vessel injuries can be temporized with intraluminal shunts or Fogarty balloons to achieve distal control in inaccessible areas.
- Tracheal injury can be temporized with airway control placed through the site of injury.

- Extensive bronchial repairs are not feasible in the patient in extremis; therefore, rapid resection of the affected lobe would be best.
- When dealing with esophageal injury, diversion and wide drainage, not definitive repair, are the best initial courses of action.
- If required, pneumonectomy must be performed extremely early in the operation and the team must be prepared for the inevitable right heart failure that will follow. This procedure has extremely high mortality and should be avoided if possible. If available, activation of extracorporal membrane oxygenation resources is indicated.
- A single layer en masse suture closure of the chest wall should be used.

For Clinical Practice Guidelines, go to
http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 13

Face and Neck Injuries

Introduction

Immediate recognition and appropriate management of airway compromise is critical to survival. The best method to quickly evaluate airway compromise is to ask the patient to speak. If the patients can speak intelligibly, then the airway is intact, they have enough pulmonary reserve to generate sound, and their Glasgow Coma Scale score is most likely >8. If the patient cannot speak, the airway needs to be emergently secured.

- Face and neck injuries can be immediately life-threatening and difficult to manage. **Focus on ABC priorities.**
- During **airway control**, maintain **cervical spine immobilization** in patients with head and neck injuries.
- **Control of bleeding** begins with direct pressure. If bleeding cannot be controlled with direct pressure, immediate operative intervention is necessary. DO NOT blindly clamp vessels in the neck.
- **Complete assessment** of remaining injuries (fractures, lacerations, esophageal injury, ocular injuries, etc) occurs only after the ABCs have been addressed.

Immediate Management of Facial Injuries

- Airway.
  - The most common site of airway obstruction in the trauma patient with head and/or neck injuries is at the base of tongue and upper pharynx. These patients typically present with obstructed breathing marked by **stertor**, a coarse snoring noise most pronounced on inspiration. Blunt or penetrating neck injuries may also result in laryngeal

trauma that can present with inspiratory **stridor**, a harsh, high-pitched sound. In either case, a noisy airway is a compromised airway, and steps must be taken immediately to relieve the obstruction. Common causes of traumatic airway obstruction include:

- ♦ Blood or secretions.
- ♦ Soft-tissue edema.
- ♦ Collapse of the tongue base against the posterior pharynx.
- ♦ A fractured, free-floating "flail" mandible may obstruct the airway due to tongue base retrodisplacement.
- ♦ Displaced tooth fragments may become foreign bodies.

- ○ Maneuvers to relieve upper airway obstruction:
  - ♦ Chin lift or jaw-thrust maneuver.
  - ♦ Remove foreign bodies (strong suction, Magill forceps).
  - ♦ Place adjunctive airway device (nasal trumpet or oropharyngeal airway). Use caution with nasal tubes in patients with suspected skull base fractures.
  - ♦ Endotracheal intubation.
  - ♦ Cricothyroidotomy (preferred emergent surgical airway technique) or urgent tracheotomy may become necessary.

- Cervical spine.
  - ○ Up to 10% of patients with significant blunt facial injuries will also have a cervical spine injury.
    - ♦ **The neck should never be hyperextended.**
    - ♦ Intubation should only be performed with in-line neck stabilization.
- **Vascular injury.**
  - ○ Injuries to the face are often accompanied by **significant bleeding**.
  - ○ Control of facial vascular injuries should progress from simple wound compression for minor bleeding to possible vessel ligation for more significant bleeding.
- Continued hemorrhage from superficial temporal artery and facial artery beneath large head wraps or in intubated patients is often missed during mass casualty operations. The patient can lose significant blood volumes in a short period of time.

Vessel ligation should only be performed under direct visualization and after careful identification of the bleeding vessel. Blind clamping of bleeding areas should be avoided because critical structures, such as the facial nerve or parotid duct, are susceptible to injury.

- Wound packing with a pressure dressing may control active craniofacial bleeding. Hemostatic gauze may also be used.
- Intraoral bleeding must be controlled to ensure a safe airway.
  - Do not pack the oropharynx in an awake patient due to the risk of airway compromise. First secure the airway with an endotracheal tube or surgical airway, if necessary. A large gauze or sponge with radiopaque marker if available should be used to pack the oropharynx and its presence relayed at patient transfers.
  - Irrigation and gram-positive antibiotic coverage (eg, cefazolin) should be used liberally for penetrating injuries of the face.

- **Evaluation.**
  - Once the casualty is stabilized, gently cleanse dried blood and foreign bodies from wound sites to evaluate the depth and extent of injury.
  - The bony orbits, maxilla, forehead, and mandible should be palpated for stepoffs or mobile segments suggestive of a fracture.
  - A complete intraoral examination includes inspection and palpation of all mucosal surfaces for lacerations, avulsions, ecchymosis, bony stepoffs, malocclusion, and dental integrity.
  - **In the awake patient, malocclusion indicates a probable fracture.**
  - Perform a cranial nerve examination to assess vision, gross hearing, facial sensation, facial muscle movement, and tongue mobility. Evaluate eyes for increased intraocular pressures (>30 mm Hg) or proptosis and perform immediate lateral canthotomy/cantholysis. Evaluate for extraocular movements, decreased vision on gross visual field testing, diplopia, corneal debris, or open globe. See Chapter 14, Ocular Injuries, for detailed discussion of ocular injury.

- If the intercanthal distance measures >40 mm (approximately the width of the patient's eye), or severe saddle nose deformity is present, suspect a nasoorbitoethmoidal (NOE) fracture. The patient should be evaluated with a CT scan as soon as possible and monitored for neurologic deterioration due to frequent concomitant skull base and cranial vault fractures.

- If an NOE fracture is suspected, minimize instrumentation of the nose. There may be a tear in the dura, and instrumentation may contaminate the cerebrospinal fluid (CSF) via the skull base defect.
- **Patients with suspected NOE, midface, and orbital fractures should be instructed not to blow their nose for 2 weeks after injury or repair.**

Facial Bone Fractures

Facial bone fractures should be realigned and fixed in correct anatomical position with 25 gauge stainless steel dental wires or titanium plates and screws to restore normal appearance and function of the face and surrounding structures.

With the exception of fractures that significantly alter normal dental occlusion or compromise the airway, repair of facial fractures may be delayed for up to 10 days after injury. Open fractures may be debrided, irrigated, and closed temporarily should time not permit immediate repair.

- **Mandible fractures**.
  - Second most commonly fractured bone of the face (after the nose).
  - Subcondylar fractures are most common.
  - Multiple mandible fractures are present in 50% of cases.
  - Patients typically present with limited jaw mobility or malocclusion.
  - Panorex is the single best plain film (but is usually unavailable in the field environment); a plain film mandible series serves as a less reliable, but satisfactory, study (might overlook subcondylar fractures).
  - Fine cut (1–3 mm) CT scan will delineate nearly all mandible fractures.

- Treatment is determined by the location and severity of the fracture and the condition of existing dentition.
  - Remove only teeth that are severely loose or fractured with exposed pulp.
  - Teeth in the line of a fracture, if stable and not impeding the occlusion, should be maintained.
- Nondisplaced subcondylar fractures in patients with normal occlusion may be treated simply with a soft diet and limited wear of a Kevlar helmet and protective mask.
- Immediate reduction of the mandible fracture and improvement of occlusion (and patient comfort) can be accomplished with a bridle wire (24 or 25 gauge) placed around at least two teeth on either side of the fracture.
- More severe fractures may require immobilization with maxillary-mandibular fixation (MMF) for 6 weeks.

Arch Bar Maxillary-Mandibular Fixation

Place commercially made arch bars onto the facial aspect of the maxillary and mandibular teeth.

- Arch bars are fixed to the teeth with simple circumdental (24 or 25 gauge) wires.
- After proper occlusion is established, the maxillary arch bar is fixed to the mandibular arch bar with wires or elastic bands.
- If portions of the mandible have been avulsed or the fragments are extremely contaminated, an internal 2.4-mm reconstruction bar or an external fixation, biphase splint should be placed to maintain alignment.

Skeletal-Based Maxillary-Mandibular Fixation

- Place a ~2.0 mm diameter screw 1 cm in length through the gingiva between roots of the teeth in the maxilla and mandible and wire them together (Fig. 13-1). This will more rapidly (or in the absence of arch bars) stabilize mandible and midface fractures.
- When fractures of the mandible and maxilla are both present, MMF should never be definitive treatment. One jaw should be stabilized with external or internal fixation.
- Wire cutters must always be with the patient who is in MMF.
- The airway must be closely monitored in the patient with maxillofacial trauma who is placed into MMF. **Consider the**

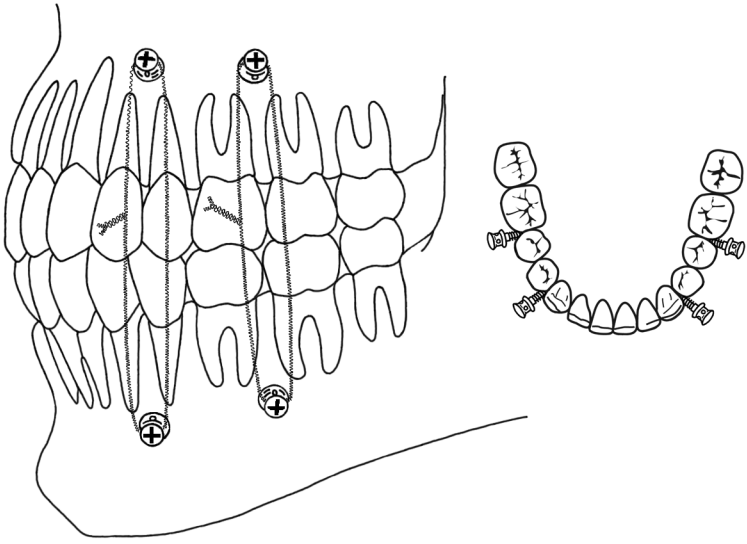

Fig. 13-1. Skeletal-based maxillary-mandibular fixation.

ability to monitor patients with MMF during aeromedical evacuation before placing a patient in MMF.

- Open reduction and internal fixation with a mandible plate across fracture sites may obviate the need for MMF.
- **In intubated patients with severe face and neck trauma requiring MMF, tracheostomy should be performed prior to aeromedical evacuation**

- **Nasal fractures.**
  - Most common fracture.
    - Control of epistaxis: Gauze or sponge packing or balloon. Hemostatic gauze may also be helpful for brisk epistaxis (Fig. 13-2).
  - Diagnosed clinically by the appearance and mobility of the nasal bones.

The patient's septum should be evaluated for the presence of a septal hematoma that, if present, must be immediately drained by incision, followed by packing to prevent delayed complications.

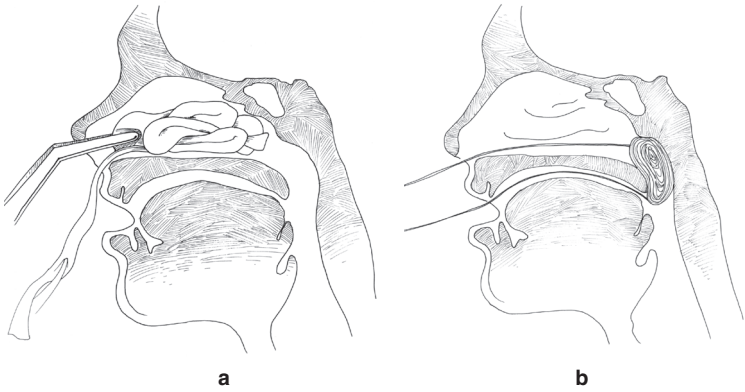

Fig. 13-2. (**a**) Anterior and (**b**) posterior packing of the nose.

- Treat by closed reduction of the fractured bones and/or septum into their correct anatomical positions up to 7 days after fracture.
  - Place a blunt elevator (Sayre) into the nasal cavity to elevate the depressed bony segment while simultaneously repositioning the bone with the surgeon's thumb placed externally.
- The nose may then be fixed with tape or a splint to maintain the reduction.

- **Maxillofacial fractures**.
  - Includes orbital, zygomaticomaxillary complex, frontal bone, and Le Fort fractures.
  - Potentially life-threatening due to loss of airway, hemorrhage, or spinal injury.
  - Fragment wounds of the maxillary sinus are commonly seen and may require surgical removal of retained fragments (can delay until specialist available).
  - Midface fractures (Le Fort).
    - Requires "significant" trauma.
    - High incidence of associated spine, brain, and orbital injuries.
    - Significant hemorrhage from lacerations of the internal maxillary artery and its branches.
      - Can be difficult to control.

- ◊ May be life-threatening.
- ◊ Treat by protecting the airway, controlling hemorrhage with pressure dressings or packing, and reducing fractures.

♦ A surgical airway is sometimes necessary. Edema may cause **immediate or delayed** airway compromise.

♦ Can be difficult to diagnose.

- ◊ Manipulate the hard palate and midface while stabilizing the skull. Place the thumb and forefinger of one hand on the nasal bridge to stabilize and, with the other hand, determine mobility of the maxilla by placing the thumb on the alveolus and forefinger on the palate and attempt gentle distraction in an anterior-posterior direction.
- ◊ Posterior and superior impaction of the fractured midface is common. Wires placed around teeth or in screws placed into the pyriform rim can allow anterior and inferior pull of the midface to dis-impact prior to internal fixation or MMF.
- ◊ Penetrating facial injury fractures may not follow classic Le Fort patterns and often have significant associated external and internal soft-tissue injuries.
- ◊ Systematically palpate the head and face looking for deformities, crepitus, tenderness, ecchymosis, or subconjunctival hemorrhages that might suggest fractures.

○ Classification of facial fractures by Le Fort (Fig. 13-3).

♦ **I**—Fracture separates the entire alveolar process from maxilla.

♦ **II**—Separation of midface, including the nasal bone, from the orbit (pyramidal).

♦ **III**—Detachment of the face from the skull (craniofacial disarticulation).

○ Treatment.

♦ ABCs.

♦ If nasal intubation is necessary, **extremely careful placement** is mandatory to avoid cribriform plate or anterior cranial fossa penetration.

♦ Check CNS and vision.

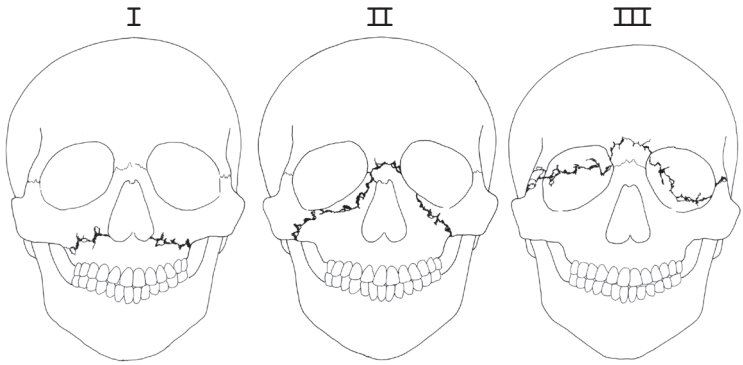

Fig. 13-3. Le Fort facial fracture classifications.

- ♦ Can immobilize the maxilla by using the mandible as a splint (wires/arch bars, **with wire cutters at bedside**). It is much easier to place patient into MMF if either a nasal airway or tracheostomy is used.
- ♦ Control nasopharyngeal and/or oropharyngeal hemorrhage by tamponade as previously described.

- ○ Definitive surgical repair.
  - ♦ **Not** an **emergency** once the airway and hemorrhage are controlled.
  - ♦ Requires expertise in otorynolaryngology/ear, nose, and throat; oral and maxillofacial surgery; plastic surgery; and/or ophthalmology.
  - ♦ Repair is often time-consuming.
  - ♦ Open fracture reductions require titanium plating systems and equipment that are usually unavailable in the field.

Soft-Tissue Injuries

- ● **General principles.**
  - ○ Avoid injury to surrounding structures, such as the facial nerve or parotid duct.
  - ○ Wounds should be gently cleansed with saline and light scrub solutions; foreign bodies should be meticulously cleaned from wounds prior to closure. Profuse irrigation is indicated.

- Sharply debride devascularized wound edges **minimally.**
- **Facial lacerations should be closed in layers within 24 hours of injury even when grossly contaminated after copious irrigation and debridement.** Large avulsion injuries may be treated with packing, regular debridement, local wound care, and closed in a delayed fashion or allowed to granulate using negative pressure dressings. The use of local flaps, skin grafts, or free vascularized tissue transfers may be necessary to cover large soft-tissue defects of the face and neck.
  - Use 4-0 or 5-0 absorbable suture for subcutaneous/dermal layers.
  - Use 5-0 or 6-0 nonabsorbable sutures on facial skin.
  - Remove sutures in 5–7 days.

- **Facial nerve injuries.**

Facial nerve branches that are lacerated at a site anterior to a vertical line drawn down from the lateral canthus of the eye do not need to be surgically reapproximated because these branches are very small and will spontaneously regenerate with good return of facial function.

- Carefully examine for facial nerve function in all **five** branches as soon as possible after injury (Fig. 13-4).
- The severed ends of the nerve may be located in the wound with a nerve stimulator for up to 3 days after injury.
- Cut nerve ends should be primarily reapproximated with three or four fine (9-0) nylon sutures placed through the epineurium.
- If a gap exists between the severed ends of the facial nerve due to tissue loss, an interposition graft may be placed using a section of the great auricular nerve to bridge the gap.
- In heavily contaminated wounds that cannot be closed primarily, the severed ends of the nerve should be located and tagged for identification and repair at a later time.
- If the temporal branch of the facial nerve is nonfunctional, lagopthalmos will be evident in both awake and unconscious patients and prevention of corneal desiccation is critical. This can be done with corneal lubricants (four times daily), moisture chamber goggles, or a frost suture.

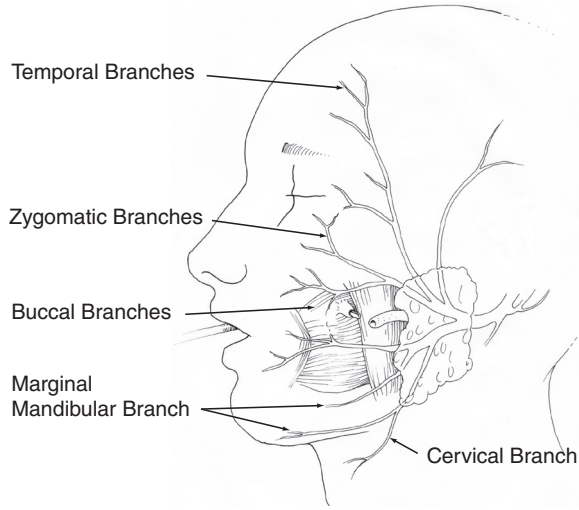

Fig. 13-4. Branches of the facial nerve parotid duct injury.

- Parotid duct injuries.
  - Evaluate penetrating wounds of the parotid/buccal regions of the face for salivary leakage due to a lacerated parotid duct (Fig. 13-5).
    - The wound may be manually compressed and inspected for salivary leakage.
    - If the parotid duct is injured by a facial laceration, the distal end of the duct may be identified by placing a lacrimal probe through the intraoral opening of the duct located near the maxillary second molar (see Fig. 13-4).
    - The proximal end may be identified by compressing the wound and looking for saliva.
  - Repair with absorbable (6-0) sutures (see Fig. 13-5).
  - A stent may be placed into the duct to facilitate closure and prevent stenosis.
    - Possible stents include lacrimal stents, large (size 0) polypropylene sutures, or long angiocaths.
    - Stents may be sutured to the buccal mucosa and removed after 7–14 days.

Fig. 13-5. Repair of the parotid duct.

- Auricular injuries.
  - Strongly consider antibiotic coverage (ciprofloxacin) for *Pseudomonas* and *Staphylococcus* infections with exposed cartilage (especially in burns of the auricle).
  - Preserve skin and soft tissue for maximal coverage of exposed cartilage.
  - Cartilage should be preserved unless severely damaged**. Minimize use of suture in cartilage or perichondrium.**
  - Auricular hematomas should be incised and drained to prevent cartilage destruction. A drain or bolster should be placed for 48 hours after incision and drainage.

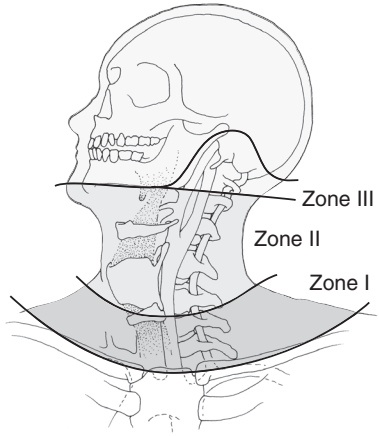

Fig. 13-6. Zones of the neck.

Penetrating Neck Trauma

- Introduction.
  - Vascular injuries occur in 20% and aerodigestive tract injuries in 10% of cases.
  - Immediate mortality is primarily due to exsanguination or airway compromise.
  - Esophageal injury, which may result in mediastinitis and intractable sepsis, is a significant cause of delayed morbidity and mortality.
- **Anatomy.**

The neck is divided into three zones to aid decision-making for diagnostic tests and surgical strategy. In each zone, the primary structures at risk of injury are different (Fig. 13-6).

  - **Zone I (clavicle to cricoid):** The structures of concern include large vessels of the thoracic outlet (subclavian artery and vein, common carotid artery), the lung, and the brachial plexus.
  - **Zone II (cricoid to angle of mandible):** Structures of concern include the common carotid artery, internal jugular vein, esophagus, and trachea.
  - **Zone III (angle of mandible to base of skull):** The structure of primary concern is the internal carotid artery.
- Immediate management.
  - ABCs.
  - Obtain chest, soft-tissue neck radiographs, and CT angiography if patient is stable.
  - Address tetanus status and antibiotic prophylaxis.
- Operative strategy.
  - Neck wounds with suspected platysma violation should only be **probed or explored in the operating room**. An approach via an incision along the anterior border of the sternocleidomastoid muscle is preferred (Fig. 13-7)
  - If multiple small wounds are present, extension and connection of existing lacerations may provide adequate exposure.
  - When laryngeal or pharyngeal exposure is needed, a wide-apron incision made from the mastoid tip to the midline of the neck at the cricoid level offers greater exposure of the pharyngeal and upper airway structures.

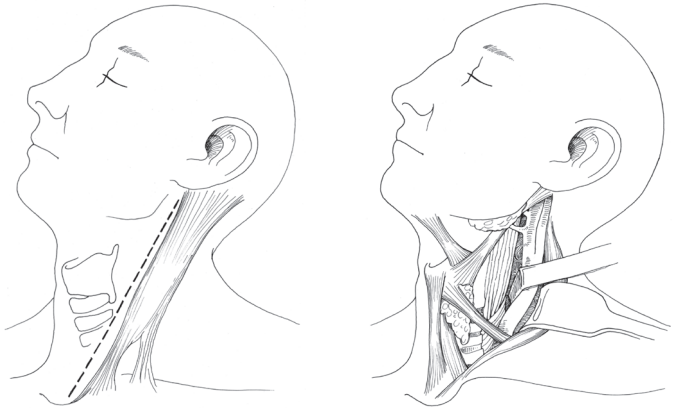

Fig. 13-7. Neck exposure of zone II.

- If the platysma is not violated, surgical intervention is not indicated.
- If the patient with penetrating neck trauma (PNT) is symptomatic, neck exploration is indicated. If the patient is asymptomatic, workup including CT angiography (CTA); panendoscopy (direct laryngoscopy, bronchoscopy, and esophagoscopy); and a water-soluble contrast swallow study should be considered. Neck exploration is indicated if the workup reveals pathology.
- **If diagnostic studies are not available and/or the ability to provide reliable skilled serial clinical observation is questionable, asymptomatic PNT of zone II should be explored.**
- Selective management based on clinical signs and symptoms should be considered for all patients with PNT, regardless of the zones involved. Nonoperative management of zone II injuries with platysma violation is acceptable in the stable patient with a negative workup as described previously. Selective management of PNT can only be performed at facilities with the resources to complete the workup and observe the patient. Surgical exposure of zones I and III is difficult and requires a high degree of surgical expertise. Nonoperative management of PNT in stable patients with zone I or zone III injuries is preferred.

- PNT patients without clinical signs of injury (see below) may be evacuated without operative intervention if the appropriate workup (CTA, panendoscopy, or swallow study) is negative.

- Important clinical signs indicating probable injuries (pertinent to all three zones) are as follows.
  - Signs of vascular injury:
    - Current or history of significant bleeding.
    - Expanding hematoma.
    - Bruit or thrill in the neck.
    - Hypotension.
    - Dyspnea, hoarseness, or stridor.
    - Absent or decreased pulses in neck or arm.
    - Focal neurological deficit or mental status change.
    - Chest radiograph findings of hemothorax or mediastinal widening.
  - Signs of aerodigestive injury (esophagus, trachea, larynx):
    - Crepitus or subcutaneous emphysema.
    - Dyspnea or stridor.
    - Air bubbling from wound.
    - Tenderness or pain over trachea; odynophagia.
    - Hoarse or abnormal voice.
    - Hematemesis or hemoptysis.

Surgical Principles

- The groin and upper thigh should be surgically prepped for possible greater saphenous vein interposition graft or patch angioplasty.
- Exsanguinating hemorrhage from injured vessels at the base of the skull (zone III) may be controlled with inflation of a directed catheter (Fogarty or Foley).
- Repair esophageal injuries in two layers and place passive Penrose drains. A muscle flap should be interposed between repaired esophageal and tracheal injuries to prevent a fistula. Obtain a contrast swallow study 7 days after repair and before feeding.
- Repair laryngotracheal injuries with either absorbable or nonabsorbable suture, stainless steel wires, or microplates. It is important to search for concomitant esophageal injuries as well.

- Major (significant segmental loss or >50% diameter loss) tracheal injuries should be managed with an endotracheal tube placed through the distal tracheal opening and placement of passive drains.
- **Vertebral artery injury.**
  - Suspect if bleeding continues from a posterolateral neck wound despite pressure on the carotid artery.
  - Preoperative angiography localizes the site of injury and establishes the existence of a patent contralateral vertebral artery.
  - Exposure of the vertebral artery may be difficult. When the contralateral vertebral artery is intact, ligation proximal and distal to the injury will likely be necessary.
  - Bone wax or surgical clips may be useful for controlling vertebral artery bleeding. May require removing the lateral aspect of the transverse process for access.
- **Intraoral injuries.**
  - Occult internal carotid artery injury should be suspected in patients with penetrating intraoral injuries LATERAL to the tonsillar fossa. Neurological testing and monitoring are critical, and a CT scan and/or angiography should be considered. A "sentinel" bleed should be considered if, after a penetrating lateral oral injury, the patient bleeds a small amount and then stops. A carotid artery blowout or occlusion may follow. Carotid artery intimal dissection may occur in patients with blunt lateral oropharyngeal trauma or in patients with high-velocity penetrating injury near the skull base that does not directly violate the carotid artery.
- **Internal carotid artery injury.**
  - Should be surgically repaired unless there is profound hemiplegia with coma (Glasgow Coma Scale score <8), in which case the common or internal carotid arteries may be ligated. The external carotid artery and its branches may always be ligated.
  - Mortality is high in patients with severe neurological deficits; carotid ligation is justifiable in complete occlusion of the entire carotid system and depending on the triage situation.

- Small carotid perforations should be minimally debrided and closed with 6-0 polypropylene.
- Vein angioplasty is required with loss of vascular tissue.
- If there is extensive destruction, segmental resection and restitution of flow are established by:
  - End-to-end anastomosis (if the vessel is sufficiently elastic to permit).
  - Interposition vein graft.
  - External carotid swing-over and interposition.
  - Temporary (24–48 hours) shunt as part of a damage control maneuver.
- A distal clot may be removed by gentle use of a balloon catheter prior to shunt insertion or repair.

- **Internal jugular vein injury.**
  - **Casualties with large venous injuries should be placed in the Trendelenburg position if there is any concern about internal jugular (IJ) vein injury and possible air embolus.**
  - If both IJ veins are interrupted by the injury, an attempt to repair one is appropriate to reduce the risk of complications resulting from elevated intracranial pressure.
  - Preferably repaired with suture.
  - Ligation is acceptable if the contralateral internal jugular is patent.
- **Larynx.**
  - After immediate control of the airway has been achieved by intubation or tracheotomy (**not through the wound in the larynx!**), a complete airway evaluation by direct laryngoscopy and bronchoscopy must be performed.
  - Debridement of laryngotracheal injuries must be careful and conservative. A fragmented larynx or trachea should be reapproximated and sutured with extraluminal sutures for tracheal injuries and nonabsorbable sutures or microplates for laryngeal fractures. All exposed laryngeal cartilage should be covered with mucosa. A buccal mucosa graft may be used when large intraluminal mucosal defects are present.
  - Management of laryngeal trauma includes accurate reduction and stabilization of fractures; mucosa-to-mucosa closure of lacerations; and use of a soft stent if there is

extensive cartilaginous damage, structural support is decreased, or the anterior commissure is involved. The stent may need to be temporarily placed for 4–6 weeks to maintain correct anatomical architecture and requires a complementary tracheotomy.
  - Excessive removal of cartilage and mucosa must be avoided to prevent tracheal or laryngeal stenosis.
- **Laryngotracheal injuries.**
  - If laryngotracheal separation is suspected (massive crepitus over the larynx/trachea) in an otherwise "stable" airway, endotracheal intubation should not be undertaken because it may cause a partial separation to become a complete separation, and/or the endotracheal tube may enter the mediastinum and occlude the distal airway.
  - Awake tracheotomy/cricothyroidotomy under local anesthesia without paralysis is preferable in patients with laryngeal trauma. Adequate local anesthesia can be achieved with a 4% (40 mg/cc) lidocaine nebulizer, 2 cc in 3 cc of saline, and direct administration of 4% lidocaine into the trachea for an awake tracheotomy (in addition to local anesthetic infiltration into the skin and subcutaneous tissues). When instilling anesthesia into the airway, aspirate and ensure that air enters the syringe before injecting.
- **Tracheal injury and reconstruction.**
  - A tracheostomy tube may be placed through small anterior wounds of the cervical trachea.
  - Repair simple lacerations with absorbable suture. Care should be taken to avoid constricting the airway when closing defects. Pedicled muscle may be used to cover small tracheal defects.
  - End-to-end tracheal anastomosis should be performed with interrupted, extraluminal 4-0 nylon or polypropylene suture.
  - The anterior cricoid ring does not need to be closed, and careless reapproximation of a fractured cricoid may result in subglottic stenosis.
  - Up to 5 cm of trachea can be resected with proximal and distal mobilization.

- Mobilize anteriorly and posteriorly to preserve lateral blood supply. A suprahyoid release may be helpful.
- Remove an oral endotracheal tube as soon as possible post-op.
- Employ maneuvers to prevent neck extension for 10 days postoperatively to avoid accidental wound separation with head extension in patients with tracheal separation repairs.

- **Esophageal and hypopharyngeal injury and repair.**
  - Commonly associated with injuries to the airway and great vessels.
  - Subcutaneous emphysema, pneumomediastinum, saliva in the neck, hemoptysis or blood-tinged saliva, odynophagia, and dysphagia are possible signs and symptoms of hypopharyngeal and esophageal injury. However, 25% of these injuries may be asymptomatic.
  - Missed injury is a major source of late morbidity/mortality.
  - Chest radiograph and esophagogram with water-soluble contrast are indicated in patients with suspected hypopharyngeal or esophageal injuries, but without a definitive indication for exploration. Esophagograms may have a false-negative rate as high as 20%. A negative water-soluble contrast study may be followed by a barium study to increase the test sensitivity.
  - Insufflation with air in an open neck flooded with saline may aid in identification during exploration.
  - Rigid and flexible esophagoscopy are complementary in the identification of hypopharyngeal and esophageal injuries.
  - Debride devitalized tissue.
  - Close esophageal wounds in two layers with absorbable sutures.
  - Pedicled muscle flaps help to bolster repairs.
  - Drain wounds with Penrose drains.
  - Contrast swallow study at 7 days post-op and prior to oral intake.
  - Leave drains in place until swallow study performed and oral diet resumed.
  - Extensive injuries may require lateral cervical esophagostomy, which is preferred to closure under tension.

- **Combined injuries.**
  - Esophageal injuries combined with airway or vascular injury require separation with healthy tissue. Strap muscles are ideal, but the use of a pedicle sternocleidomastoid muscle is an alternative if the strap muscles are devitalized.
- **Esophageal fistula.**
  - 10%–30% incidence.
  - Due to inadequate debridement, devascularization of remaining esophageal wall, closure under tension, or infection.
  - Treatment.
    - NPO.
    - Maintain nutrition with tube feeds.
    - Ensure fistula control with drains.
    - Weekly water-soluble contrast study to assess closure.
    - Resume oral intake prior to removing drains.

Skull Base, Temporal Bone, and Otological Injury

- All patients with suspected temporal bone fractures or acoustic barotrauma, with or without tympanic membrane perforation, should undergo audiometric testing (with an audiometer) as soon as feasible. In addition, these patients deserve special consideration because of the high incidence of other neurological and cognitive problems that may occur with these injuries.
- Documentation of facial nerve function is performed on all awake patients and as early as possible in a patient who has regained consciousness. Delineation between delayed versus sudden onset facial paralysis is critical for determining the prognosis and management of facial nerve injuries. Also critical is the delineation between a distal and proximal nerve injury. If a proximal injury is present, one or more facial nerve branches may be affected.
  - Be as complete as possible in describing facial motion, even if not technically accurate. Accurate documentation may spare the patient from unwarranted surgical intervention to explore the entire length of the facial nerve. It is desirable to accurately describe the motion of EACH branch of the facial nerve. An injury of the main trunk will most likely result in

all branches being equally affected. Eyelid movement does not ensure that the facial nerve is intact, since the levator palpebrae muscle is innervated by the oculomotor nerve and will remain intact despite facial nerve injury.
    - In the absence of medical contraindications, systemic steroids should be administered for suspected facial nerve paralysis. Crush injuries to the facial nerve may present with delayed-onset paralysis, and the severity and course of the paresis may be improved with systemic administration of steroids.
- Skull base fractures are often occult. Assess the patient for evidence of basilar skull fractures (Battle's sign, raccoon eyes, CSF rhinorrhea, or CSF otorrhea). Any patient with blood or CSF in the ear canal should be presumed to have a temporal bone fracture.
- **Carefully examine the external auditory canal, but do not instrument the canal if there is CSF or blood in the canal. If a temporal bone fracture is present and the dura is not intact, instrumentation may introduce bacteria into the CSF with resulting meningitis. Sterile instruments may be used to suction and debride** the ear canal with microscopic visualization.
- A tear in the lining of the external auditory canal suggests a temporal bone fracture.
    - When a temporal bone fracture is suspected, facial nerve function and hearing must be assessed.
- Dry tympanic membrane perforations can be observed. The vast majority of them will heal spontaneously, but the patient should be followed for potential complications or failure to heal. Wet or contaminated tympanic membrane perforations should be treated with ototopical antibiotics for at least 10 days (4 drops twice daily of ofloxacin are adequate). The patient should be instructed to keep the ears dry (avoid water contamination).
- Hemotympanum may be seen with acoustic and temporal bone trauma. These patients will have hearing loss. If possible, perform a gross audiological evaluation with tuning forks. Hemotympanum-associated hearing loss should resolve itself in about 6–8 weeks.

- Examination of hearing can be accomplished with a single 512-Hz tuning fork.
  - The handle of a vibrating tuning fork is placed on the mastoid tip and then alternately the tuning fork is held in the air outside the external canal while asking the patient which is heard louder (Rinne test). Documentation as A > B (air > bone) or B > A is sufficient (do not report as "positive" or "negative"):
    - Air conduction greater than bone conduction with a 512-Hz tuning fork is normal.
    - Bone conduction greater than air is suggestive of a conductive hearing loss in the affected ear.
  - Place the 512-Hz tuning fork on the frontal bone/nasal dorsum or central incisors (Weber test).
    - The sound will be heard loudest in the ear with a conductive hearing loss or in the ear contralateral to an ear with sensorineural hearing loss.
    - If the Rinne test suggests a conductive hearing loss (ie, bone conduction > air conduction), the tuning fork should be heard louder on the side with the conductive loss.

- Any otological blast injury or injury to the temporal bone may result in tinnitus. Management is expectant because tinnitus following acoustic trauma usually resolves spontaneously. Hearing should be evaluated and documented.
- Any patient with acoustic trauma should be removed from noisy environments and have serial audiograms performed over 14–21 days to assess recovery. Recovery of most traumatic hearing loss is expected, except in cases of temporal bone fractures, very large tympanic membrane perforations, or penetrating temporal bone injuries.
- Steroids should be considered if sensorineural hearing loss is suspected and documented after a blast injury or acoustic trauma. A dose of 1 mg/kg of prednisone is appropriate. If there is no improvement after 5 days of therapy, steroids may be discontinued. If improvement is noted, a taper over 3–4 weeks is indicated. Be mindful that steroids may alter a patient's affect, impair judgment, or impair wound healing.

- Dizziness and vertigo may result from acoustic trauma. If true vertigo (observed nystagmus) exists after an otological injury, the patient may have a perilymphatic fistula from depression of the stapes into the oval window or rupture of the round window. These patients may also have tinnitus and hearing loss. If a perilymphatic fistula is suspected, the patient should be seen by an otolaryngologist as soon as possible to prevent further damage to the inner ear.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 14

Ocular Injuries

Introduction

The preservation of the eyes and eyesight of service personnel is an extremely important goal. Although accepted medical priorities are described as "life, limb, and sight," most casualties would reprioritize the list as "life, SIGHT, and limb." Despite comprising as little as 0.1% of the total body surface area, eye injuries accounted for 6%–13% of all combat casualties in Operation Iraqi Freedom/Operation Enduring Freedom. Between 66% and 75% of eye casualties will be medically disqualified from service. In the Vietnam War, almost 50% of casualties with penetrating eye wounds lost the injured eye. The best outcomes are heavily predicated on proper early mitigation and treatment of the injury, as well as prompt transfer to ophthalmic surgical care. Nevertheless, 96% of eye casualties (or more) may be improperly treated at the point of injury. Although improvements in ophthalmic care in the last 30 years offer hope that blindness in combat casualties will be less common in future wars, the eye continues to demonstrate its notorious intolerance of injury—and error—underscoring the critical need for proper initial casualty care.

True Ocular Emergencies

- Chemical injury.
- Open globe.
- Orbital compartment syndrome.
- Acute glaucoma.
- Retinal detachment.

Triage of Patients With Eye Injuries: SHIELD AND SHIP

- Advanced Trauma Life Support protocols: After primary survey is complete and the patient is stable, identify and treat ocular injuries in the secondary survey.

- Casualties with minor eye injuries may be treated and returned to duty.
- Casualties with more severe injuries should be urgently evacuated to the nearest ophthalmic facility within 12 hours to save vision.
- Distinguishing serious ocular injuries from minor ones may be difficult; maintain a high index of suspicion and err on the side of major injury, especially if any part of the eyes/lids that would otherwise be protected by eye protection is involved.
- At Roles 1 and 2, due to time, equipment, and capability constraints, medical personnel should simply document vision, administer systemic antibiotics, and "shield and ship" the patient to the nearest ophthalmologist. If an open globe is suspected, protect the eye with a rigid shield that vaults the eye cleanly and distributes forces to the bony orbit and away from the eye, and evacuate the casualty emergently. DO NOT apply pressure to the eye, patch it, or place any dressings under the shield. Commercially made shields are included in modern Individual and Joint First Aid Kits (IFAK/JFAK), Combat Medic Aid Bags, and Combat Lifesaver Kits, but simply replacing ballistic eye armor (even if moderately damaged) will effectively protect the eye from additional trauma. Metal shields can be molded like splints to accommodate eyelid and orbital swelling.
- Ensure an eye shield is in place and maintained at every echelon of care.

Identifying Severe Eye Injuries

- Associated injuries.
  - Fragmentation wounds of the face—think open globe and intraocular foreign body, especially if any part of the eye/eyelid is injured that would otherwise be covered by eye armor.
  - Lid laceration—open the eyelids (gently) and check for underlying globe laceration.
- Vision.
  - Use book print; uniform insignia, lettering and icons; medication labels; finger counting; etc., to evaluate vision.
  - Compare sight in the injured eye to the uninjured eye.

  - Severe vision loss (20/200 or worse) is a strong indicator of serious injury and evacuation urgency.
  - However, good vision does not rule out serious injury.
- Eyeball structure.
  - Obvious corneal or scleral lacerations.
  - Subconjunctival hemorrhage (SCH), hemorrhagic chemosis—may overlie an open globe.
  - Dark uveal tissue presenting on the surface of the eye indicates an open globe.
  - Foreign body—did it penetrate the eye?
  - Blood in the anterior chamber (hyphema) indicates severe blunt trauma or penetrating trauma.
- Proptosis (protrusion of the eye), particularly tense proptosis—may indicate a retrobulbar hemorrhage and orbital compartment syndrome, which is an ocular emergency.
- Pupils.
  - Pupillary peaking or distortion—may be associated with an open globe; peaked pupil points to the laceration.
  - Unequal size or reactivity, whether constricted or dilated.
- Motility.
  - Decreased motility on one side may be caused by an open globe.
  - Other causes include muscle injury, orbital fracture, and orbital hemorrhage.

Open Globe

- May result from penetrating or blunt eye trauma.
- **May cause loss of vision from either disruption of ocular structures or secondary infection (endophthalmitis).**
- Biplanar radiographs or a CT scan of the orbit may help to identify a distorted eye or a metallic intraocular fragment in a casualty with severe vision loss, a traumatic hyphema, a large SCH, or other signs suspicious for an open globe with an intraocular foreign body. Fine orbit cuts at every 1 to 1.5 mm are required to properly view the globe. Routine "head" protocol 4-mm CT cuts may miss a high number of globe injuries or foreign bodies.
- Open globes MUST be evacuated to the nearest ophthalmologist for proper repair. Non-ophthalmologists must not attempt to repair an open globe, even "to stabilize for transport."

Immediate Treatment of an Open Globe: SHEILD AND SHIP

- Perform a rapid field test of visual acuity.
- Tape a rigid eye shield (NOT a pressure patch) over the eye. Do not put any dressings/gauze/patches under the shield.
- Do not apply pressure on or manipulate the eye, including ultrasound.
- Start systemic quinolone antibiotic PO or IV (eg, moxifloxacin or levofloxacin 500 mg qd).
- Administer tetanus toxoid if indicated.
- Prevent nausea and emesis (ondansetron [Zofran]).
- Administer analgesics as needed. Analgesic doses of ketamine are not contraindicated.
- Do not apply any topical medications.
- Can close opposite eye to limit motion of injured eye.
- Arrange urgent (within 8–12 hours) referral to an ophthalmologist with surgical capabilities.
- Maintain eye shield at every echelon of care.

Treatment of Other Anterior Segment Injuries

Subconjunctival Hemorrhage

- Small SCHs may occur spontaneously or in association with blunt trauma. These lesions require no treatment.
- Bullous SCHs may occur in association with a rupture of the underlying sclera.
- Warning signs for an open globe include a large SCH with chemosis (conjunctiva bulging away from the globe) in the setting of blunt trauma, or **any** SCH in the setting of penetrating injury.
- Casualties with blast injury and normal vision may not require immediate care but may still harbor significant injury that will be unmasked later.
- Suspected open globe patients should be treated as described previously.

Treatment of Chemical Injuries of the Cornea

- Begin copious and continuous irrigation immediately. Do not delay for eye examination.
- Nonsterile water may be used if it is the only liquid available.

- Use topical anesthesia and lid speculum before irrigating, if available (tetracaine or proparacaine ophthalmic); however, do not delay.
- Remove any retained particles. Examine and sweep conjunctival fornices and under the lids.
- Measure the pH of tears to ensure that, if there is either acid or alkali in the eye, irrigation continues until the pH returns to normal. Do not use alkaline solutions to neutralize acidity or vice versa.
- Using the fluorescein test, look for epithelial defect (ie, corneal abrasions):
  - If none, then mild chemical injuries or foreign bodies may be treated with artificial tears and lubricating ointments.
  - If an epithelial defect is present, use a broad-spectrum antibiotic ophthalmic ointment (bacitracin/polymyxin [Polysporin]), erythromycin, or bacitracin) 4 times per day.
- Noncaustic chemical injuries usually resolve without sequelae.
- More severe chemical injuries require prompt ophthalmological evaluation.
- Monitor (daily topical fluorescein evaluation) for a corneal ulcer until epithelial healing is complete.
- Severe acid or alkali injuries of the eye (recognized by pronounced chemosis, limbal blanching, and/or corneal opacification) can lead to infection of the cornea, glaucoma, and possible loss of the eye. Refer to an ophthalmologist urgently, within 12 hours (SHIELD AND SHIP).
- Treat mustard eye injuries with bland ophthalmic ointments, such as 5% boric acid ointment (if available), to provide lubrication and minimal antibacterial effects. Apply sterile petrolatum jelly (if available) between the eyelids to provide additional lubrication and prevent sealing of the eyelids.
- Treat nerve agent ocular symptoms with 1% atropine sulfate ophthalmic ointment (if available); repeat as needed at intervals of several hours for 1–3 days.

Corneal Abrasions

- Diagnosis.
  - Be alert for the possibility of an associated open globe, or if a consequence of blast, significant internal blunt ocular trauma.

- The eye is usually very symptomatic, with pain, tearing, and photophobia.
- Vision may be diminished from the abrasion itself or from the profuse tearing.
- Diagnose with topical fluorescein and cobalt blue light (Wood's lamp). Fluorescein that washes away in a rivulet indicates an open and leaking globe (Seidel sign)—treat appropriately.
- A topical anesthetic as above may be used for diagnosis, but should NOT be used as an ongoing analgesic agent—this delays healing and may cause other complications.

- Treatment.
  - Apply broad-spectrum antibiotic ointment (bacitracin/polymyxin [Polysporin], erythromycin, or Bacitracin) qid.
  - Options for pain relief:
    - Diclofenac: 0.1% drops qid.
    - Larger abrasions may require a mild cycloplegic agent (1% tropicamide [Mydriacyl] or cyclopentolate [Cyclogyl]).
    - More severe discomfort can be treated with homatropine or 0.25% scopolamine 1 drop bid, but this will result in pupil dilation and blurred vision for 5–6 days.
  - Small abrasions usually heal well.
  - If the eye is not shielded:
    - Antibiotic drops (fluoroquinolone or aminoglycoside) may be used qid instead of ointment.
    - Sunglasses are helpful in reducing photophobia.
  - Ask about contact lens wear. Be aware that troops will wear contact lenses in the field even though they are prohibited. Contact lens-associated corneal abrasions may quickly develop into corneal ulcers, which require aggressive and intense antibiotic treatment and often require evacuation to ophthalmology/optometry.
  - Abrasions will normally heal in 1–4 days.
  - Initial treatment of thermal burns of the cornea is similar to that for corneal abrasions.
  - White phosphorous exposures (flares, pyrotechnics, tracer rounds, etc) must be treated under fluid (water, ointment) because the chemical ignites on air contact and can cause devastating burns.

All corneal abrasions need to be checked once a day until healing is complete to ensure that the abrasion has not been complicated by secondary infection (corneal ulcer, bacterial keratitis).

Corneal Ulcer and Bacterial Keratitis

- Diagnosis.
  - **Corneal ulcer and bacterial keratitis are serious conditions that may cause loss of vision or even loss of the eye!**
  - A history of corneal abrasion or contact lens wear.
  - Increasing pain and redness.
  - Decreasing vision.
  - Persistent or increasing epithelial defect (positive fluorescein test).
  - White or gray spot on the cornea seen on examination with a penlight or direct ophthalmoscope.
- Treatment.
  - Quinolone drops (eg, ofloxacin [Ocuflox]), 1 drop every 5 minutes for 5 doses initially, then 1 drop every 30 minutes for 6 hours, and then 1 drop hourly around the clock thereafter.
  - Scopolamine 0.25%, 1 drop bid, may help relieve discomfort caused by ciliary spasm.
  - Patching and use of topical anesthetics for pain control are contraindicated (see pain control measures discussed previously).
  - Expedited referral to an ophthalmologist within 3–5 days, sooner if condition is deteriorating (decreasing vision, increasing pain/redness, hypopion). Infection may worsen, leading to permanent injury.

Conjunctival and Corneal Foreign Bodies

- Diagnosis.
  - Abrupt onset of discomfort and/or history of suspected foreign body.
  - If an open globe is suspected, treat as discussed previously.
  - Definitive diagnosis requires visualization of the offending object, which may sometimes be quite difficult.

- ♦ A hand-held magnifying lens or pair of reading glasses will provide magnification to aid in the visualization of the foreign body.
- ♦ Stain the eye with fluorescein to check for a corneal abrasion.

- The casualty may be able to help with localization if asked to indicate the perceived location of the foreign body prior to instillation of topical anesthesia.
- Eyelid eversion with a cotton-tipped applicator helps the examiner identify foreign bodies located on the upper tarsal plate.

- Treatment.
  - Superficial conjunctival or corneal foreign bodies may be irrigated away or removed with a moistened sterile swab under topical anesthesia.
  - Objects adherent to the cornea may be removed with a swab or a sterile 22-gauge hypodermic needle mounted on a tuberculin syringe (hold the needle **tangential** to the eye).
  - If no foreign body is visualized, but the index of suspicion is high, vigorous irrigation with artificial tears or sweeps of the conjunctival fornices with a moistened cotton-tipped applicator after topical anesthesia may be successful in removing the foreign body.
  - If an epithelial defect is present after removal of the foreign body, treat as discussed previously for a corneal abrasion.

Hyphema: Blood in the Anterior Chamber

- Can occur after blunt or penetrating trauma and significant intraocular injury. SHIELD AND SHIP.
- Treatment (to prevent vision loss from increased intraocular pressure):
  - Be alert for a possible open globe and treat for that condition if suspected.
  - Avoidance of rebleeds is a major goal of management.
    - ♦ **Avoid** aspirin and nonsteroidal antiinflammatory drugs.
    - ♦ If a polytrauma patient must be systemically anticoagulated (eg, enoxaparin), monitor eye status for expansion of hyphema or rebleed.

    - ♦ No strenuous activity (bedrest with head of bed elevated) for 7 days.
    - ♦ No reading for 7 days to minimize rapid eye movements.
  - o Prednisolone 1%—1 drop 4 times a day.
  - o Scopolamine 0.25%—1 drop twice a day.
  - o Cover eye with protective shield.
  - o Elevate head of bed to promote settling of red blood cells in anterior chamber.
  - o Provide a 24- to 48-hour referral to an ophthalmologist to monitor for increased intraocular pressure (which may cause permanent injury to the optic nerve) and to evaluate for associated intraocular injury.
  - o If evaluation by an ophthalmologist is delayed (>24 hours), treat with a topical beta-blocker (timolol or levobunolol) bid to help prevent intraocular pressure elevation.
  - o If intraocular pressure is found to be markedly elevated (above 30 mm Hg) with a tonometry device (eg, Tonopen), other options for lowering intraocular pressure include acetazolamide (Diamox) 500 mg PO or IV and mannitol 1–2 g/kg IV over 45 minutes.

Orbital Compartment Syndrome (Retrobulbar Hemorrhage)

- A clinical diagnosis. This is a true ocular emergency in which minutes matter and that cannot wait on diagnostic imaging or transfer to an ophthalmologist.
- Retrobulbar hemorrhage most often occurs after blunt or penetrating orbital trauma, but there are other etiologies.
- Keys to recognition: Severe eye pain, tense proptosis ("rock hard" orbit), vision loss, afferent pupillary defect, and decreased eye movement.
  - o Marked lid edema may make the proptosis difficult to appreciate. Inability to open the lids, even with cotton swabs, is highly suspicious for this.
  - o Failure to recognize the condition may result in blindness within 60–90 minutes from increased ocular/orbital pressure and ischemia.
- Perform an immediate lateral canthotomy and cantholysis.
- Provide an urgent referral to an ophthalmologist, within 24–48 hours (SHIELD AND SHIP).

- If evaluation by an ophthalmologist is delayed (>24 hours), treat with a topical beta-blocker (timolol) bid to help lower intraocular pressure elevation.
- If intraocular pressure remains elevated (>30 mm Hg), treat as discussed previously, including acetazolamide, mannitol, or hypertonic saline to decrease intraorbital pressure.

Lateral Canthotomy/Cantholysis

The indication for lateral canthotomy/cantholysis is orbital compartment syndrome. It is not an easy procedure to do properly in the face of marked orbital distention and tight tissues. Do not perform such procedures if the eyeball structure has been violated. If there is a penetrating globe injury, apply a rigid eye shield for protection and seek immediate ophthalmic surgical support (SHIELD AND SHIP).

- Inject 2% lidocaine with 1:100,000 epinephrine into the lateral canthus (Fig. 14-1a).
- Crush the lateral canthus with a straight hemostat, advancing the jaws to the lateral fornix and bony orbital rim (Fig. 14-1b).
- Using straight blunt-tipped scissors, make a 1-cm horizontal incision of the lateral canthal tendon (canthotomy) in the middle of the crush mark (Fig. 14-1c). Incision should extend to the bony lateral orbital rim.
- Grasp the lower eyelid with large toothed forceps (eg, Adson), pulling the eyelid vertically away from the face, toward the ceiling. This pulls the inferior crus (band of the lateral canthal tendon) tight so it can be easily cut loose from the orbital rim (Fig. 14-1d). It will have a "banjo string" feel against the tip of the scissors.
  - Use blunt-tipped scissors to cut the inferior crus.
  - Keep the scissors parallel (flat) to the face with the tips pointing toward the corner of the mouth or nasal ala.
  - Make a FULL THICKNESS cut across the lower lateral lid, incorporating the conjunctiva and skin (cantholysis).
  - The eyelid should swing freely away from the rim, detaching like a hammock, thereby relieving pressure on the globe. (Fig. 14-1e)
  - Cut residual lateral attachments of the lower eyelid if it does not move freely. (Strum with scissors tips, feeling for restricting tethers; incise any residual bands)

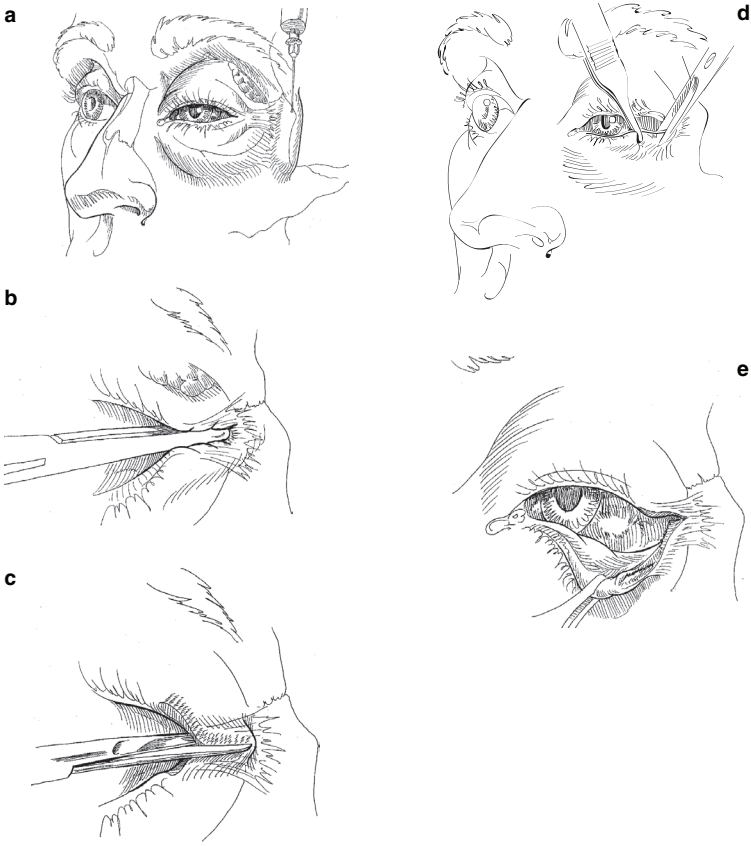

Fig. 14-1. Lateral canthotomy and inferior cantholysis are indicated for casualties presenting with serious orbital hemorrhage.

- Do not worry about the cosmetics of cutting 1 cm of conjunctiva or skin.
- The lower eyelid is cut, relieving orbital pressure. If the intact cornea is exposed, apply, hourly, copious erythromycin ophthalmic ointment or ophthalmic lubricant ointment to prevent devastating corneal desiccation and infection. Relief of orbital pressure must be followed by lubricating protection of the cornea and urgent ophthalmic surgical support. Do NOT apply absorbent gauze dressings to the exposed cornea.

- Continue to monitor vision throughout evacuation.

Orbital Floor (Blowout) Fractures

These fractures are usually the result of a blunt injury to the globe or orbital rim, often associated with head and spine injuries. Blowout fractures may be suspected on the basis of enophthalmos (sunken eye), diplopia, decreased ocular motility, hypoesthesia of the V2 branch of the trigeminal nerve, associated SCH, or hyphema.

- Presence of an afferent pupillary defect (or Marcus Gunn pupil), in which light shone into the affected eye causes less pupillary constriction than the consensual reflex when light is shone into the unaffected eye, may represent bony optic nerve impingement and is an indication for immediate orbital exploration and repair if fractures are present.
- If severe impingement of upward gaze is present, especially when accompanied by bradycardia or nausea/vomiting (oculocardiac reflex), impingement of an extraocular muscle should be presumed and the orbit should be explored urgently, ideally within 1 hour.
- Immediate treatment includes pseudoephedrine 60 mg q6h and a broad-spectrum antibiotic for 7 days, ice packs, and instructing the casualty not to blow their nose.
- Definitive diagnosis requires CT scan of orbits with axial and coronal views.
- Indications for non-urgent repair include severe enophthalmos and diplopia in the primary or reading gaze positions.
- If conditions described above are not present, this condition is not an urgent matter; surgery may be performed 1–2 weeks after the injury.

Lid Lacerations

Treatment Guidelines for Lid Lacerations Not Involving the Lid Margin

- Excellent blood supply—delayed primary closure is not necessary. Do not excise or sharply debride tissue.
- Eyelid function (protecting the globe) is the primary consideration.

- Begin with irrigation, cleansing debridement, and antisepsis (any topical solution, but no detergent or chlorhexidine-based products—eg, povidone iodine soap [Betadine Scrub, Hibiclens]), and check for retained foreign bodies.
- Superficial lacerations of the eyelid not involving the eyelid margin may be closed with running or interrupted 6-0 silk or monofilament.
- Visible orbital fat, by definition, indicates a deeper orbital injury requiring more sophisticated evaluation and treatment—SHIELD AND SHIP.
- Horizontal laceration closure should include the superficial orbicularis muscle and skin. Avoid layered closures.
- If skin is missing, an advancement flap may be created to fill in the defect, but preferably, defer flap creation to ophthalmology. For vertical or stellate lacerations, use traction sutures in the eyelid margin for 7–10 days.
- Antibiotic ointments qid.
- Skin sutures may be removed in 5 days.

Laser Eye Injuries

- Battlefield lasers may be designed to cause eye injuries or may be part of other weapons or sensor systems.
- **Prevention is the best option!** Wear eye protection designed for the appropriate light wavelengths if there is a known laser threat.
- The type of ocular damage depends on the wavelength and power of the laser. Retinal injuries are most common.
- The primary symptom of laser injury is loss of vision, which may be preceded by seeing a flash of light. Pain may not be present.
- Immediate treatment of corneal laser burns is similar to that for corneal abrasions.
- Laser retinal burns have no proven immediate treatment, although improvement with corticosteroids and nonsteroidal antiinflammatories has been reported.
- Routine evacuation for evaluation by an ophthalmologist is required.

Enucleation

Because there is no method to restore vision, the decision to remove an eye is not to be taken lightly. The following recommendations apply to treatment of friendly and coalition forces, understanding that exigencies of combat may dictate providing care to host nationals or local populations who cannot be treated by more sophisticated echelons.

A general surgeon in a forward unit should not remove a traumatized eye, and under no circumstances should a bilateral primary enucleation be performed by anyone other than an ophthalmologist. Primary enucleation should only be considered if the patient has a devastatingly severe injury with non-salvageable disorganization, no light perception using the brightest light source available, or early endophthalmitis. Because of new surgical technologies and methods—and because there is no going back on the decision to enucleate—the ophthalmologist is the best judge of determining such hopelessness. Sympathetic ophthalmia is a condition that may result in loss of vision in the fellow eye if a severely traumatized, nonseeing eye is not removed; however, it rarely develops prior to 21 days after an injury. **Thus, delaying enucleation until the patient is in the care of an ophthalmologist is relatively safe.**

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 15

Head Injuries

Introduction

The motor exam is one of the most important aspects for determining prognosis and role for surgical intervention in head-injured patients. Those patients who follow commands have the best prognosis; however, a subsequent neurological deterioration may indicate an enlarging intracranial hemorrhage or increased intracranial pressure (ICP) with brainstem compression. Those patients who fail to follow commands, but localize or withdraw to stimuli, may also benefit from neurosurgical intervention. The worst category of patients who demonstrate flexion or extensor posturing less frequently benefit from surgical decompression unless done quickly and appropriately. In the case of a large mass lesion, such as an epidural hematoma, outcome is closely related to timing of decompression, with a steep survival fall-off at times >2 hours.

Any subsequent neurological improvement may indicate salvageability and should prompt reevaluation. In theater, survival of combat-related head-injured patients has been better than expected, compared with traditional civilian literature. This is likely related to the rapid on-site airway and hemorrhage control, with rapid evacuation to in-theater neurosurgeons. Currently, US/coalition military patients presenting with a Glasgow Coma Scale (GCS) score of 3–5 have a 35% survival; those with a GCS score of 6–8 have a 90% survival, with aggressive multimodality care. One-year outcomes of casualties sustaining a gunshot wound to the head in Operation Iraqi Freedom and presenting with a GCS score of 3–5, who were treated with aggressive operative decompression and advanced critical care, have been significantly better than reported in civilian literature. Of survivors in this group, 55% of these patients had a 1-year Glasgow Outcomes Score (GOS) of ≥4. (The GOS is a functional outcomes score ranging from 1 to 5, with 1 being dead; a GOS of 4 is independent, but disabled.)

Neurosurgical damage control includes early intracranial pressure control (which may include surgical decompression); cerebral blood flow preservation; and prevention of secondary cerebral injury from hypoxia, hypotension, and hyperthemia.

A motor examination of the most salvageable severely brain-injured patients will demonstrate localization to central stimulation. Immediate intubation with adequate ventilation ($PaCO_2$ of 35) and oxygenation and restoration of intravascular volume are the most critical first-line treatment for a severely head-injured patient. Evacuating to the nearest neurosurgeon, avoiding diagnostic delays, and initiating cerebral resuscitation allow the best chance for ultimate functional recovery. A properly trained surgeon at Role 2 may, at times, find it necessary to surgically intervene should the situation dictate. However, the neurotrauma patient's care should be ideally centralized in the theater of operations, where a neurosurgeon, CT scanner, and fixed air transport are established.

Combat Head Injury Types

- Blunt (closed-head injury).
- Penetrating.
  - Penetrating from fragments.
  - Penetrating from a gunshot wound.
  - Guttering (grooving the skull).
- Primary blast (overpressure central nervous system injuries).
  - A direct injury to the brain or via a force transmitted by the great vessels of the chest to the brain; associated with unconsciousness, confusion, headache, tinnitus, dizziness, tremors, increased startle response, and occasionally (in the most severe forms) increased ICP. Bleeding may occur from multiple orifices, including the ears, nose, and mouth. Alternatively, a blast-injured patient may have no external signs of injury and only subtle signs of cognitive dysfunction in attention, concentration, reaction time, and balance.

A combination of multiple injury types is typically involved in combat-related brain injuries. Those injuries generally involve the face, neck, and orbit; entry wounds may be through the upper neck, face, orbit, or temple (Fig. 15-1).

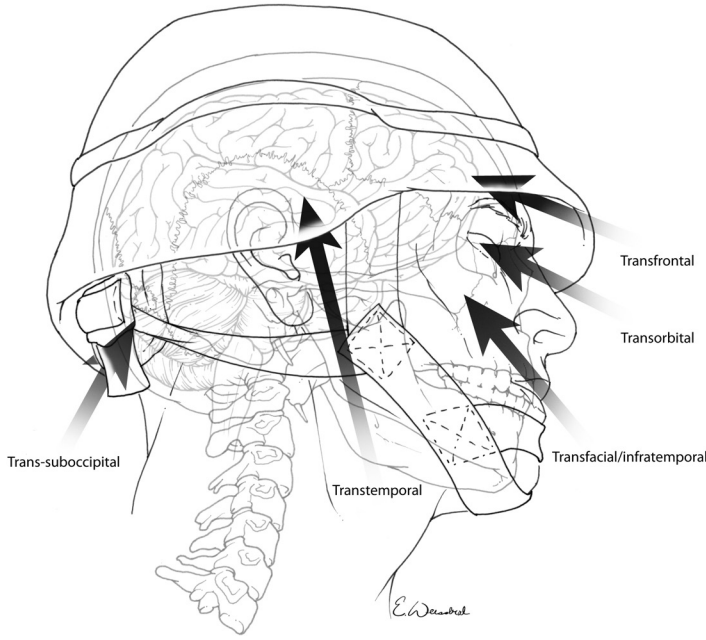

Fig. 15-1. Common vectors of penetrating injury. Courtesy of E. Weissbial.

The subocciput, occiput, and retroauricular regions are often overlooked. Injuries to these areas can indicate underlying injury to the posterior fossa, major venous sinus, and vertebral or carotid artery, as fragments pass through the skull base. Reconstructing the fragment path based on a combination of plain films and CT scan can be challenging, but may be beneficial in triage. In transorbital, lateral temporal, or penetrating injuries that cross the midline, an underlying injury to intracranial vessels should be suspected with associated pseudoaneurysms, dissections, or venous sinus injury.

Explosion results in penetrating fragment injury, as well as blunt injury to the brain. Depending on proximity to the explosion, a blast overpressure phenomenon may also result. In a severely

brain-injured patient, more deficits than indicated by the CT scan may be due to underlying injury to brachiocephalic vessels, shear injury, or the late effects of blast overpressure, with resulting delayed cerebral vasospasm. Plain films, more useful in penetrating than in blunt trauma, may reveal a burst fracture of the skull indicating the tremendous force of a penetrating missile. Transventricular bihemispheric fragment tracts portend a poor prognosis. However, bilateral injuries above the level of the ventricles may be better tolerated and respond to bifrontal decompressive craniectomies.

Severe head injuries are often seen in combination with significant chest, abdomen, and extremity injuries. Rapid hemorrhage control, utilizing damage control concepts, is the priority to minimize secondary brain injury. Additionally, many combat penetrating or severe blast injuries include head and neck structures. It is critical for a coordinated plan that includes oral maxillofacial, ENT, and ophthalmology.

Traditional Classification of Head Injuries

- **Open** injuries are more common in combat-injured versus civilian trauma.
- **Closed** injuries are still very common in blunt trauma sustained during combat operations. Blast injury may present as a closed-head injury.
- **Scalp** injuries may be closed (eg, contusion) or open (eg, puncture, laceration, or avulsion).
  - Any scalp injury may be associated with a skull fracture and/or underlying brain injury.
  - Open scalp injuries bleed profusely, even to the point of lethal blood loss, but usually heal well when properly repaired.
- **Skull fractures** may be open or closed, and are described as linear, comminuted, or depressed.
  - Skull fractures are usually associated with some degree of brain injury, varying from mild concussion, to devastating diffuse brain injury, to intracranial hematomas.
  - Open skull fractures are prone to infection if not properly treated.

Note: The previous descriptions remain a generalized broad classification that does not always correlate with the prognosis, role for treatment, or level of consciousness. Massive amounts of bleeding and soft-tissue injury can occur in the scalp and superficial cortex with relatively little significant injury to the deep structure of the brain. Alternatively, no external signs of trauma may be present in a patient with a severe "shear" injury to the brainstem, diencephalon, or corpus callosum with a severe comatose state that may persist to a vegetative coma.

Mechanisms of Injury

- **Primary injury** is a function of the energy transmitted to the brain by the offending agent.
  - Very little can be done by healthcare providers to influence the primary injury.
  - Enforcement of personal protective measures (eg, helmet, seatbelts) by the command is essential prevention.
- **Secondary injury** results from disturbance of brain and systemic physiology by the traumatic event.

Hypotension and hypoxia are the two most acute and easily treatable mechanisms of secondary injury.

  - Other etiologies include seizures (seen in 30%–40% of patients with penetrating brain injuries), fever, electrolyte disturbances (specifically hyponatremia or hyperglycemia), and infection.
  - **All of the previously described conditions can be treated**.
  - Elevations of ICP may occur early as a result of a space-occupying hematoma or develop gradually as a result of brain edema or hydrocephalus.
  - Normal ICP is 5–15 mm Hg, with normal CPP (CPP = MAP–ICP) usually >70 mm Hg (where CPP = cerebral perfusion pressure; MAP = mean arterial pressure).
  - Decreases in perfusion pressure, as a result of systemic hypotension or elevated ICP, gradually result in alteration of brain function (manifested by impairment of

consciousness), and may progress to global brain ischemia and death if untreated.

Patient Assessment and Triage

- The most important assessment is the **vital signs.**
- Next is the **level of consciousness**, best measured and recorded by the postresuscitation GCS score (Table 15-1).

Table 15-1. Glasgow Coma Scale

Component	Response	Score
Motor response (best extremity)	Obeys verbal command	6
	Localizes pain	5
	Flexion withdrawal	4
	Flexion (decortication)	3
	Extension (decerebration)	2
	No response (flaccid)	1
	Subtotal	**1–6**
Eye opening	Spontaneously	4
	To verbal command	3
	To pain	2
	None	1
	Subtotal	**1–4**
Best verbal response	Oriented and converses	5
	Disoriented and converses	4
	Inappropriate words	3
	Incomprehensible sounds	2
	No verbal response	1
	Subtotal	**1–5**
	TOTAL	**3–15**

Note: Glasgow Coma Scale in intubated patients is followed by a "T," with a maximum score of 11T (ie, E4M6V1).

- During the secondary assessment, attention should be placed on a complete examination of the scalp and neck. Fragments that enter the cranial vault with a lateral, transorbital, crossing the midline trajectory, or bridging the cranial–cervical junction should be suspected as having associated neurovascular injuries. Wounds are typically contaminated. These wounds should be debrided with removal of foreign material; however,

this should not delay definitive neurosurgical intervention for an underlying hematoma, brainstem compression, or depressed skull fracture that may exist. The scalp should be copiously irrigated clean with control of ongoing scalp hemorrhage. This can be accomplished with a head wrap, scalp clips, or surgical staples; **a meticulous plastic surgical closure before neurosurgical evaluation is not appropriate and should not delay transfer.**

- Triage decisions in the patient with craniocerebral trauma should be made based on first available GCS score (**admission or prehospital**), pupillary reactivity, and available resources.
  - A GCS score of ≤5 indicates a poor prognosis; however, with aggressive comprehensive treatment, the combat casualty can have a higher survival than standard civilian neurotrauma patients (up to 35%) and higher GOSs. This is particularly true for patients who will have access to further rehabilitative care and higher treatment facilities. If triaged to an expectant category, they should be reassessed.
  - A GCS score of ≤9 indicates that a casualty may do well if managed appropriately.
    - In general, neurologically stable patients with penetrating head injury can be managed effectively in the ICU with airway and ventilatory support, antibiotics, and anticonvulsants while awaiting surgery.
    - An exception to this would be a clinically deteriorating patient (ie, a suspected large hematoma—this should be considered a surgical emergency).
  - **Casualties with a GCS score of 6–8 can be the most reversible, with in-theater neurosurgical management involving control of ICP and preservation of cerebrospinal fluid. Treatment decisions may have to take into account access to further rehabilitative and supportive care.**
  - **Casualties requiring evacuation to neurosurgical care should not have transportation delayed for surgical management of injuries that are not life-threatening.**
- **Pupillary reactivity**.
  - Be aware that eye injuries are common with associated intracranial injuries and can therefore affect pupillary exam.

- A single dilated or nonreactive pupil adds urgency and implies the presence of a unilateral space-occupying lesion with secondary brain shift. Immediate surgery may be indicated.
- The presence of bilateral dilated or nonreactive pupils is a dismal prognostic sign in the setting of profound alteration of consciousness.

A single dilated or nonreactive pupil adds urgency and implies the presence of a unilateral space-occupying lesion with secondary brain shift. Immediate surgery may be indicated. Transportation to neurosurgical care should not be delayed for treatment of injuries that are not life-threatening.

- **Radiographic evaluation.**
  - CT scanners are often available at Role 3 medical treatment facilities.
    - Noncontrast **CT is the definitive radiographic study in the evaluation of acute head injury,** and should be used liberally, as it greatly improves diagnostic accuracy and facilitates management. A CT angiogram should be performed after noncontrast CT in those cases wherein a major neurovascular injury may have occurred, including dural venous sinus injury, traumatic pseudoaneurysm, or dissection.
  - Skull radiographs still have a place in the evaluation of head injury (especially penetrating trauma).
    - In the absence of CT capability, AP and lateral skull radiographs help to localize foreign bodies in cases of penetrating injuries and can also demonstrate skull fractures.
    - This can help direct otherwise "blind" surgical intervention initially to the side of the head where the fracture is identified.
  - Closed-head injury can be associated with injury of the cervical spine.
    - Survivable cervical spine injury occurs in less than 2% of isolated penetrating head injury in combat trauma.

- In blunt trauma (blast injury included), assume the presence of cervical spine injury and keep the cervical spine immobilized with a rigid collar until a standard CT of the cervical spine can be obtained. The CT scan should be of fine cuts (3 mm), and with sagittal and coronal reconstructions. AP, lateral, and open-mouth radiographs do not definitively clear a spine for bony injury in the obtunded patient, but may be of assistance when a CT scan is not available. (See Joint Theater Trauma System [JTTS] Clinical Practice Guidelines.)
- In penetrating head trauma that may involve the cervical spine, CT scan should also be performed when the patient is obtunded or presents with motor or sensory deficits.

Management

- **Medical.**
  - Primary tenets are basic, but vital: protect the airway, ensure adequate ventilation, and assess and treat for shock (excessive crystalloid administration should be avoided).
  - In general, patients with a GCS score of ≤13 should be managed in a monitored setting.
  - **Management should be directed toward preventing secondary brain injury.**
    - Avoid cerebral hypoxia by maintaining the PaO_2 >80 mm Hg or oxygen saturation >93%.
    - Avoid cerebral hypoperfusion by keeping SBP >90 mm Hg.
    - Avoid vasoconstriction or vasodilation by maintaining the $PaCO_2$ between 35 and 40 mm Hg.
    - The head of the bed should be elevated >30°. (Use reverse Trendelenburg position of the bed if the thoracolumbar spine is unable to be cleared.)
    - The neck should be positioned in the midline and the cervical collar loosened to prevent occlusion of the internal jugular veins (and subsequent elevation of the ICP). Avoid placement of the internal jugular vein central line that may induce jugular vein thrombosis and subsequent increased ICP.
    - Sedate the severely brain-injured patient with short-acting agents (to allow frequent neuro exams) to

limit stimulation and to avoid dyssynchrony with the ventilator—both leading to ICP elevation. (Propofol has been the preferred early sedating agent. Be cautious of hypotension with its use.)

- Early initiation of hyperosmolar therapy with 3% saline is recommended for a GCS score of <12. May be given as a 250-mL bolus, followed by an infusion. The goal is serum sodium of 145–155 mEq/L with serum Osm <330 mmol/L. (See JTTS Clinical Practice Guidelines on Severe Head Trauma.)
- Administer Cefazolin 2 grams every 6–8 hours for 5 days in patients with penetrating injuries. (Vancomycin is a second-line alternate.)
- Administer 5 days of Metronidazole for grossly contaminated wounds or those open wounds whose treatment has been delayed more than 18 hours.
- Phenytoin should be administered in patients with penetrating head injury or those with suspected or demonstrated significant intracranial blood volume (>1 cm) on CT scan. Use a 17-mg/kg load, in a normal saline piggyback and given over 20–30 minutes (no more than 50 mg/min, because rapid infusion may cause cardiac conduction disturbances).
  - A maintenance dose of 300–400 mg/day, either in divided doses or once before bedtime, should be adequate to maintain a serum level of 10–20 mg/L.
- Alternatively, a Levetiracetam (Keppra) load of 1,500 mg IV with 1,000 mg bid has been effective with a lower cross-reactivity with other medications, including antibiotics, and less side-effect profile than phenytoin.
- Measure serum chemistries daily to monitor for hyponatremia or severe hypernatremia (>160 mEq/L). This should be done q6h if 3% NaCl or mannitol has being utilized.
- Treat initial coagulopathy aggressively (goal INR <1.4).
- Hyperglycemia and hypoglycemia should be treated.
- Blast overpressure central nervous system injuries.
  - Supportive medical therapy is usually sufficient. Only in rare cases is an ICP monitor, ventriculostomy, or

cranial decompression necessary. Delayed intracranial hemorrhages have been reported. Additionally, these patients have a higher susceptibility to subsequent injury and should be evaluated at a Role 4 medical treatment facility. Repetitive injury and exposure to blast overpressure may result in irreversible cognitive deficits.

- **Monitoring of ICP is recommended for all patients with a GCS score of ≤8 or for those patients undergoing intertheater aeromedical evacuation, wherein serial neurological examination is needed (in essence, it is an adjunct to a neurological examination).**
  - An intraparenchymal ICP monitor (ICP EXPRESS by Codman is the US Air Force aeromedical-approved device) can be placed with relative ease into the brain parenchyma and gives an accurate reflection of the ICP. Cerebrospinal fluid is not able to be withdrawn.
  - A ventriculostomy is preferred in a comatose patient at a Role 3 medical treatment facility, since both the measurement and treatment of increased ICP can be performed. (A simple, fluid-coupled monitor ensuring that no pressurized bag is paired with the transducer.)
    - Administer prophylactic antibiotic (Cefazolin 2 grams) prior to insertion.
    - Make an incision just at or anterior to the coronal suture, approximately **2.5–3 cm** lateral to the midline (Fig. 15-2a,b).
    - A twist drill craniostomy is performed, the underlying dura is nicked, and a ventricular catheter is placed into the frontal horn of the lateral ventricle (encountered at a depth of 5–6 cm) (Fig. 15-2b,c). Catheter should be directed toward the medial epicanthis on the coronal plane and toward the tragus in the sagittal plane.
    - Even small ventricles can be easily cannulated by aiming the tip of the catheter toward the nasion in the coronal plane.
    - Antibiotic-impregnated ventricular catheters are highly preferable; acceptable substitutes are an 8 Fr Robinson catheter or pediatric feeding tube.

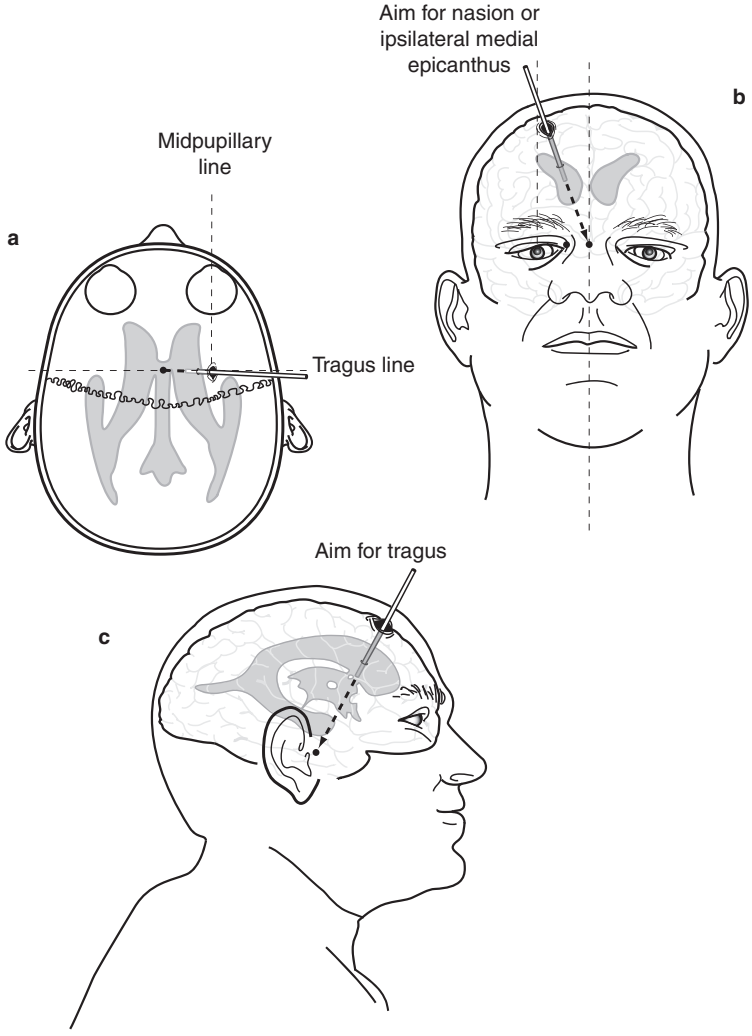

Fig. 15-2. Placement of the intracranial ventricular catheter.

- A key feature of this technique is to tunnel the drain out through a separate incision 2–3 cm from the primary one, thus reducing the risk of infection.

- ◊ A sustained ICP >20 mm Hg for more than 5 minutes should be treated (Fig. 15-3). (See JTTS Clinical Practice Guidelines.)

♦ Once an ICP monitor is in place, calculate a CPP (CPP = MAP – ICP).

- ◊ The goal of management is to maintain a CPP of>60 mm Hg.
- ◊ Intravascular volume status should be assessed, with euvolemia being the goal. This is difficult in the deployed setting and one reason to avoid mannitol. A central venous pressure (CVP) of 8–10 mm Hg in a young patient on normal levels of positive end-expiratory pressure (5 cm H_2O) should be suggestive of an adequate volume. Values less than this may indicate a need for additional fluid resuscitation. If additional blood is warranted, ensure that the packed red blood cell unit is the freshest available to facilitate brain tissue oxygenation.
- ◊ If CPP remains low after adequate fluid resuscitation and reassessment for other sources of hypotension (bleeding, pharmacological, etc), initiate a vasopressin infusion at 0.04 units/min. If CPP remains low, begin a vasopressor, such as phenylephrine or norepinephrine

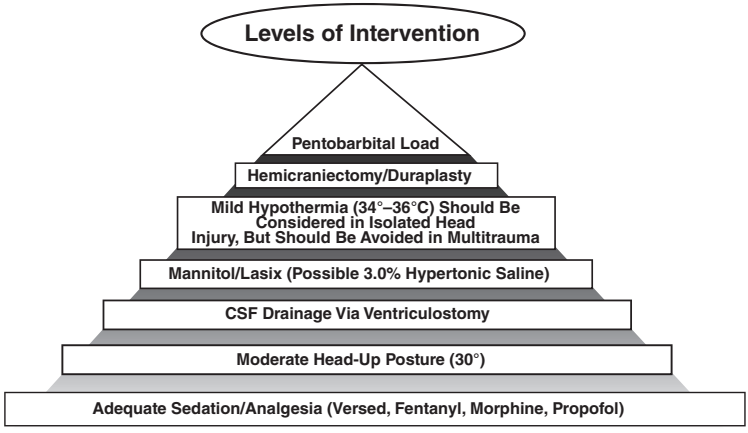

Fig. 15-3. Levels of intervention to reduce ICP. CSF: cerebrospinal fluid.

(norepinephrine should begin at 5 mg/kg/min and titrate as needed; maximum dose being 20 mg/kg/min). If CPP is low, the initiation of a vasopressor to support CPP is warranted while the other measures previously mentioned can be performed.

- Sedation, head elevation, neck midline, and cervical collar loosened.
- Cerebrospinal fluid drainage to an ICP of 20 mm Hg if a ventricular catheter is in place.
- **Mild hyperventilation to a $PaCO_2$ of 30–35 mm Hg ONLY AS A BRIDGING MANEUVER until other measures take effect.** (Prolonged levels below this are deleterious, as a result of small vessel constriction and ischemia.) Once the acute ICP elevation is treated, ventilation should then be titrated to a $PaCO_2$ of 35–40 mm Hg.
- Hyperosmolar therapy should be initiated with a 250-mL bolus of 3% NaCl, followed by an infusion of 50 mL/h. If 3% NaCl has already been initiated and serum sodium levels remain below 150, consider a second bolus at this time. (See JTTS Clinical Practice Guidelines.)
- Normothermia should be maintained. Uncover the patient, use fans, apply ice to the groin and axilla. Fever will lead to increased metabolic activity of the brain, increased ICP, and increased vasospasm. At Role 3/4, this can be performed with surface cooling gel pads with a closed-loop automated system calibrated with a Foley catheter thermistor.
- Utilize pharmacological paralysis if heavy sedation is not effective or as needed for transport (Vecuronium 5–10 mg IV PRN or as a drip for longer acting use). Maintain paralysis by assessing with a neurostimulation device to a "train of 4" (1/4) to prevent overmedication or undermedication.
- **Any patient who develops intracranial hypertension or deteriorates clinically should undergo prompt head CT to reassess for need for surgical intervention.**

- Refractory intracranial hypertension may be managed with an initial bolus of 1 g/kg of **mannitol** and intermittent dosing of 0.25–0.5 g/ kg q4h as needed.
  - □ Aggressive treatment with mannitol should be accompanied by placement of a CVP line because hypovolemia may ensue.
  - □ Serum osmolality is not able to be measured in the deployed setting, making mannitol's use complex and further management more difficult. **It can be used to "buy time" en route to the neurosurgeon.**
  - □ **Do not use mannitol in hypovolemic or under resuscitated patients because it will produce hypotension.**
- Pentobarbital coma can be used in refractory ICP elevation, but has been essentially replaced by decompressive craniectomy. Pentobarbital coma requires a CVP monitor and ideally EEG to titrate dose to burst suppression. Duration of therapy is usually limited to 72 hours. (**Load:** 2.5 mg/kg q15 min × 4 doses, 10 mg/kg/h ggt × 3 hours; **Maintenance:** 1.5 mg/kg/h; ideally, one would check a level and decrease maintenance if >5 mg% or becomes hypotensive.) The pulmonary, infectious, and cardiac adverse effects have limited its utility and recent application.
- At Role 4, mild hypothermia (32°–34°C) may be considered in isolated head injury, unresponsive to other measures. It should be avoided in the multisystem trauma patient. Care should be taken to prevent rapid unintentional re-warming because it can cause a secondary brain injury.

- Surgical.
  - Goals: Stop hemorrhage, relieve/prevent intracranial hypertension, and prevent infection.
  - **ROLE 2:** Indications for emergent exploration and a damage control craniectomy **(must be done in consultation with regional neurosurgeon, if available)**. These may be

"presumed" at a Role 2 medical treatment facility, because CT scan will rarely be available.

- ♦ Presumed space-occupying lesions with neurological deterioration (eg, acute epidural hematoma). This may be suspected with an unreactive/dilated pupil, especially when associated with contralateral hemiparesis.
- ♦ Compound depressed fracture with significant neurological deterioration.
- ♦ Penetrating injuries with significant neurological deterioration.

- o Relief of ICP with hemicraniectomy.
  - ♦ A large trauma flap should be planned for the evacuation of a mass lesion with significant underlying edema in the supratentorial space.
  - ♦ The common mistakes are failure to make the bone flap large enough due to a misplacement of the burr holes, not anterior enough, not posterior enough, or inadequate temporal bone removal at the skull base (Fig. 15-4).
- o Shave hair widely and scrub and paint the scalp with betadine.
- o General anesthesia.
- o Administer empiric antibiotics (Cefazolin: 2 grams).
- o Positioning can be adequately managed with the head in a doughnut or horseshoe-type head holder. The head will be turned away from the side of the craniectomy.
- o Make a generous scalp incision to create an adequate flap (Fig. 15-5a).
- o The flap should extend a minimum of 4 cm posterior to the external auditory canal and 2–3 cm off midline. Exposing the frontal, temporal, and parietal lobes allows for adequate cerebral swelling and avoids brain herniation at the craniectomy edge.
- o Ensuring that decompression in adults measures 15 cm in the AP dimension and 12 cm from the middle cranial fossa to the vertex is essential.
  - ♦ The flap should have an adequate pedicle to avoid ischemia; preservation of the superficial temporal artery should be performed.
  - ♦ Scalp hemorrhage can be controlled with a running, locking suture or Raney clips.

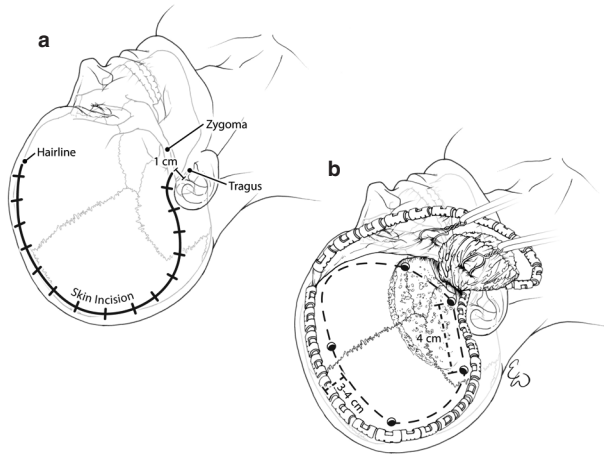

Fig. 15-4. Cranial landmarks and location of standard burr holes. Courtesy of E. Weissbial.

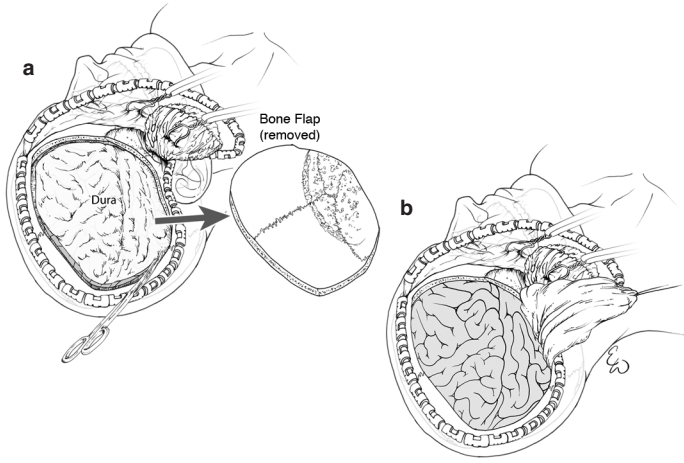

Fig. 15-5. Craniectomy flap. Courtesy of E. Weissbial.

- Retraction of the scalp flap over a rolled laparotomy sponge will avoid kinking the flap, which also may lead to ischemia. Avoid placement of the sponge over the globe, however, since this can result in increased intraocular pressure and therefore ICP and, in rare cases, blindness.
- **Burr holes alone are inadequate to treat acute hematomas**, but are potentially of diagnostic utility in the absence of a CT scanner. Exploratory burr holes may miss subfrontal or interhemispheric hematomas (Fig. 15-6).

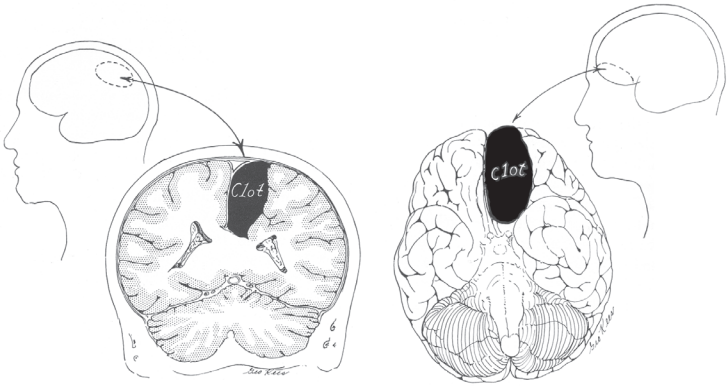

Fig. 15-6. Hematomas missed with routine exploratory burr holes.

  - The bone work may be done with a Hudson brace and Gigli saw (passed beneath the cranium with the help of a Gigli saw passer or tonsil clamp), though a power craniotome is certainly preferable if available (see Fig. 15-5a).
- A large dural opening should be created, using the entire expanse of the cranial opening with enough edge (~5 mm) left to close the dura at a later time.
  - The base of the dural opening should be on the side near any neighboring major venous sinus to avoid injury to large draining veins and aggravation of cerebral edema.
- For the **damage control craniectomy** by the general surgeon, removal of devitalized tissue should be deferred to the neurosurgeon, as long as bleeding can be controlled.

- ♦ The hematoma should be gently evacuated with a combination of irrigation and mechanical removal. Copious irrigation will help to "float" bone fragments to the surface for easier removal.
- ♦ Thrombin-soaked gel foam may be the best and easiest adjunct measure for bleeding control. Bipolar cautery is ideal, or unipolar electrocautery with forceps, clips, and suture may be used. Avoid injury to the large midline sagittal sinus.
- ♦ The dura should be left open.
- ♦ The scalp can be closed full thickness with a running nylon suture.

- o Skull flap (the removed portion of the skull) management has been evolving.
  - ♦ For local nationals, options include: wash aggressively and place the skull flap in the abdominal-wall fat pocket, freezer storage (if available) of the bone flap, hinge cranioplasty.
  - ♦ Discard the flap in US patients. Reconstruction can be performed using titanium, methyl methacrylate or acrylic at a later date.
- o Apply a loose dressing using roller bandages around the entire head.
- o Evacuate patient to neurosurgical care as soon as possible.
- o **ROLE 3:** Indications for emergent surgical intervention by neurosurgeon include:
  - ♦ Space-occupying lesions with neurological changes (eg, acute subdural/epidural hematoma, abscess).
  - ♦ Intracranial hematoma producing a >5 mm midline shift or similar depression of cortex.
  - ♦ Compound depressed fracture with neurological changes.
  - ♦ Penetrating injuries with neurological deterioration.
- o A similar procedure will be followed, but with the addition of the following:
  - ♦ Relief of ICP with wide hemicraniectomy/duraplasty/ventriculostomy.

- A capacious duraplasty should be constructed with a subdural ICP/ventricular catheter in place, allowing monitoring and drainage from the injured hemisphere.
- For unusual positioning of the head, so as to gain access to the subocciput, a standard 3-point Mayfield fixation device may be useful.

- Approach to **penetrating injury with neurological changes** is aimed at removal of devitalized brain and easily accessible foreign bodies.
  - Perform copious irrigation with an antibiotic solution (eg, Bacitracin) and a concerted attempt made to achieve watertight skin closure.
  - Tension-free scalp closure is also essential, but replacement of multiple skull fragments in an attempt to reconstruct the skull defect is not appropriate if other options for reconstruction are available.
    - Excellent results can be achieved with cranioplasty after evacuation from theater and a sufficient delay to minimize risk of infection.
- An expansion duraplasty should always be performed. A commercial dural substitute may be available; otherwise, pericranium, temporalis fascia, or tensor fascia lata may be used. There is no need to perform a water-tight dural repair.
- Tack-up sutures should be placed around the periphery (no central tack-ups in the absence of a bone flap) of the dural exposure to close the dead space and discourage postoperative epidural hematoma formation.
- The galea of the scalp should be closed separately with an absorbable suture and staples used to close the skin.
  - A single layer closure with heavy monofilament nylon is acceptable, but should definitely include the galea, with the sutures remaining in place for at least 14 days.
  - A subgaleal or epidural drain should be used at the discretion of the surgeon.
- Apply a noncompressive dressing using roller bandages around the entire head.
- Obtain a postoperative CT scan.

Note: Injuries that include the frontal sinus, anterior skull base, and orbital roof should undergo early repair, which includes frontal sinus exenteration; cranialization of the frontal sinus; obstruction of the nasofrontal duct; and a multilayer closure with pericranium, fat, fascia, and autologous split-thickness bone.

Evacuation of the Head-Injured Patient

- A postoperative craniotomy/craniectomy patient should ideally first be observed for 12–24 hours prior to transport. Evacuating immediately may lead to the inability to treat delayed, postoperative hematomas that may occur.
  - All patients with a GCS score of ≤12 are likely to benefit from intubation prior to evacuation.
  - Patients with a GCS score of ≤8T or patients who cannot be awakened en route by the transport team (each hour) will require ICP monitoring.
  - Arterial catheterization is necessary in patients where CPP monitoring is critical.
  - Patients with intracranial pathology should be neurosurgically "optimized" on the ground prior to departure (eg, placement of a ventriculostomy, wide craniectomy, or evacuation of a hematoma).
  - The ICP monitor should be placed, position confirmed, secured, and working prior to departure. A ventriculostomy gives the transport team the therapeutic option of cerebrospinal fluid drainage for an elevated ICP.
  - The critical care evacuation team must be confident in its ability to medically treat increased ICP, treat related complications (eg, diabetes insipidus with DDAVP [Desmopressin]; hyperthermia; and seizure), and troubleshoot the ventriculostomy.
  - In addition to all standard preevacuation preparation (see Chapter 4, Aeromedical Evacuation):
    - Drain the ventriculostomy; avoid laying it down flat because the vent filter may become moist and lead to an "air-lock." Venting the tubing filter can be performed with a clean 21-gauge needle, if needed.

- If a head-injured patient deteriorates in flight and is not already intubated, intubation should be considered.
- Medical management of ICP in flight should follow the same algorithm as previously described; however, repeat CT scanning or return to the operating room are no longer an option.
- Loading a patient head-of-bed toward the front of the aircraft limits the effect of takeoff and a "nose up" attitude of the aircraft while in flight (3% in the C-17) on ICP.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 16

Thoracic Injuries

Introduction

About 15% of war injuries involve the torso. Those injuries involving the vasculature of the mediastinum (heart, great vessels, and pulmonary hilum) are generally fatal on the battlefield. The vast majority of injuries of the lung parenchyma are managed by the insertion of a chest tube and local wound care. Although penetrating injuries are more common, blunt chest trauma does occur and may result in disruption of the thoracic contents and injury to the chest wall itself. Blast injuries can result in the rupture of air-filled structures (the lung), as well as penetrating injuries from fragments.

The immediate recognition and treatment of tension pneumothorax is an important lifesaving intervention in the treatment of chest injuries in combat. Distended neck veins, tracheal shift, decreased breath sounds, hyperresonance in the affected hemithorax, and hypotension are the cardinal signs, BUT may not be readily evident in the presence of other injuries/hypotension/hypovolemia. Immediate decompression is lifesaving.

The protection afforded by body armor greatly reduces the incidence of thoracic injuries, compared with extremity or head/neck injuries. Unfortunately, not all individuals have such protection; some tactical situations limit the use of body armor and some service members sustain chest injuries despite protection. Furthermore, military surgeons routinely treat injured civilians who generally have no such protection.

Anatomical Considerations

- Superior border of the thorax is at the level of the clavicles anteriorly and the junction of the C7–T1 vertebral bodies posteriorly. The thoracic inlet at that level contains major arteries (common carotids and vertebrals), veins (anterior and internal jugulars), trachea, esophagus, and spinal cord.
- Within or traversing the thoracic cavity itself are the heart; the great vessels (aortic arch, innominate/right subclavian/common carotid, left common carotid, left subclavian, and descending aorta); veins (superior and inferior vena cava, azygous vein, and brachiocephalic vein); and pulmonary arteries and veins (distal trachea, main stem bronchi, lungs, and esophagus).
- The inferior border is bounded by the diaphragm, attached anteriorly at the T6 level and gradually sloping posteriorly to the T12 level.

Penetrating thoracic injuries below the T4 level (nipple line) mandate evaluation for abdominal injuries due to the variable position of the diaphragm during the respiratory cycle (Fig. 16-1).

Evaluation and Diagnosis

Knowledge of the mechanism of injury (eg, blast, fragment) may increase the index of suspicion for a particular injury. A complete and accurate diagnosis is often not possible due to limited diagnostic tools. Nonetheless, injuries to the chest can profoundly affect breathing and circulation, and a complete and rapid assessment of each injury is mandatory.

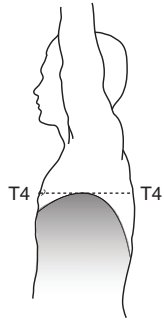

Fig. 16-1. Diaphragm level.

- If the casualty is able to talk without hoarseness or stridor, there is reasonable assurance that the airway is intact.

Life-Threatening Injuries

Injuries requiring urgent intervention include tension pneumothorax, massive hemothorax, cardiac tamponade, and open pneumothorax. Flail chest is not immediately life-threatening in most cases, but can present with a severe associated lung injury.

- **Tension pneumothorax.**
  - A patient with a known chest injury presenting with a patent airway and difficulty breathing has a tension pneumothorax until proven otherwise. It requires rapid decompression and the insertion of a chest tube. Needle decompression alone is insufficient.
- **Massive hemothorax.**
  - The return of blood on chest tube placement may indicate a significant intrathoracic injury. Generally, the **immediate return of 1,500 mL of blood mandates thoracotomy**. When initial blood loss is <1,500 mL, but bleeding continues such that ongoing blood transfusions are required and all other sources of hemorrhage are eliminated, then thoracotomy may be indicated. Needle decompression will not identify hemothorax.
  - Casualties with massive thoracic hemorrhage require damage control resuscitation and rapid surgical intervention (see Chapter 12, Damage Control Surgery).
  - Chest tube output is not always reliable because tubes may kink or become occluded from clot. In the setting of persistent hypotension after chest tube placement for hemothorax, you should not hesitate to place a second chest tube (in addition to evaluating for other sources of bleeding, such as intrapericardial, intraabdominal, or in the contralateral pleural space).
- **Cardiac tamponade.**
  - Distended neck veins (may be absent with significant blood loss) in the presence of clear breath sounds and hypotension indicate the possibility of life-threatening cardiac tamponade.

- This diagnosis must be suspected in any hypotensive patient with an injury to the chest.
- Judicious fluid resuscitation may temporarily stabilize a patient in tamponade.
- Perform an ultrasound if time permits and/or if the diagnosis is unclear.
  - If **positive,** proceed to the OR. For a stable patient, perform a subxiphoid pericardial window, with conversion to sternotomy if any blood is present in the pericardial space. For a patient with instability and isolated chest trauma, sternotomy or left anterolateral thoracotomy is appropriate (see below). With combined abdominal and chest trauma and instability/hypotension, a pericardial window can be performed in combination with exploratory laparotomy (with the addition of a sternotomy if blood is encountered in the pericardial space).
  - A **negative** ultrasound but persistent clinical suspicion for tamponade mandates either repeat ultrasound or pericardial window, depending on the level of clinical suspicion.
- Pericardiocentesis is not recommended for cardiac trauma.

- **Open pneumothorax occurs when a defect in the chest wall is sufficiently large to impair effective air exchange (generally larger than 2/3 the tracheal diameter).** It is treated by placing a chest tube through a separate incision and sealing the hole. Alternatives include one-way valve chest dressings or a square piece of plastic dressing taped to the chest on three sides as a "flap valve."
- **Flail chest** (entire segment of the chest wall floating due to fractures of a block of ribs, with at least two fractures on each rib) is commonly associated with pulmonary contusion under the flail segment. Patients with flail chest should be monitored closely for respiratory distress. Pain control is essential and may require intercostal nerve blocks or epidural catheters to optimize pulmonary mechanics. Patients with evidence of respiratory distress, poor or marginal oxygenation or ventilation should be intubated and mechanically ventilated prior to air evacuation. If an ipsilateral chest tube is not already in place, one should be placed before transport.

Surgical Management

Most penetrating chest injuries reaching medical attention are adequately treated with tube thoracostomy (chest tube) alone.

Tube Thoracostomy (Chest Tube)

- Indications.
  - Known or suspected pneumothorax.
  - Hemothorax.
- Procedure (Fig. 16-2).
  - In cases of tension pneumothorax, **immediate decompression with a large bore needle may be lifesaving**. An IV catheter (14 gauge, 3.25 inches in length) is inserted in the mid-clavicular line in the second interspace (approximately 2 fingerbreadths below the clavicle on the adult male). **Do not place medial to the nipple to avoid cardiac or vascular injury.** Entry is confirmed by the sound of air passing through the catheter, if a pneumothorax was actually present. **Needle decompression is a temporizing measure**, and is always followed by the immediate insertion of a chest tube (regardless of whether needle compression results in a rush of air or clinical improvement).
  - Although some providers advocate placing the patient's ipsilateral arm above the head to increase the room between ribs for chest tube placement, this is not mandatory, and is generally not practical for a combat injured patient. Instead, the arm can be placed at the patient's side on a rolled sheet/towel, in an extended position at the elbow, but slightly flexed at the shoulder to allow adequate chest wall access.
  - If time allows, prep the anterior and lateral chest on the affected side.
  - Identify the incision site along the anterior axillary line, at approximately the 5th or 6th rib. This is at nipple level in males and at the inframammary crease in women. If rib levels are difficult to determine, err on the high side to avoid abdominal entry.
  - Inject a local anesthetic at the skin and muscle level in an awake patient, if conditions allow.

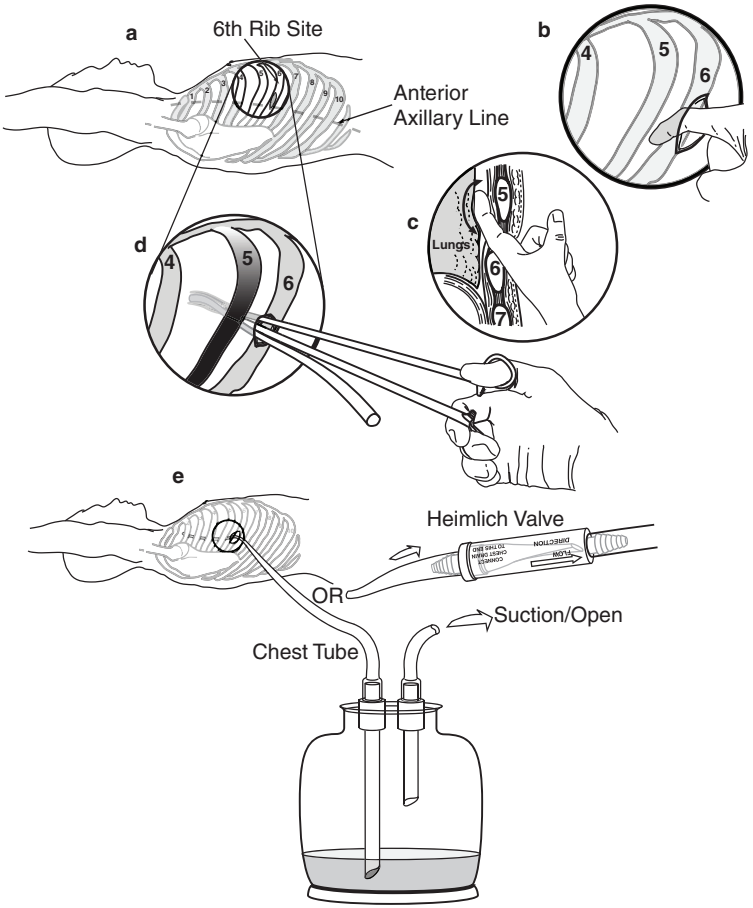

Fig. 16-2. Procedure for tube thoracostomy. Numbers indicate rib sites.

- Make a transverse incision, 3–4 cm in length, along and centered over the rib, carrying it down to the bone (Fig. 16-2a).
- Insert a curved clamp in the incision, and spread several times with a clamp to bluntly mobilize overlying chest wall muscle. Then direct a clamp over the top of the rib, and push into the chest through the pleura. A distinct pop is encountered when entering the chest, and a moderate

amount of force is necessary to achieve this entry. A rush of air or blood out of the chest will confirm a pneumothorax or hemothorax, respectively. Insertion depth of the tip of the clamp should be limited by the surgeon's hand to only 3 or 4 cm to make sure that the clamp does not travel deeper into the chest, resulting in damage to underlying structures.
  - Spread the clamp gently with the tips at the level of the ribs and remove. The operator's finger is then inserted to confirm entry (Fig. 16-2b,c).
  - Insert a chest tube (24–36 Fr gauge) into the hole, directing it posteriorly and apically. All chest tube side holes must be in the pleural space (ie, not just below skin level).
  - Attach a chest tube to a Heimlich valve, standardized closed drainage system, or bottles. In a resource-constrained environment, a cutoff glove with a slit in the end or a Penrose drain may be attached to the end of the chest tube (Fig. 16-2e). Although these are only temporizing measures for chest tube drainage, they should serve as a one-way valve to prevent tension pneumothorax.
  - Secure the tube with sutures, if possible, and dress to prevent contamination.

Resuscitative Thoracotomy

- **Indications**
  - Penetrating injury and loss of vital signs after arrival to facility (or within minutes of arrival) with ongoing CPR.
  - Patient with penetrating injury in extremis (**signs of life but impending loss of vital signs**).
  - **No role in blunt trauma or with isolated head injury.**
  - **Only appropriate in a facility with bona fide surgical capability (Role 2 or above)**, and must always be preceded by careful consideration of available resources and the effects of this resource-intensive procedure on the care of other casualties (or the risk of injury to assistants). Generally **not appropriate in a mass casualty scenario**.
  - Should be accompanied by endotracheal intubation, initiation of damage control resuscitation, placement of an oro/naso-gastric tube, and adequate IV or IO access.

- **Procedure**
  - With the patient supine and the ipsilateral arm flexed at the shoulder to expose the chest wall, make an incision in the left inframammary fold starting at the lateral border of the sternum and extending to the table. Following the line of the ribs, the incision should be curved in a cephalad direction in its posterior extent (Fig. 16-3).

Fig. 16-3. Incision for resuscitative thoracotomy.

  - The procedure should be abandoned upon discovery of devastating injuries to the heart and great vessels.
  - An immediate right chest thoracostomy should be performed concurrently. If bleeding is identified from the right chest, a rapid extension through the sternum with a Lebsche knife or sternal saw should ensue, thus performing a "clamshell" thoracotomy. The clamshell approach will provide wide access to the mediastinum and both pleural spaces. In the course of this procedure, both internal mammary arteries are divided, which will be a significant source of bleeding that must be controlled with clips, ties, or suture. Bleeding may not be immediately evident, but may be profuse after restoration of arterial perfusion.
- Quick identification and treatment of a penetrating cardiac injury probably provides the highest chance of salvage. After thoracotomy, place a large rib-spreading retractor, pack the lung posteriorly, and open the pericardium to assess the heart. Use an anterior longitudinal incision in the pericardium to avoid phrenic nerve injury. The phrenic nerve may be difficult to identify during a resuscitative thoracotomy, but generally runs 1–3 cm anterior to the hilum of the lung and is always accompanied by blood vessels (which are often more visible than the adjacent nerve).

- **Priorities after thoracotomy are to control bleeding and restore central perfusion.**
  - Lacerations in the heart and/or great vessels should be temporarily occluded.
    - Temporary occlusion of cardiac injuries can be achieved with fingers, Foley catheters with 30-mL balloons, or any other sterile device of opportunity. A finger is usually sufficient, and less traumatic.
    - Temporary occlusion of the great vessels can be addressed with side-biting clamps or manual pressure.
  - If there is no blood in the pericardium or obvious cardiac injury but cardiac activity appears reduced (or if the heart is fibrillating), two-handed open cardiac massage can be instituted to facilitate resuscitation. If there is cardiac standstill, it is unlikely that the patient has a survivable injury.
  - The hilum of the lung should be cross-clamped en masse for suspected air embolism or major pulmonary hilar injuries.
  - In the case of penetrating injury and suspected uncontrolled bleeding below the diaphragm, the distal thoracic aorta should be cross-clamped. Clamping the aorta is facilitated by placing an orogastric tube to palpate and avoid clamping the adjacent esophagus, and by sharply or bluntly opening the mediastinal pleural anterior and posterior to the distal thoracic aorta just above the diaphragm to allow secure placement of an atraumatic vascular clamp. This temporizing measure will allow for resuscitation (including open cardiac massage if necessary) until definitive control of bleeding via laparotomy or other appropriate measures. Once bleeding is controlled, you must be prepared for transient acidosis, hyperkalemia, and significant hemodynamic shifts after clamp removal.
  - If unable to restore cardiac function rapidly, abandon the operation.
- With successful restoration of cardiac function, injuries should be more definitively repaired in the OR.

Subxiphoid Pericardial Window

Subxiphoid pericardial window should not be attempted in an unstable patient. Unstable patients with penetrating injuries suspicious for cardiac injury should undergo immediate median sternotomy/anterolateral thoracotomy.

Procedure

- With the patient supine, make a 4–5 cm longitudinal midline incision just on and below the xiphoid process through the skin and fascia. The xiphoid process can then be grasped/lifted with a Kocher clamp to access the pericardium, or it can be excised (with a heavy scissor or with electrocautery).
- Bluntly dissect superiorly toward the heart, exposing the phrenopericardial membrane below the heart.
- Sharply incise pericardium with care to avoid the heart, opening the pericardial sac, and exposing the underlying beating heart.
- Presence of pericardial blood mandates sternotomy to assess/repair cardiac injury.

Median Sternotomy

- Indications.
  - Suspected cardiac injury.
  - Positive pericardiocentesis/subxiphoid pericardial window.
  - Suspected injury to the great vessels in the chest.
  - Sternotomy does not afford adequate access to the left subclavian artery or descending thoracic aorta (both better accessed via left thoracotomy).
  - Suspected distal tracheal injury.
- Procedure.
  - In the supine position, make a midline skin incision from the sternal notch to just below the xiphoid.
  - Score the sternum with Bovie from the mid-portion of the sternal notch to the xiphoid to aid in creating a midline sternotomy.
  - Through blunt dissection, develop a substernal plane such that a finger can hook under the sternal notch superiorly, and under the xiphoid inferiorly.

- Divide the sternum in the midline with a sternal saw or Lebsche knife. Bone wax or Gelfoam can be used to decrease bleeding on the cut edges of the marrow, and cautery should be used to control bleeding from the sternal periosteal edges.
- Separate the halves of the sternum using a chest retractor.

- Once the retractor is placed, divide the thymic remnant and mediastinal fat down to the shiny whitish pericardium, from the level of the diaphragm up to the innominate vein, which runs transversely at the superior border of the sternotomy field. This structure must be carefully preserved to avoid significant bleeding. For great vessel access, isolating the innominate vein with a vessel loop will aid in exposure.
- Elevate the pericardium with forceps, make a small rent in it, then open the rest in the midline over a finger. Begin caudally, teeing off the pericardium along the diaphragm on both sides. Superiorly, open up to the pericardial reflection along the front of the ascending aorta.
- Place stay sutures ("pericardials") along the edge of either side of the pericardium, which should be snapped to the drapes or skin outside the incision under a fair bit of tension. Usually 2 or 3 on either side are adequate, and any suture (3-0 or bigger) will work fine.
- **Pericardial sutures are critical for exposure**; they will keep the ventilating lungs out of your field, and will help retract the heart/great vessels closer to you.

In general, exposure to the heart and great vessels is best achieved through a median sternotomy. For proximal left subclavian artery injuries, additional exposure (trap door) may be necessary.

- See below for the management of injuries within the pericardium.
- Prior to closing the sternum, place one or two mediastinal tubes for drainage, exiting through a midline stab wound inferior to the mediastinal skin incision.
- A sternotomy is closed with a series of interrupted wire sutures directly through the halves of the sternum,

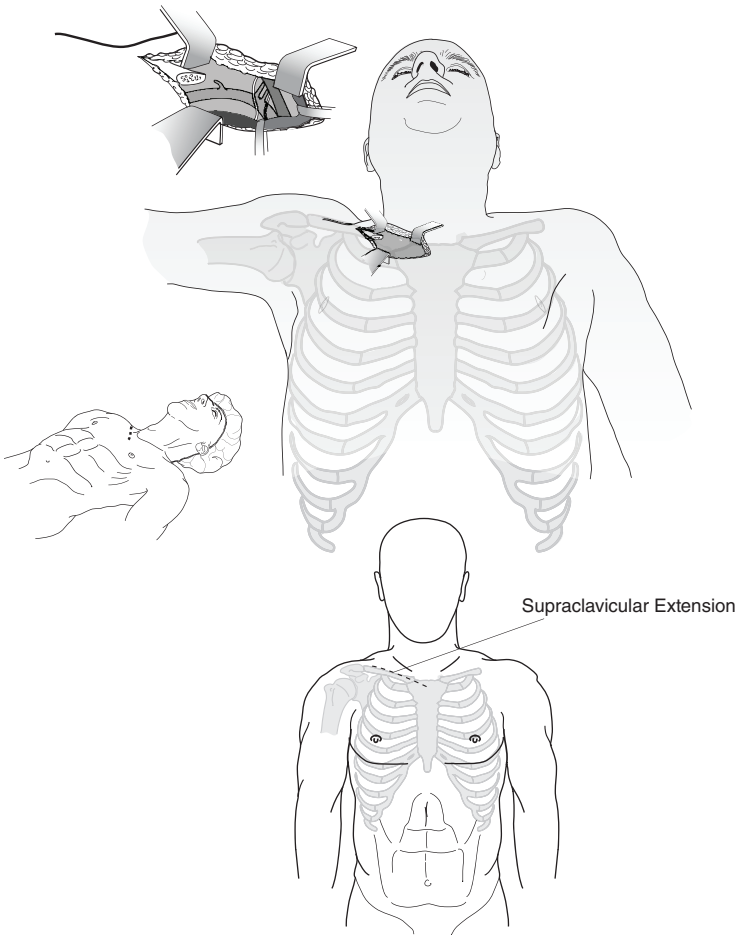

Fig. 16-4. Supraclavicular approach.

approximately 2 cm from the edge, or around the sternum through the costal interspaces. Large, permanent sutures can be used if wire is unavailable.

- In a damage control setting (unstable patient, ongoing resuscitation), temporary chest closure is appropriate. A laparotomy pad (or negative pressure dressing) can be placed beneath the edges of both sides of the sternum (to

avoid laceration of the heart from movement). An occlusive adherent dressing is then placed, and the chest tubes are placed to suction and evacuate any residual bleeding.

Other Approaches

- **Supraclavicular** (Fig. 16-4)**.**
  - Indication.
    - Mid- to distal subclavian artery injury.
  - Procedure.
    - Make an incision 2 cm above and parallel to the clavicle, beginning at the sternal notch and extending laterally 8 cm. The subclavian vein will be anterior and caudal to the artery.
    - For complex injuries, division of the clavicle (with a Gigli saw) or removal of part of the clavicle may facilitate additional exposure.
- **Trap door** (Fig. 16-5)**.**
  - Indication.
    - Proximal left subclavian artery injury.
  - Procedure.
    - Perform a left supraclavicular approach as previously described.
    - Perform a partial median sternotomy to the 4th intercostal space.
    - At the 4th intercostal interspace, incise the skin laterally in the submammary fold to the anterior axillary line.
    - Divide the sternum laterally with sternal saw or a Lebsche knife, be prepared to divide and control the left internal mammary vessels, and continue in the 4th intercostal space to the anterior axillary line.
    - It may be necessary to either divide or remove a section of the clavicle to gain adequate exposure of the proximal left subclavian artery.
    - Approach distal left subclavian artery injuries through a supraclavicular incision.
- **Thoracoabdominal.**
  - Indication.
    - Combined thoracic and abdominal injuries.
  - Procedure.

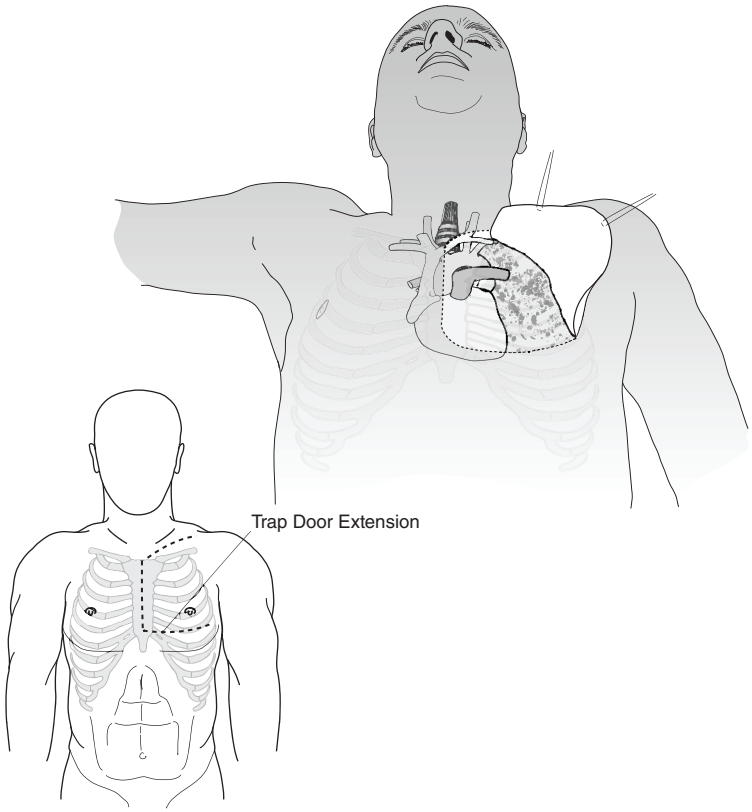

Fig. 16-5. Trap door procedure.

- The resuscitative thoracotomy can be continued medially and inferiorly across the costal margin into the abdominal midline to complete a thoracoabdominal incision.
- Alternatively, a separate abdominal incision can be made.
- With right-sided lower chest injuries, the liver and retrohepatic vena cava can be exposed well using a right thoracoabdominal approach.

Specific Injuries

- **Vascular.**

- Initially, holes in vessels should be controlled with a fingertip if possible. Provisional measures include placing Fogarty or Foley catheters, side-biting clamps, or—in the case of venous injuries—sponge sticks.
- Temporary proximal and distal control may be necessary to allow for resuscitation and restoration of cardiac function.
- If cardiac function cannot be restored within 5 to 10 minutes, the procedure should be abandoned (on-the-table triage) and the patient managed expectantly.
- Repair of vessels should follow the principles detailed in Chapter 25 (Vascular Injuries), with shunting or repair by autogenous or synthetic grafts as indicated.

- **Heart.**

Generally, high-velocity injuries to the heart result in irreparable destruction of the muscle.

- Isolated injuries to the heart should be exposed (after opening the pericardium and placing pericardial stay sutures), and occluded initially by finger pressure. Other temporizing methods include the use of a Foley catheter or skin staples.
- Use pledgeted horizontal mattress sutures (2-0 PROLENE) on a large, tapered needle (MH or SH) for definitive repair. **Care must be taken to avoid additional injury to coronary vessels** or tearing cardiac muscle. Autologous pericardium can be used if commercial pledgets are not available (Fig. 16-6).
- Atrial repairs may include simple ligature, stapled repair, or running closures.
- Temporary inflow occlusion (occluding the superior and inferior vena cave) may prove helpful in repair.
- More complex repairs are impractical without cardiac bypass.

- **Lung.**
  - **Tube thoracostomy alone is adequate treatment for most simple lung parenchymal injuries.**
  - **Large air leaks not responding to chest tubes** or that do not allow adequate ventilation will require open repair (see section on "Tracheobronchial Tree").

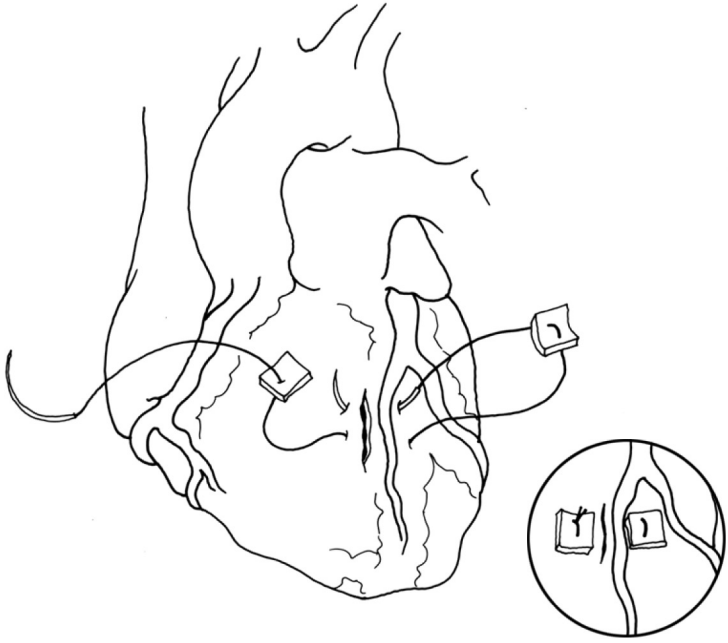

Fig. 16-6. Repair of penetrating cardiac injury.

- **Posterolateral thoracotomy is preferred for isolated lung injuries, but is only appropriate in a stable patient with adequate resuscitation and no other uncontrolled injuries.** Anterior thoracotomy may also be used, and provides for greater flexibility.
- Control simple bleeding with absorbable suture on a tapered needle. Alternatively, staples (eg, GIA or TA-90) may be used for bleeding lung tears.
- **Tractotomy**: Open any bleeding tracts (through-and-through lung penetrations) with a GIA stapler or between straight vascular clamps and ligate bleeding points.

Do not simply close the entrance and exit points of penetrating tracts in the lung. With positive pressure ventilation, the risk is air embolism. The more central the injury, the higher the risk.

- Resection for bleeding may be indicated with severe parenchymal injury. Anatomical resections are not indicated, and simple stapled wedge excisions are recommended.
- Uncontrolled parenchymal/hilar bleeding, or complex hilar injuries with massive air leak, should be controlled with hilar clamping and subsequent repair. Pneumonectomy is performed as a last resort, because survival with this procedure in the context of traumatic injury is very low.

- **Tracheobronchial tree.**
  - Suspect the diagnosis with massive air leak, frothy hemoptysis, pneumomediastinum, or sudden hypotension/arrest after intubation and initiation of positive pressure ventilation.
  - Confirm by bronchoscopy (if available).
  - Airway control is paramount. If after endotracheal intubation in a patient with a suspected airway injury, there is no large air leak, ventilation appears adequate, and there is no other surgical indication, further intervention should be deferred to a higher level of care where more diagnostic and therapeutic resources are available.
  - Median sternotomy is the best approach for injuries to the mid trachea, with right thoracotomy providing more optimal access to the distal trachea and carina. Injuries to the left mainstem bronchus generally require left thoracotomy for repair.
  - Repair over endotracheal tube with absorbable suture. Bolster with pleural or intercostal muscle flap, especially between the trachea and esophagus.
  - Temporizing measures include:
    - Single lung ventilation (although double-lumen endotracheal tube placement is not indicated in a combat trauma setting). In some cases, intentional mainstem intubation or the use of a large Fogarty catheter as a "bronchial blocker" may isolate a major ipsilateral airway injury.
    - Control the airway through the defect (for cervical tracheal injury).

- **Esophagus.**
  - Isolated thoracic esophageal injuries are exceedingly rare. Esophageal injury will usually be diagnosed incidentally associated with other intrathoracic injuries.
  - Diagnostic clues include pain, fever, leukocytosis, cervical emphysema, or chest X-ray evidence of pneumothorax, mediastinal air, or pleural effusion.
  - Start IV antibiotics as soon as the diagnosis is suspected. This is an adjunctive measure only. **Drainage and control of contamination of the mediastinum and pleural space are paramount.**
  - For stable patients in a forward location, chest tube drainage and a nasogastric tube placed above the level of injury are temporizing measures. Ideally, primary repair is performed within 24 hours of injury. Primary repair can be more challenging (or even impossible) after this interval.

The preferred approach for intrathoracic esophageal injuries in a stable patient is posterolateral thoracotomy: right side for the upper esophagus, and left side for the lower esophagus.

  - Locate the injury by mobilizing the esophagus (ideally aided by placement of a nasogastric or orogastric tube). Primarily repair with a single layer or two layers of 3-0 absorbable sutures and buttress with pleural or intercostal muscle flap.
  - Drainage with chest tubes (one apical, one posterior) is recommended.
  - If repair is not feasible or if you are uncomfortable with esophageal mobilization and repair, most patients can be temporized with (1) wide drainage of the pleural space and mediastinum, (2) careful placement of a nasogastric tube, and (3) the initiation of broad spectrum antibiotics and fluid resuscitation. The patient can subsequently be evacuated to a higher level of care.
- Diaphragm.
  - All injuries of the diaphragm should be closed. Generally, penetrating injuries to the diaphragm are identified

during exploratory laparotomy. If identified at the time of thoracotomy, you must evaluate for associated intra-abdominal injury.
    - ♦ Lacerations should be reapproximated with nonabsorbable 0 or 2-0 running or interrupted sutures.
  - o If there is significant contamination of the pleural space by associated enteral injuries, copious irrigation and placement of one or more pleural drains is indicated after diaphragm repair.
- **Chest Wall.**
  - o Because the intercostal arteries are direct branches of the thoracic aorta or internal mammary artery, chest wall injuries can be associated with major hemorrhage, which may or may not abate with chest tube placement alone.
  - o If bleeding exceeds 1.5 L after tube thoracostomy, persists at over 100–200 mL/hour, or is associated with persistent hemodynamic effects, thoracotomy is indicated to address the chest wall bleeding and to assess for underlying pulmonary or major thoracic vascular injury. In practice, it is difficult to discern the exact source of thoracic bleeding (lung versus chest wall versus great vessels, etc) until after thoracotomy.
  - o Intercostal arterial bleeding may be controlled with sutures or clips. One option is a figure-of-eight suture around the rib and intercostal bundle, with a blunt needle and suture 2-0 or larger. Temporarily holding ventilation will aid in exposure and repair. In general, separate repair will be needed on both sides of the injured vascular pedicle.
  - o Access and visualization to chest wall bleeding may require enlarging an incision, or making a separate counter-incision to improve the angle of approach.
  - o If repair of chest wall bleeding is not successful or not possible (eg, chest wall bleeding posterior to hilum, not well visualized without lung isolation), packing the chest will temporize the vast majority of bleeding. This should be followed by temporary chest closure, continued resuscitation, and transfer to a higher level of care once the patient is stable for transport.

For Clinical Practice Guidelines, go to
http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 17

Abdominal Injuries

Introduction

Changing patterns of warfare coupled with improvements in protective body armor have combined synergistically to decrease truncal and abdominal trauma in contrast to previous conflicts. Despite the many advances in protective body armor, penetrating abdominal trauma remains an inevitable component of war surgery. Rapid recognition and treatment of intraabdominal injuries are necessary to ensure maximal survival with the minimum amount of morbidity.

Trauma to the abdomen, both blunt and penetrating, can lead to occult injury that can be devastating or fatal if not recognized and treated in a timely manner. In an unstable patient who presents with an abdominal injury, the decision to operate is usually straightforward. In this circumstance, exploratory laparotomy should be performed as soon as the diagnosis is made. In a few rapidly hemorrhaging patients with thoracoabdominal injuries, a rapid decision must be made as to which cavity to enter first. This chapter addresses some of these issues.

Penetrating injuries below the nipples, above the symphysis pubis, and between the posterior axillary lines must be treated as injuries to the abdomen and mandate further workup and/or exploratory laparotomy.

- Posterior truncal penetrating injuries from the tip of the scapula to the sacrum may also cause retroperitoneal and/or intraabdominal injuries. A low threshold for exploratory laparotomy in these patients is warranted when limited diagnostic modalities are available.

Diagnosis of Abdominal Injury

- Document a focused history including time of injury, mechanism of injury, previous treatments employed, and any drugs administered.
- Inspection of the fully exposed chest, abdomen, and back will be the most reliable part of the physical examination, especially regarding penetrating injuries.
- The most important determination is whether or not a patient requires urgent laparotomy. Do not focus on making a specific diagnosis.

Indications for Laparotomy

The most important decision is to determine **who** needs surgery.

- Patients who mandate expeditious abdominal exploration are patients with the following signs and symptoms:
  - Physiological instability on presentation with an obvious penetrating abdominal injury.
  - Penetrating abdominal wounds in the zones as described above when no means to exclude an intraabdominal injury are available (eg, CT scan).
  - Other penetrating truncal injuries with potential for peritoneal penetration and clinical signs/symptoms of intraperitoneal injury.
  - Physiological instability with potential for blunt abdominal injuries.
- When aeromedical evacuation is uncertain or will involve substantial distance, unstable patients with life- or limb-threatening circumstances should undergo laparotomy at the nearest facility that can provide surgical care.
- Laparotomy may be delayed if necessary, depending on the operational situation. These circumstances can be generally managed by the following guidelines:
  - Stable patients with intraperitoneal injury and no signs of shock can be managed nonoperatively for several hours.
  - Initiate resuscitation.
  - Start broad-spectrum antibiotics.
  - Arrange for transport as soon as possible to the next higher role of care.

When the tactical situation permits, aeromedical evacuation is effective, and the distance between Role 2 (Forward Surgical Team) and Role 3 (Combat Support Hospital) or higher level hospitals is short, all critically ill casualties should be medically regulated to the higher role when possible.

Diagnostic Adjuncts

Nonoperative adjuncts to diagnosing intraabdominal injuries—such as CT scan, ultrasound (US), and diagnostic peritoneal aspiration (DPA)—have been used to decrease the negative laparotomy rate in stable patients with blunt abdominal trauma. Some of the aforementioned modalities have been used in lieu of laparotomy to evaluate patients with penetrating injuries when the clinical suspicion is low for an intraabdominal injury. The practice of nonoperative management of penetrating abdominal trauma and reliance on diagnostic modalities to rule out intraabdominal injury have the potential for missing injuries, particularly in the resource-constrained environment with limited diagnostic modalities. The use of CT, DPA, and US in penetrating abdominal trauma should be reserved for stable patients with a mechanism of injury suggesting intraabdominal injury, but who lack obvious operative indication. These diagnostic modalities should be relied on only when good follow-up is possible and patients will not require long transports where rapid surgical intervention is not possible. US and DPA have some utility in unstable patients to help guide which cavity, thoracic or abdominal, should be entered first when planning operative strategy. US and DPA may also serve as triage tools in the mass casualty situation.

Focused Abdominal Sonography for Trauma (FAST)

- Has become an extension of the physical examination of the abdomen, and should be performed whenever indicated and available in the setting of an abdominal injury.
- SonoSite is the current standard US military device used.
  - A 3.5–5 MHz curvilinear probe is optimal, but a phased array probe can be used as well.

- The abdomen is examined through four standard sonographic windows: right upper quadrant, subxiphoid, left upper quadrant, and suprapubic.
- Extended FAST (EFAST) allows identification of lung pathology.

Advantages:

- Noninvasive, may repeat frequently, quick, easy, identifies fluid in the abdomen reliably.
- Aids in prioritization of penetrating injury patients for the OR.
- Helps identify which cavity to open first in patients with thoracoabdominal injuries.
- Identifies pericardial fluid and may assist in the diagnosis of tamponade as well as hemopneumothorax.

Disadvantages:

- Operator-dependent, may miss small amounts of fluid and hollow viscus injuries.
- Assists the surgeon in determining the need for laparotomy in patients with blunt abdominal injury, but does little to identify specific injuries.
- **DOES NOT** identify or stage solid organ or hollow viscus injury.

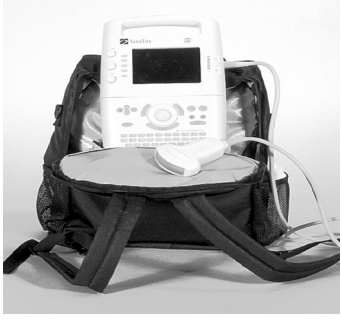

Fig. 17-1. Typical sonography device.
Courtesy of SonoSite, Inc, Bothell, WA.

FAST Views

A typical portable sonography device is shown in Fig. 17-1. The standard locations for "sonographic windows" are shown in Fig. 17-2. Examples of positive and negative sonographic examinations are shown in Figs. 17-3 through 17-6.

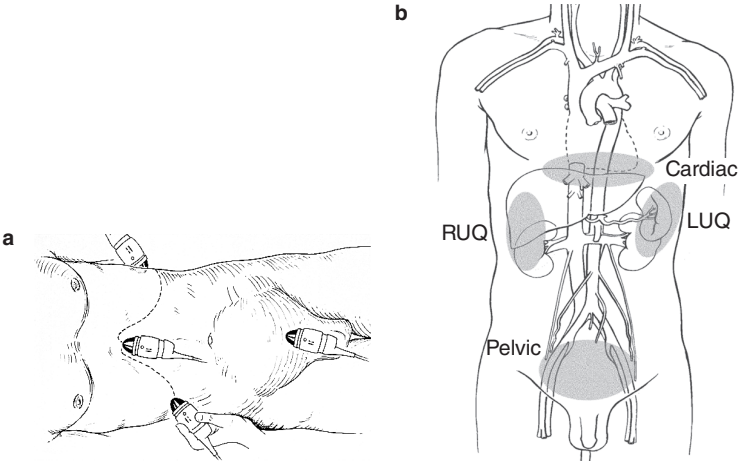

Fig. 17-2. The standard four locations for sonographic windows. (**a**) Subxiphoid. (**b**) Suprapubic. LUQ: left upper quadrant; RUQ: right upper quadrant.

Diagnostic Peritoneal Aspiration

Historically, diagnostic peritoneal lavage played a role in blunt abdominal trauma diagnosis; however, the utility of the lavage continues to decrease in the setting of improvements in both US skills and technology, coupled with the widespread use of CT scan. Far-forward combat medical units are not routinely outfitted with appropriate equipment, such as microscopic and laboratory functions that provide cell counts or fluid enzyme determinations. Thus, the only reliable information obtained from a lavage is the aspiration of gross blood or DPA.

Advantages:

- Quickly ascertain intraperitoneal blood.
- May help determine which body cavity to enter first in an unstable patient with truncal injury.

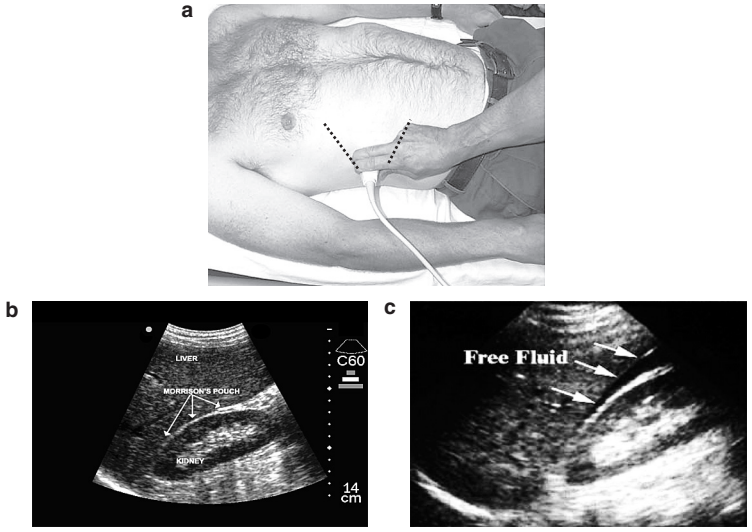

Fig. 17-3. (**a**) Right upper quadrant. (**b**) Normal and (**c**) abnormal negative sonographic examinations for the right upper quadrant.

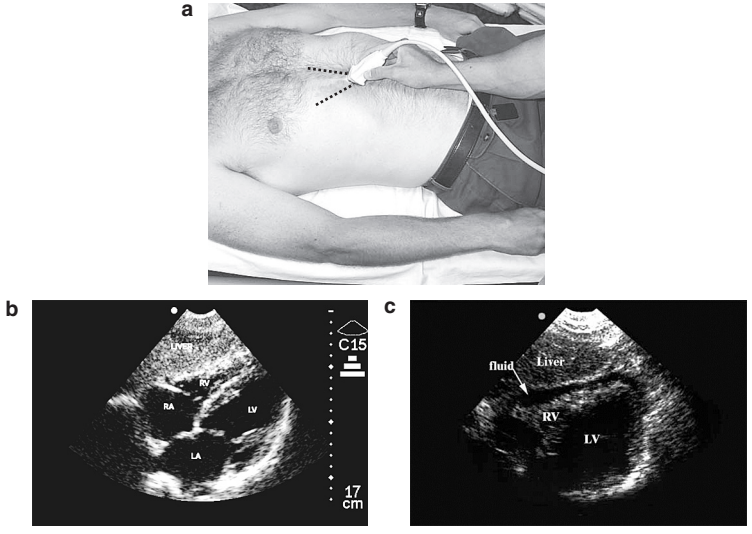

Fig. 17-4. (**a**) Subxiphoid. (**b**) Normal and (**c**) abnormal negative sonographic examinations for the cardiac window. LA: left atrium; LV: left ventricle; RA: right atrium; RV: right ventricle.

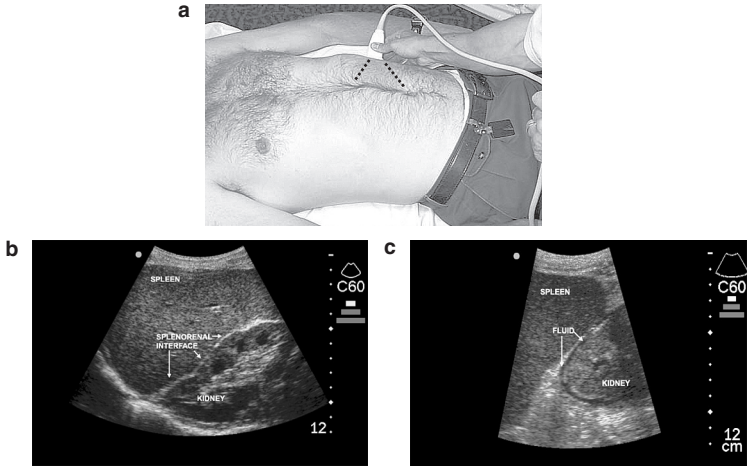

Fig. 17-5. (**a**) Left upper quadrant. (**b**) Normal and (**c**) abnormal negative sonographic examinations for the left upper quadrant.

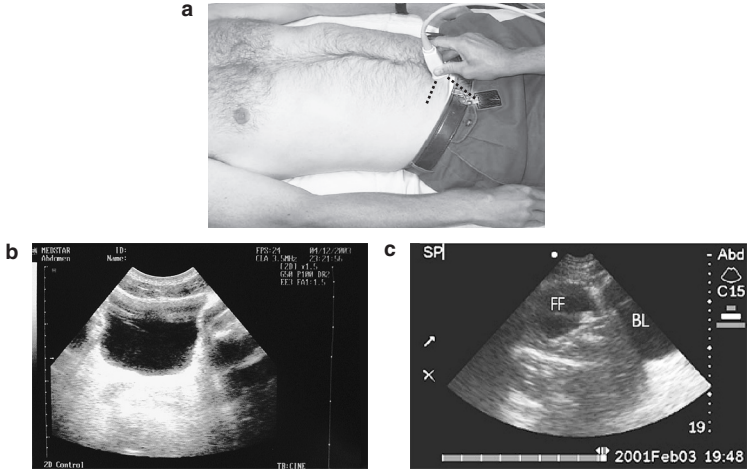

Fig. 17-6. (**a**) Suprapubic. (**b**) Normal and (**c**) abnormal negative sonographic examinations for the pelvic window. Abd: abdomen; BL: bladder; FF: free fluid.

Disadvantages:

- Invasive, often not reproducible, significantly slower than FAST.
- May be useful when US and/or CT are not available, or as triage tool.
- The following represent positive DPA:
  - Aspiration of 10 mL of gross blood.
  - Aspiration of enteric contents.
- DPA is **NOT** recommended for penetrating abdominal trauma.
- Basic technique:
  - Open technique using a small, vertical infraumbilical incision and any tubing (IV, Foley, straight, or balloon catheter).
  - Aspirate peritoneum.
  - A supraumbilical incision is recommended if a pelvic fracture is suspected.

CT Scan Advantages:

- Defines injured anatomy in stable patients and provides a modality that may prevent unnecessary laparotomy in appropriately selected patients.
- When available and in **STABLE** patients, CT scan may be useful for:
  - The workup of penetrating abdominal injuries where there is a question of whether or not the projectile traversed the peritoneal cavity.
  - The evaluation of isolated penetrating retroperitoneal and posterior injuries.
- When using CT scan to evaluate penetrating retroperitoneal injuries, the use of triple-contrast (oral, IV, and rectal contrast) remains important to rule out injuries.

Disadvantages:

- Slow.
- Requires contrast use and equipment availability.
- May miss small hollow organ injury.
- Requires transport away from the resuscitation area.
- Operator/interpreter-dependent.

There is NO ROLE for CT scan in the evaluation of an unstable patient with obvious abdominal trauma, regardless of the mechanism of injury.

Wound Exploration

- Blast injuries and improvised explosive devices create many fragments that may penetrate the skin but not the abdominal cavity. Operative local wound exploration in the stable patient with a normal or equivocal examination may help determine the need for formal exploratory laparotomy.
- When possible, wound exploration should be performed in the OR with adequate instruments and lighting.
- Finding of an isolated fragment in the abdominal wall superficial to the anterior fascia may obviate the need for formal laparotomy.
- If there is any doubt that the fragment penetrated the abdominal cavity (eg, the tract of the projectile is not adequately identified or the fragment cannot be seen on plain film radiograph), formal laparotomy should be performed.
- CT scan, when available and used as an adjunct to wound exploration, may also be helpful in determining the trajectory of fragments and help plan wound exploration.

Operative Planning and Exposure Techniques

- Administer broad-spectrum IV antibiotic prior to surgery and continue for 24 hours.
  - Redose short half-life antibiotics intraoperatively and consider redosing antibiotics with large amounts of blood loss.
- Laparotomy should be performed through a midline incision.
  - When wide exposure is needed, extend the incision superiorly just lateral to the xiphoid process and inferior to the symphysis pubis.
- Quickly pack all four quadrants with lap sponges while looking for obvious injuries.
- Control hemorrhage with packing or clamping of bleeding vessels.
- Once packed and hemorrhage controlled, assess physiological status.

- Considering casualty physiology, your current resources, and location, create an operative plan to control hemorrhage, contamination, and truncate the operation if necessary (ie, damage control).
- Attempt to limit initial exploratory laparotomy to <60 minutes.
- **ALWAYS** consider damage control principles throughout the procedure (see Chapter 12, Damage Control Surgery).
- If the patient is stable, consider definitive surgery. In general, definitive surgical procedures should be limited to procedures once the patient has been resuscitated and at a level of care with the greatest diagnostic and therapeutic resources available for patient care (ie, Role 3 facility).

- Identify all solid organ and hollow viscus injuries.
- Eviscerate the small bowel to increase workspace, if needed.
  - If needed, divide both the left and right triangular ligamentous attachments of the liver to improve exposure in the right upper quadrant or upper midline.
- Fold the left lateral segment of the liver down and to the right to improve exposure at the gastroesophageal junction.
- Improve exposure to the liver by extending the incision into the inferior sternum and/or across into the lower right chest (thoracoabdominal).

Gastric Injuries

- The stomach is a vascular organ and will do well after almost any repair.
- The entire stomach must be visualized.
  - When exploring the stomach, enter the lesser sac by dividing the gastrocolic ligament and reflecting the stomach up toward the head to evaluate for posterior wall injuries.
- Encircle the distal esophagus with a Penrose drain to provide traction and improve visibility for high midline injuries.
- Once all gastric injuries have been identified, minimally debride and primarily close stomach defects in 1 or 2 layers with permanent sutures.
- Place the nasogastric tube and confirm position with palpation.
  - Consider use of a large gastrostomy tube (a large Foley or Malecot may work if no gastrostomy tubes are available).

- It may be useful to have the nasogastric tube or gastrostomy tube irrigate postoperatively with 30 mL of saline every 2 hours to ensure that the tube does not become clogged.

Duodenal Injuries

Injuries to the duodenum are typically associated with massive upper abdominal trauma. Thus, early consideration for damage control surgery should be considered (see Chapter 12, Damage Control Surgery).

- Missed injuries of the duodenum have devastating morbidity.
- Bile staining or hematoma in the periduodenal tissues mandates full exploration of the duodenum (Kocher maneuver).
- Minor injuries can be primarily repaired in two layers and closed-suction drains (JP [Jackson-Pratt] drains) placed around the repair.

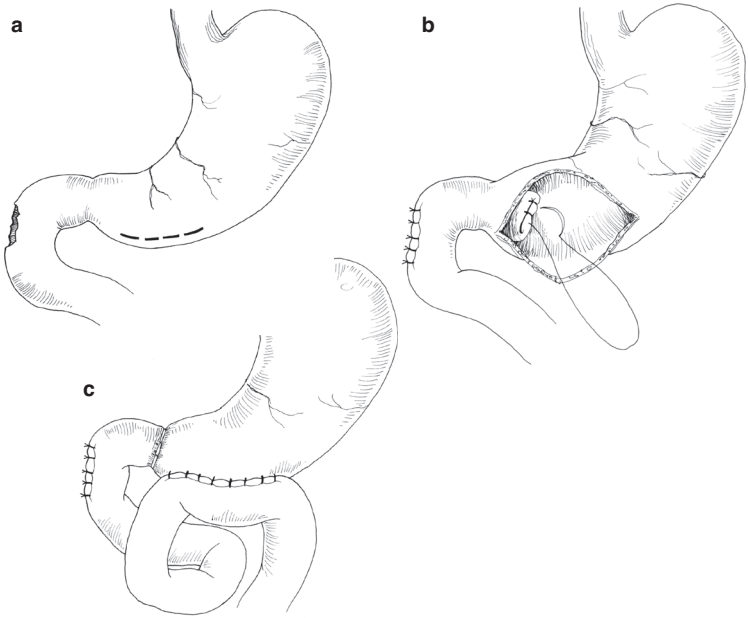

Fig. 17-7. (**a**) Pyloric exclusion. (**b**) Duodenal injury repair. (**c**) Gastrojejeunostomy.

- Major injuries should be primarily repaired if they do not involve the ampulla, and luminal diameter will not be narrowed by >50%.
- Options for closing injuries of >50%:
  - Close duodenal wall around a tube duodenostomy.
    - Use a no. 2-0 absorbable suture (VICRYL).
    - Use the largest Malecot catheter or drainage tube available.
- Perform a pyloric exclusion procedure.
  - Through a gastrotomy, ligate the pylorus with an absorbable suture or by using a noncutting TA stapling device. Staple but **do not divide** the pylorus.
  - Close the duodenal injury.
  - Create a gastrojejeunostomy anastomosis between the jejeunal limb and the gastrotomy (Fig. 17-7).
  - Remember to place a feeding jejunostomy for nutrition.
  - The procedure of **LAST RESORT** is pancreaticoduodenectomy. In the acute and damage control settings, there is NO role for reconstruction during the initial procedure in patients with traumatic pancreaticoduodenectomy.
- Duodenal injury caveats.
  - Widely drain all injuries with multiple closed-suction drains.
  - Any method used to close the pylorus will typically last only 14–21 days.
  - The possibility of injury to the biliary and pancreatic ducts should be considered when injuries involve the second portion of the duodenum or the pancreatic head.

Pancreatic Injuries

- Any injury to the pancreas/duct requires drainage.
- Even if ductal injury is not identified, it should be presumed and drained with **multiple** closed-suction drains.
  - Resect clearly nonviable pancreatic body/tail tissue.

Major injuries to the head of the pancreas may require pancreaticoduodenectomy. If pancreaticoduodenectomy is performed as part of damage control surgery, reconstruction should be delayed until the patient has been resuscitated. Consideration for reconstruction should be given if definitive surgery will take more than 72 hours from time of injury. If reconstruction is not possible, then wide drainage with multiple closed-suction drains should be used and the patient's abdomen left open to facilitate reconstruction.

- Transection or near-transection of the pancreatic duct can be treated by:
  - Drainage.
  - Distal pancreatectomy (typically requires splenectomy).

Liver Injuries

- Most liver injuries can be successfully treated with direct pressure and/or packing, followed by aggressive resuscitation and correction of coagulopathy.
- If packing is not successful, generous exposure is required and should be gained early and aggressively.
  - Mobilize triangular, falciform, and coronary ligaments for full exposure.
  - Use extension into the pericardium and/or right chest, if needed.
  - Place several laparotomy pads above the dome of the liver to displace it down into the field of view.
- Short duration clamping of the hepatic artery and portal vein (Pringle maneuver) may be required to slow bleeding while gaining other control.
- If bleeding continues despite the Pringle maneuver, especially from behind the liver, this indicates a retrohepatic venous injury or a retrohepatic vena caval injury. These injuries carry an extremely high mortality. If the retrohepatic hemorrhage is controlled with packing, the best mechanism to deal with these injuries is to maintain tamponade by aggressively packing the liver and ICU resuscitation. If necessary, these injuries may be addressed once the patient has been more adequately resuscitated and transferred to a higher role of care with the resources to care for the patient.

- As a last resort, consider cross-clamping the aorta in the left chest or upper abdomen if all other modalities fail to control hemorrhage to the liver.
- Use finger fracture of liver parenchyma to expose deep bleeding vessels and oversew directly.
- Large exposed injuries of the liver parenchyma can be controlled in a number of ways:
  - Exposed large vessels and ducts should be suture-ligated.
  - Overlapping mattress sutures of no. 0 chromic on a blunt liver needle is fast and effective for controlling raw surface bleeding.
  - Placement of Surgicel on the raw surface and high-power electrocautery is also effective.
- Bleeding tracts through the liver can be controlled by tying off the end of a Penrose drain, placing it through the tract, and "inflating" it with saline to tamponade the tract.
- Urgent surgical resection is **strongly discouraged**:
  - Indicated only when packing/pressure fails.
  - Follow functional or injury pattern, not anatomical lines.
- Use a pedicle of omentum in a large defect to reduce dead space.

Prevention and treatment of coagulopathy, hypothermia, and acidosis are essential in the successful management of major liver injuries. APPLY DAMAGE CONTROL TECHNIQUES EARLY. Remember that the majority of liver injuries can be controlled by adequate packing.

- Retrohepatic vena cava and hepatic vein injuries require a tremendous amount of resources (blood products, operating room time, equipment) typically unavailable in a forward surgery setting (on-table triage in mass casualty).
  - Packing is the most successful option.
  - If packing fails, consider hemorrhage control by total hepatic vascular isolation or atriocaval shunt (Fig. 17-8) in order to effect injury repair.
- Provide generous closed-suction drainage around major liver injuries.

Biliary Tract Injuries

- Injuries to the gallbladder are treated by cholecystectomy.
- Repair common bile duct injuries over a T-tube.
  - A no. 4-0 or smaller absorbable suture is used on the biliary tree.
- Extensive segmental loss requires choledochoenterostomy or tube choledochostomy (depending on time and patient physiology).
- Drain widely.

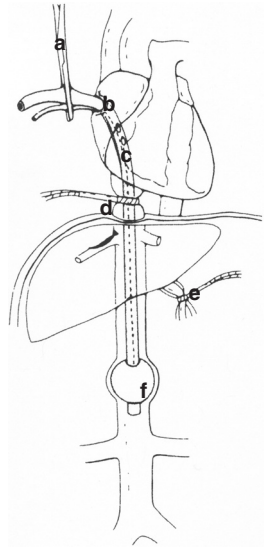

Fig. 17-8. Atriocaval shunt. (**a**) Proximal clamp occlusion; (**b**) purse-string suture, right atrium; (**c**) fenestrations made in tube; (**d**) suprahepatic inferior vena cava control; (**e**) Pringle maneuver; and (**f**) endotracheal tube, balloon inflated above renal veins.

Splenic Injuries

- Intraoperative splenic salvage has **NO ROLE** in combat surgery.
- Empiric left subphrenic drains should not be routinely placed postsplenectomy if the pancreas is uninvolved in the injury.
- Splenic injury should prompt exploration for associated diaphragm, stomach, pancreatic, and renal injuries.
- Theater clinical practice guidelines exist to help guide protocols for postsplenectomy immunization. All postsplenectomy patients should be immunized with pneumococcal, hemophilus, and meningococcal vaccine.

Small Bowel Injuries

- Basic tenets:
  - Debride wound edges to freshly bleeding tissue.
  - Close enterotomies in 1 or 2 layers (skin stapler is a rapid alternative for damage control).
- With multiple enterotomies to one segment of <50% of small bowel length, perform single resection with primary anastomosis. Avoid multiple resections.

Colon Injuries

Simple, isolated colon injuries are uncommon. In indigenous populations and enemy combatants (eg, patients who cannot be readily evacuated), diversion with colostomy should be the procedure of choice.

- Simple, isolated colon (nonrectal) injuries should be repaired primarily.
  - Debride wound edges to normal, noncontused tissue.
  - Perform two-layer closure or anastomosis.
- For **complex** injuries, **strongly consider damage control followed by colostomy/diversion**, especially when associated with:
  - Massive blood transfusion requirement.
  - Ongoing hypotension.
  - Hypoxia (severe pulmonary injury).
  - Reperfusion injury (vascular injury).
  - Multiple other injuries.
  - High-velocity injuries.
  - Extensive local tissue damage.
  - Distal colon (ie, distal sigmoid and rectal) injuries should be resected and ostomy formed due to the high incidence of leak from anastomosis.
- Potential breakdown of a repair or anastomosis is high in the setting of concomitant pancreatic injury.
- Damage control technique for colon injury:
  - Control contamination with ligation/stapling of bowel.
  - Resuscitation in the ICU.
  - Creation of a stoma during the definitive reconstruction.
  - Intestinal continuity should be restored or ostomy performed within 72 hours of original damage control procedure.
- Clearly document treatment for optimal follow-up throughout roles of care.
- At the time of formation, a colostomy should be matured.

Rectal Injuries

Rectal injuries can be difficult to diagnose unless very dramatic. Any question of an injury raised by proximity of another injury, rectal examination, or plain abdominal film radiography

MANDATES proctoscopy. Gentle distal washout with dilute Betadine solution may be required to be able to perform rigid proctoscopy.

- Findings can be dramatic disruptions of the rectal wall, but more commonly are subtle punctuate hemorrhages of the mucosa. All abnormal findings should prompt corrective intervention.
  - **D**iversion, **D**ebridement, **D**istal washout, and **D**rainage (the 4 D's of rectal injury). Diversion is the most important aspect of rectal injury management.
    - Transabdominal sigmoid colostomy is easiest.
    - If the injury has not violated the peritoneum, exploration of the extraperitoneal rectum should NOT be done at laparotomy unless indicated for an associated nonbowel injury. This avoids contaminating the abdominal cavity with stool.
  - Debridement and closure of small- to medium-sized rectal wounds are unnecessary in patients who have been diverted and drained.
  - Distal washout may be necessary to assess the injury. Use gentle pressure when irrigating to minimize contamination of the perirectal space.
  - Routine use of presacral drains is discouraged unless gross contamination and infection are present at the time of surgery. **The creation of a space to place drains should be avoided.**
    - If needed, presacral drains are placed through the perineum into the retrorectal space (Fig. 17-9).

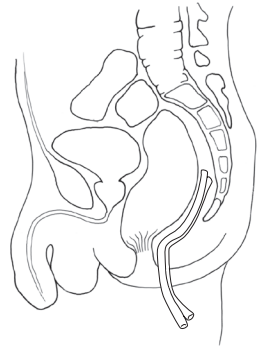

Fig. 17-9. Presacral drain.

- Peritonealized rectal injuries are easily accessed transabdominally and should be repaired and protected with diversion.

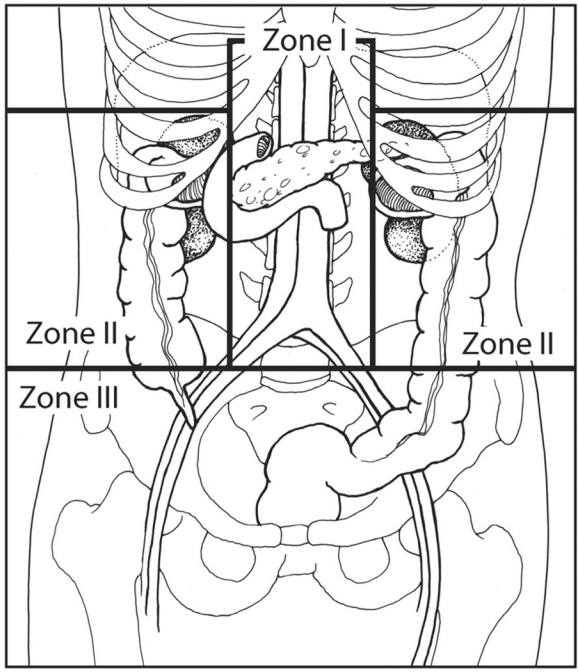

Fig. 17-10. Three zones of the retroperitoneum.

Retroperitoneal Injuries

- Left medial visceral rotation moves the colon, pancreas, and small bowel to expose the aorta rapidly. Proximal aortic control can be rapidly obtained with compression or a clamp on the aorta at the esophageal hiatus, or through the left chest.
- Right medial visceral rotation (colon + Kocher maneuver to elevate duodenum) exposes the subhepatic vena cava.
- Three zones of the retroperitoneum (Fig. 17-10):
  - **Zone I—central, supracolic:** explore for all injuries.
  - **Zone II—lateral:** blunt trauma, avoid exploration if possible because exploration increases the likelihood of opening a stable hematoma and, thus, precipitating nephrectomy. **Explore for penetrating trauma and expanding hematoma.**

  - **Zone III—pelvic:** blunt trauma, do not explore, likely associated with pelvic fracture. **Explore for penetrating trauma and expanding hematoma.**
- Gain proximal vascular control before entering the hematoma.

Abdominal Closure

- Massive swelling associated with large amounts of blood loss and resuscitation and large injuries may necessitate temporary closures (see Chapter 12, Damage Control Surgery).
  - Avoid closing the fascia under the following circumstances:
    - Further abdominal procedures are anticipated.
    - Enteric viscera left in discontinuity.
    - Damage control laparotomy.
- A few penetrating battlefield wounds are isolated, small, and without visceral contamination, and it is perhaps safe to close the skin. **Most are not, and these patients will be passed quickly from one surgeon to the next, so the risk of missed and catastrophic infection is increased; the skin should not be closed.**
- Retention sutures should be considered, but should be reserved for patients undergoing definitive surgical repair. There is no role for the placement of retention sutures if a patient is going to return to the OR for scheduled repeat laparotomy.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 18

Genitourinary Tract Injuries

Introduction

Genitourinary injuries constituted approximately 5% of the total injuries encountered in combat during the 20th century; however, this rate has risen to nearly 10% during the busiest years of recent conflicts. The treatment of these injuries adheres to the established surgical principles of hemostasis, debridement, and drainage. Proper radiographic evaluation prior to surgery may replace extensive retroperitoneal exploration at the time of laparotomy in the diagnosis of serious genitourinary injuries.

Genitourinary wounds, aside from injuries of the external genitalia, are typically associated with serious visceral injury.

Renal Injuries

- Most renal injuries, except for those of the renal pedicle, are not acutely life-threatening. Undiagnosed or improperly treated injuries, however, may cause significant morbidity.
- Although the vast majority of blunt renal injuries will heal uneventfully with observation and conservative therapy, a significant number of renal injuries in combat will come from penetrating wounds and require exploration.

The evaluation of a suspected renal injury is based on the type of injury and physical examination.

- Hematuria is usually present in patients with renal trauma, and gross hematuria in the adult patient is concerning for a significant injury. **The absence of hematuria, however, does not exclude renal trauma**. Renal injury must be suspected in

patients who have sustained significant concurrent injuries, such as multiple rib fractures; vertebral body or transverse process fractures; crushing injuries of the chest or thorax; or penetrating injury to the flank, chest, or upper abdomen.

RENAL INJURY Penetrating renal injury = abdominal exploration	• **Blunt Trauma** All patients with gross hematuria (regardless of initial SBP) **and** those patients with microscopic hematuria, **whose initial SBP is <90 mm Hg**, should undergo contrast-enhanced CT scan **if/when they become hemodynamically stable**. • **Renal Injury Grading** **Grade 1:** Subcapsular hematoma. **Grade 2:** Small parenchymal laceration. **Grade 3:** Deeper parenchymal laceration without entry into the collecting system. **Grade 4:** Laceration into the collecting system with extravasation; vascular injury with contained hemorrhage. **Grade 5:** Shattered kidney or renal pedicle avulsion. • Hemodynamically stable patients can usually be managed without operation. • Vascular repair is indicated for salvageable kidneys with renal artery or vein injury (see vascular CPGs for more details). • Ureteral stent may need to be placed for persistent urinary extravasation.

CPGs: Clinical Practice Guidelines; CT: computed tomography; SBP: systolic blood pressure.

- Adult patients who present with gross hematuria require further evaluation of their kidneys.
- CT provides excellent staging of renal injuries and aids in the decision of whether or not to explore the injured kidney.
- Renal trauma is categorized by the extent of damage to the kidney.
  - **Minor injuries.**
    - Consist of renal contusions or shallow cortical lacerations.

- Most common after blunt trauma and usually resolve safely without renal exploration.

- **Major injuries.**
  - Consist of deep cortical lacerations (with or without urinary extravasation), shattered kidneys, renal vascular pedicle injuries, or total avulsion of the renal pelvis.
  - There is an 80% incidence of associated visceral injuries with major renal trauma. Most cases will require a laparotomy for evaluation and repair of concurrent intraperitoneal injuries.
  - Operative intervention includes debridement of nonviable renal tissue (partial nephrectomy), closure of the collecting system, and drainage of the retroperitoneal area.
  - Kidney preservation should be considered if at all possible, although total nephrectomy may be required for the severely damaged kidney or the unstable patient. An attempt for verification of the presence of contralateral kidney by palpation should be attempted prior to nephrectomy.

Vascular control of the renal pedicle can be obtained prior to opening the perirenal fascia, when control of hemorrhage from the kidney requires exploration of the retroperitoneum.

- **Operative technique.**
  - Total nephrectomy is immediately indicated in extensive renal injuries when the patient's life would be threatened by attempted renal repair. The preferred approach in these situations is transabdominal with early vascular control of the kidney by medial visceral rotation. This approach has been shown to be faster and is associated with less blood loss, compared with attempting vascular control of the renal pedicle prior to exploration.
  - When partial or complete renal salvage is planned, obtain vascular control from a periaortic approach to the renal vascular pedicle.

Fig. 18-1. Exposure of the left renal hilum.

- ♦ The small intestine is retracted laterally and superiorly, and the posterior peritoneum is incised over the aorta.
- ♦ The left renal vein, crossing anterior to the aorta, must be mobilized (retracted cephalad) to expose and gain control of either renal artery.
- ♦ Atraumatic vascular clamps are used to occlude the appropriate artery.

- ○ Although vascular control in this fashion may provide the safest approach against renal hemorrhage and reduce the likelihood of nephrectomy, it is not a commonly performed maneuver by either urologists or general surgeons. Direct reflection of the colon to expose the kidney is feasible (Fig. 18-1). A kidney pedicle clamp should be readily available for this approach.

- Damaged renal parenchyma can be locally debrided (Fig. 18-2), excised in a partial nephrectomy (Fig. 18-3), or removed in a total nephrectomy, depending on the degree of injury and the condition of the patient.

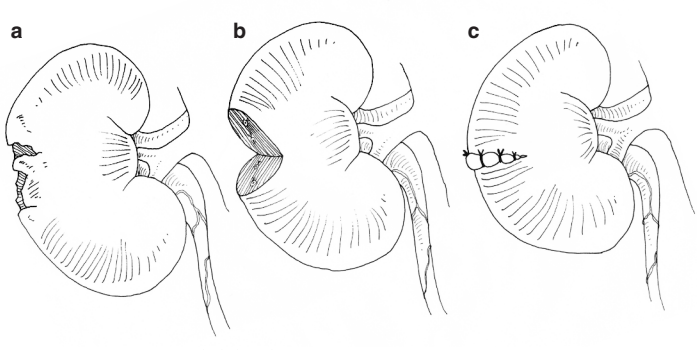

Fig. 18-2. Steps in renal debridement.

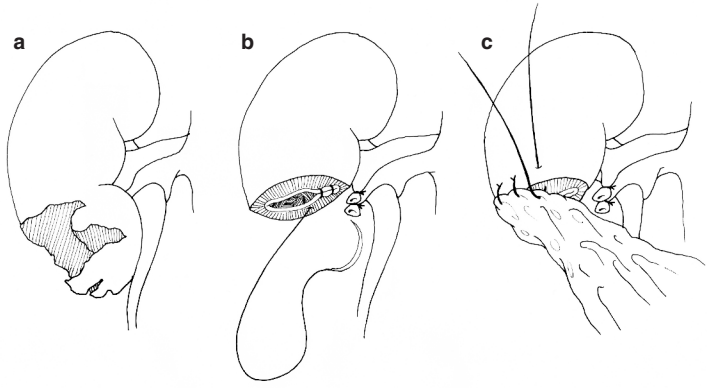

Fig. 18-3. Steps in partial nephrectomy.

Damage control management may require nephrectomy for major renal injuries as a lifesaving measure.

- Watertight closure of the collecting system with absorbable suture prevents the development of a urine leak (Fig. 18-3b).
  - Urinary diversion is typically unnecessary if formal renal reconstruction is accomplished.

- ◊ For the sake of expedience or in the presence of associated injuries of the duodenum, pancreas, or large bowel, diversion may be required.
- ◊ Tube nephrostomy, ureteral stent, or ureterostomy may be utilized.

- The reconstructed kidney should be covered by perirenal fat, omentum, or fibrin sealant (see Fig. 18-3c).
- A closed-suction drain should be left in place.

Ureteral Injuries

Ureteral injuries are rare, but are frequently overlooked when not appropriately considered. They are more likely in cases of retroperitoneal hematoma and injuries of the fixed portions of the colon, duodenum, and spleen.

- Isolated ureteral injuries are rare and usually occur in conjunction with other significant injuries. They can represent a difficult diagnostic challenge in both the preoperative and intraoperative settings.
  - Hematuria is frequently absent.
  - Blast injury to the ureter may produce significant delayed complications even when the CT is normal and the ureter appears visibly intact. Placement of an indwelling stent is reasonable when a high-velocity or blast injury occurs in proximity to the ureter.
  - If a ureteral injury is initially missed and presents in a delayed fashion, urinary diversion with a nephrostomy tube and delayed repair at 3–6 months is a safe approach.
- Operative technique.
  - Intraoperative localization of the ureteral injury is facilitated by IV injection of indigo carmine/methylene blue or direct injection into the collecting system under pressure.
  - Basic principles of repair.
    - ♦ Minimal debridement and mobilization.
    - ♦ Primary tension-free, 1-cm spatulated anastomosis using an interrupted single-layer absorbable suture (4–0 or 5–0) closure technique.
    - ♦ Internal (double J ureteral stent) and external drainage.

- Lengthening maneuvers.
  - Ureteral mobilization.
  - Kidney mobilization.
  - Psoas hitch (Fig. 18-4).
  - Boari flap.

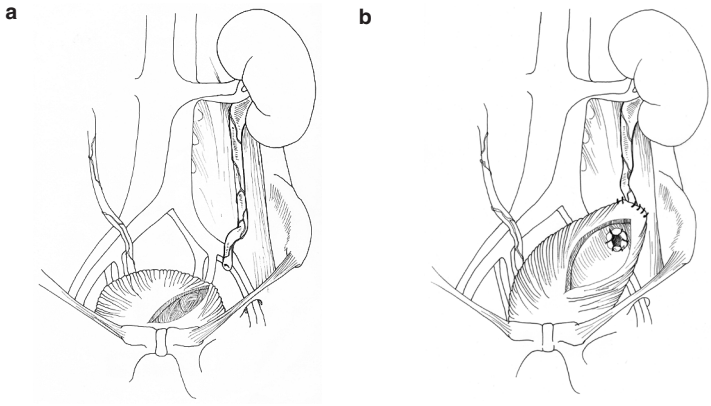

Fig. 18-4. The psoas hitch.

  - Isolate repairs with omentum or posterior peritoneum.
- The type of repair is based on the following:
  - Anatomical segment of the traumatized ureter (upper, middle, and lower third).
  - Extent of segmental loss.
  - Other associated injuries.
  - Clinical stability of the patient.
- Upper or middle ureteral injuries.
  - Short segment loss/transaction: Perform a primary ureteroureterostomy over stent (Fig. 18-5).
  - Long segment loss: May require a temporizing tube/cutaneous ureterostomy with stent placement or ureteral ligation with tube nephrostomy.
- Lower ureteral injuries.
  - When the injury occurs near the bladder, a ureteroneocystostomy should be performed (Fig. 18-6). This is typically completed by fixing the bladder to the fascial covering of the psoas muscle using permanent

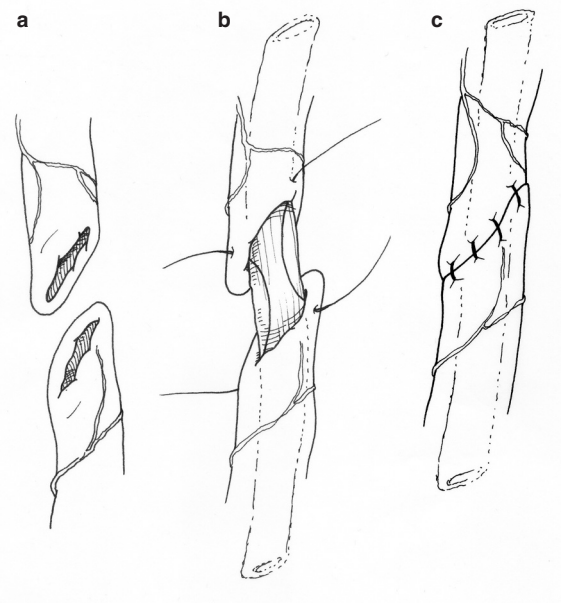

Fig. 18-5. Ureteroureterostomy.

suture, such as 2.0 or 3.0 Prolene. A transverse cystotomy assists in elongating the bladder to that location and facilitates the construction of a tension-free anastomosis.

- When a distal ureteral injury is associated with a rectal injury, ureteral reimplantation is not recommended; temporary diversion should be performed.

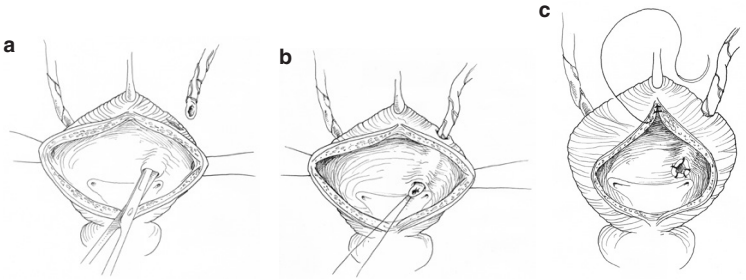

Fig. 18-6. Ureteroneocystostomy.

Ureteral injuries in the combat setting may be best managed with temporary tube drainage with a small feeding tube or ureteral stent, followed by delayed reconstruction.

Bladder Injuries

Bladder wounds should be considered in patients with lower abdominal gunshot wounds, pelvic fractures with gross hematuria, or those patients unable to void following abdominal or pelvic trauma.

- Bladder disruptions can occur on the intraperitoneal or extraperitoneal surface of the bladder. The location may change the symptoms, complications, and management of this injury.
- After ensuring urethral integrity in appropriate cases (see Urethral Injuries, below), evaluation of the bladder is performed radiographically with a cystogram.
  - Cystography is performed using a three-film technique: scout or plain film KUB concentrating on the pelvis, full-bladder radiograph after retrograde filling of the bladder with contrast, and a postdrainage radiograph.
  - **Technique:** Fill the bladder by gravity with a urethral catheter using radiopaque contrast medium elevated 20–30 cm above the level of the abdomen. At least 300 mL (5–7 cc/kg in children) are required for an adequate study. Take a full-bladder radiograph.
  - Drain the bladder using the catheter and take a postdrainage radiograph. Small extraperitoneal areas of extravasation may be apparent only on the postevacuation film. CT cystogram is the preferred study when available.
- Operative technique.
  - Intraperitoneal injuries.
    - Cystography reveals contrast medium interspersed between loops of bowel.
    - Management consists of immediate exploration, multilayer repair of the injury with absorbable suture, suprapubic tube cystostomy, and drainage of the

perivesical extraperitoneal space. Consider opening the bladder to allow more thorough inspection for injuries and then repairing bladder through cystotomy.

- Extraperitoneal injuries.
  - Bladder laceration is most often the result of laceration by bony fragments from a pelvic fracture.
  - Cystography reveals a dense, flame-like extravasation of contrast medium in the pelvis on the postevacuation film.
  - The bladder usually heals with 10–14 days of Foley catheter drainage without the need for primary repair. If the urine is clear, catheter drainage alone is preferred for treatment of most extraperitoneal ruptures.
  - In cases of abdominal exploration for other injuries, primary repair and drainage are necessary if the extraperitoneal space is entered. Repair can be completed from inside the bladder through a cystotomy to avoid disturbing any pelvic hematoma. Patients with concurrent rectal injuries should be managed more aggressively and may benefit from hematoma evacuation and primary bladder repair.

Urethral Injuries

A urethral injury should be suspected in patients with a scrotal hematoma, blood at the meatus, or a floating/high-riding prostate. Catheterization is contraindicated until urethral integrity is confirmed by retrograde urethrography.

- Retrograde urethrography is performed to evaluate the anatomy of the urethra.
  - Take oblique radiographs of the pelvis to avoid "end-on" imaging that obscures the bulbar urethra.
  - Insert the end of a sterile catheter tip syringe (60 cc) into the urethral meatus while grasping the glans to prevent leakage. Alternately, insert an unlubricated Foley catheter into the fossa navicularis (approximately 3 cm) and inflate the balloon with 3 cc of water.
  - Gently instill 15–20 cc of water-soluble contrast. The radiograph is taken during injection.

- Contrast must be seen flowing into the bladder to clear the proximal urethra of injury. Posterior urethral injuries seen in pelvic fractures may be missed otherwise.
- If no injury is identified, carefully place a Foley catheter.

If any difficulty in passing the catheter is encountered, the urethra should not be instrumented, and a suprapubic tube cystostomy should be performed.

- Operative technique.
  - The urethra is divided into **anterior** and **posterior** (prostatic) segments by the urogenital diaphragm.
    - Anterior urethral injuries may result from blunt trauma, such as results from falls when astride an object (straddle) or from penetrating injuries.
      - Blunt trauma resulting in minor nondisruptive urethral injuries may be managed by gentle insertion of a 16 Fr Foley catheter for 7–10 days.
      - Penetrating wounds should be managed by exploration and judicious debridement.
        - Small, clean lacerations may be repaired primarily by reapproximation of the urethral edges using interrupted 4-0 chromic suture.
        - Do not mobilize the entire urethra for a primary anastomosis, because the shortened urethral length in the pendulous urethra may produce ventral chordee and an anastomosis under tension.
        - Instead, marsupialize the injured urethral segment by suturing the skin edges to the cut edges of the urethra. Marsupialization should be performed until healthy urethra is encountered both proximally and distally. Closure of the marsupialized urethra is subsequently performed at 6 months to reestablish urethral continuity.
    - Posterior urethral disruption commonly occurs following pelvic fracture injuries.
      - Rectal examination reveals the prostate to have been avulsed at the apex.

- ◊ Improved continence and potency rates are attained when suprapubic tube cystostomy is used as the initial management.
- ◊ Suprapubic urinary diversion is maintained for 10–14 days, and urethral integrity is confirmed radiographically prior to removal of the suprapubic tube.
- ◊ With expectant observation, virtually all these injuries will heal with an obliterative prostatomembranous urethral stricture, which can be repaired secondarily in 3–6 months after reabsorption of the pelvic hematoma.
- ◊ Initial exploration of the pelvic hematoma is strictly reserved for patients with concomitant bladder neck or rectal injury.

External Genitalia Injuries
(See Chapter 19, Gynecological Trauma and Emergencies)

Management of wounds to the penis, scrotum, testes, or spermatic cord should be as conservative as possible, and consists of hemorrhage control, debridement, and early repair to prevent deformity.

- Injuries to the penis that disrupt Buck's fascia should be sutured to prevent further bleeding and avoid future penile curvature with erection. When extensive penile skin is lost, cover exposed corpora with remaining skin and sterile moist dressing.
- The scrotum is highly vascularized, and extensive debridement is usually not necessary for scrotal wounds.
  - o Most penetrating scrotal injuries should be explored to evaluate the testicle for injury and reduce the risk of hematoma formation.
  - o Most partial scrotal avulsions are best treated by primary closure with absorbable 3-0 sutures in two layers.
  - o Primary closure is selected for patients without associated life-threatening injuries who sustained injury less than 8 hours prior. A Penrose drain or small closed drain can be placed to reduce hematoma formation.

- It is essential when dealing with testicular wounds to conserve as much tissue as possible.
  - Herniated parenchymal tissues should be debrided, and the tunica albuginea closed by absorbable mattress sutures.
  - The testicle is placed in the scrotum or wrapped in moist gauze.
  - A testicle should never be resected unless it is hopelessly damaged and its blood supply destroyed.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 19

Gynecological Trauma and Emergencies

Introduction

The current active duty population consists of 16% women (approximately 202,849 women were documented in 2016; DoD has a goal to achieve 25% of the force female by 2025), many of whom are subject to the same risks of combat injury as their male colleagues, especially now that all combatant roles have been opened to females. This chapter deals with OB/GYN emergencies that may present to a deployed medical treatment facility, particularly in military operations other than war. In a civilian epidemiologic study of childbearing-age women undergoing hospitalization for injuries, 4.6% of these women were identified as being pregnant (many were previously unrecognized). Up to 6% to 7% of pregnancies are complicated by trauma, and nearly 50% of maternal deaths are related to trauma.

Gynecological Trauma

Vulva

- Vulvar injuries include lacerations and hematomas.
  - **Lacerations** that are superficial, clean, and less than 6 hours old can be primarily closed with absorbable suture. Debridement of obviously devitalized tissue is recommended.
    - Deep lacerations should be examined and explored to rule out urethral, anal, rectal mucosa, or periclitoral injuries.
    - Placing a urethral catheter will assist in determining urethral injury, and can protect the urethra during repair of nearby injuries. If urethral injuries are identified, single-layer closure with fine (4-0 or smaller), absorbable

sutures, leaving the catheter in place, is recommended. Rectal and periclitoral injuries are closed in a similar fashion.

- ♦ Anal lacerations should be repaired by approximating the cut ends of the anal sphincter with size 0 or 1 absorbable suture. Consideration for diversion of fecal stream should be included in the setting of anorectal injury.
- ♦ Antibiotics (second-generation cephalosporin) are recommended with contaminated wounds.

- Vulvar trauma may cause **infrafascial** (below the pelvic diaphragm) **hematoma**.
  - Because the deeper layer of subcutaneous vulvar fascia is not attached anteriorly to the pubic rami, hematoma can spread freely into the anterior abdominal wall.
  - **Most vulvar hematomas are treated conservatively.**
  - **External compression** and ice packs should be applied until hemostasis is ensured by serial examination of the vulva, vagina, and rectum.
  - Hematoma may preclude adequate urination, and an indwelling catheter may need to be placed.
  - Large hematomas may need to be incised and bleeding vessels ligated (usually venous) to avoid skin necrosis.
  - **Signs of shock in association with a decreasing hematocrit should prompt consideration of an extraperitoneal expansion.** Ultrasound or CT is useful for detecting extraperitoneal expansion not diagnosed by clinical exam.

Vagina

- Trauma to the vagina can cause **lacerations**, and less commonly, suprafascial (above the pelvic diaphragm**) hematoma.**
- Vaginal trauma has been reported in **approximately 3.5% of women with traumatic pelvic fractures**. **Concomitant urological trauma, most often involving the bladder and/or urethra, has been described in about 30% of patients with vaginal trauma.**
- Thorough inspection and palpation of the vagina and rectovaginal exam are necessary to detect vaginal trauma and to determine the need for further urological evaluation/imaging. **Due to pelvic instability (in fracture cases) or pain, examination under sedation or anesthesia may be necessary.**

- Patients with vaginal lacerations typically present with bleeding, sometimes profusely, from the well-vascularized vagina.
- Lacerations are repaired using the guidelines given previously for vulvar lacerations. Larger suture and needles such as 2-0 absorbable suture on a CT or CT-1 with locking stitches can be beneficial.
- A vaginal hematoma is usually accompanied by severe rectal pressure and is diagnosed by palpation of a firm, tender mass bulging into the lateral vagina**. Vaginal hematomas should be treated by incision, evacuation, ligation, and packing.** A urinary catheter should be used while a vaginal pack is left in place during prolonged periods of observation.
- Unrecognized vaginal trauma can result in dyspareunia, pelvic abscess, and fistula formation.

Uterus/Cervix

- Trauma to the uterus and cervix is most commonly found in association with pregnancy, but may be seen as a result of penetrating vaginal or abdominal trauma.
- Non-infected simple cervical lacerations should be repaired to optimize restoration of normal anatomy (and possibly decrease the risk of cervical incompetence or stenosis with dysmenorrhea from poor healing). Absorbable size 2-0 or 0 grade suture can be used.
- Acute penetrating trauma involving the uterine fundus usually causes little bleeding and can be managed expectantly without repair. Damage to the uterine wall with bleeding can be repaired with size 0 absorbable suture.
- **Trauma involving the lateral wall of the uterus may cause significant bleeding**, but can usually be controlled by successive ligation of the ascending and descending branches of the uterine artery, as described in the obstetrical section Uterine Atony.

Hemorrhage not responding to ligation, or extensive mutilating damage to the cervix or uterus, should be treated by hysterectomy.

- Prophylactic antibiotics should be given if proceeding to hysterectomy (first-generation cephalosporin).

Basic Steps for Performing an Emergent Total Abdominal Hysterectomy

- Ligate/cauterize round ligaments (Fig. 19-1).
- Incise anterior leaves of broad ligaments bilaterally, then continue across the midline to incise the vesicouterine fold.
- Mobilize bladder downward by blunt dissection (and sharp dissection if necessary) from the lower uterine segment and cervix.*
- To **retain** adnexa, clamp/cut/ligate utero-ovarian ligaments and fallopian tubes near their connections to the uterine fundus (Fig. 19-2).
- **Adnexa should be retained unless there is an indication for removal.**
- To **remove** adnexa with the uterus, clamp/cut/ligate infundibulopelvic ligaments after making windows in the posterior leaves of the broad ligaments above the ureters.
- Incise posterior peritoneum to mobilize adnexa either away from (if being retained) or toward (if being removed) the uterus.
- Incise peritoneum overlying rectovaginal space, then mobilize rectum downward and away from the posterior vagina by blunt dissection (Fig. 19-3).*
- Clamp/cut/ligate uterine arteries along the lateral surface of the uterus at the uterocervical junction, staying close to (within 1 cm of) the uterus to avoid damaging ureters.
- Clamp/cut/ligate the remainder of the cardinal ligaments, paracervical tissue, and uterosacral ligaments by taking successive inferior bites until the cervicovaginal junction is reached; each bite should be placed medial to the previous bite to avoid injuring the ureter and bladder.
- Cross-clamp the vagina below the cervix.
- Transect vagina, removing uterus (and attached adnexa, if applicable).
- Suture vaginal cuff closed, ensuring that the bladder and/or rectum are not incorporated.

*In case of dense adhesions between the cervix and bladder or rectum in an emergent setting, or ongoing hemorrhage with poor visualization, supracervical hysterectomy can be performed. After mobilizing the bladder and rectum from the uterus and ligating uterine arteries, the uterine fundus is transected from the cervix with a knife. The cervix is then oversewn with a baseball stitch, staying medial to the ligated uterine arteries.

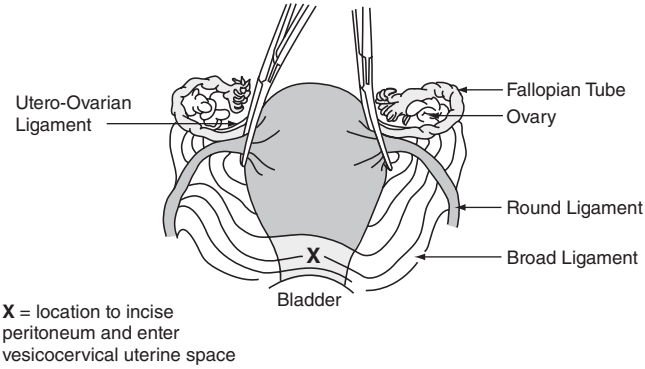

Fig. 19-1. Abdominal hysterectomy—anterior view.

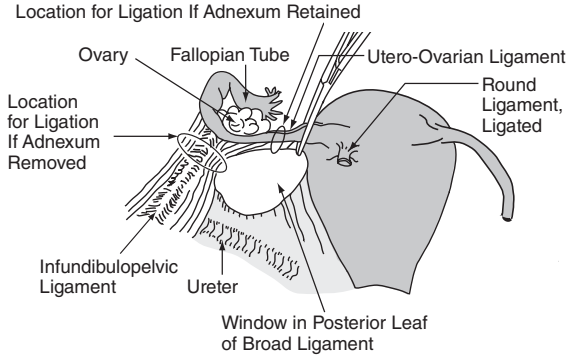

Fig. 19-2. Abdominal hysterectomy—adnexal view.

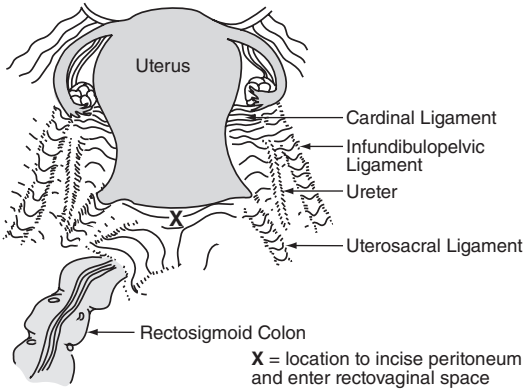

Fig. 19-3. Abdominal hysterectomy—posterior view.

Adnexa

- **Fallopian tubes.**
  - Damage to the wall of the fallopian tube by ruptured ectopic pregnancy or penetrating abdominal trauma should be treated by salpingectomy, if there is significant damage to the tube, due to the risk of subsequent or recurrent ectopic pregnancy if left in situ. If the damage is equivalent to a linear salpingotomy, achieve hemostasis, then allow healing by secondary intention.
  - The mesosalpinx is ligated or cauterized, then the tube is ligated and cut at its connection with the uterine fundus.
  - Unruptured ampullary/isthmic ectopic pregnancy can be treated by linear salpingotomy, with extraction of the ectopic gestation. The tubal incision is left open to heal by secondary intention.
  - An unruptured or ruptured cornual/interstitial ectopic pregnancy requires wedge resection of the uterine cornu with salpingectomy.
  - An ectopic pregnancy spontaneously aborted into the abdominal cavity through the end of the tube should be removed, but the tube may be left in situ if hemostasis is attained.
- **Ovaries**
  - A **ruptured ovarian cyst** should be treated via cystectomy by shelling the cyst wall out of the ovary, then cauterizing or ligating any bleeding vessels, usually at the base of the cyst.
  - **Torsion of an ovarian mass** is first treated by assessing the ovary. Untwist the ovary and/or fallopian tube. If it appears healthy, with some continuing blood supply, it can be left in situ. If the ovary contains a large (>4 cm), simple-appearing cyst, the cyst can be drained and the cyst wall removed. Interrupted sutures using a fine monofilament or electrocautery can be used to obtain hemostasis. If the ovary appears dark and dusky after untwisting and observation, perform a salpingo-oophorectomy by ligating the infundibulopelvic ligament first (after identifying the ureter), then the utero-ovarian ligament and fallopian tube.

- Hemorrhage from an infundibulopelvic ligament, as a result of penetrating abdominal trauma, is best treated by ligation with salpingo-oophorectomy.

Retroperitoneal Hematoma

- **Laceration of an arterial branch of the hypogastric artery can cause a retroperitoneal hematoma.**
- A large amount of blood may collect in the broad ligament with few symptoms. Dissection of the hematoma can extend up to the level of the renal vessels. The hematoma may be discovered during emergency surgery for trauma or during reoperation or post-pelvic surgery, or suspected by signs of shock suggesting internal bleeding.
- Retroperitoneal hematoma can be treated by hypogastric artery ligation on the affected side. **Bilateral hypogastric artery ligation may be necessary for hemostasis.** The uterus, tubes, and ovaries may be left in situ if viable and without other indication for removal.

Gynecological/Obstetrical Emergencies

- **Acute vaginal hemorrhage unrelated to trauma.**
  - **Bright red vaginal bleeding filling more than one large perineal pad per hour is considered vaginal hemorrhage. Obstetric hemorrhage is quantified by an estimated blood loss (EBL) of 1,000 mL or when the patient demonstrates signs or symptoms of hypovolemia regardless of EBL volume.** A pregnancy test and pelvic exam direct initial therapy.
    - **If the patient is not pregnant, a hemorrhaging mass in the vagina is most likely cervical cancer.** The vagina should be packed to tamponade the bleeding after placing a urethral catheter. Placing sutures is generally futile and may make the bleeding worse.
    - If a **premenopausal non-pregnant female** has a normal vaginal/pelvic exam, hormonal management with 25 mg IV conjugated estrogen (Premarin) or 50 mg estrogen-containing oral birth control pills should be given every 6 hours. Anovulation is one of the most common causes of bleeding in this population.

- ◊ If bleeding responds to hormonal management, oral birth control pills should be continued 4 times per day for 5–7 days, while more definitive diagnosis and management plans are made.
- ◊ If bleeding has not decreased significantly within 24 hours or the patient becomes unstable secondary to profuse or prolonged bleeding, proceeding with dilatation and curettage is reasonable. Imaging studies and possibly coagulation studies will be needed to help direct further therapy.

♦ **In the pregnant patient,** heavy bleeding from the cervical os with uterine size <20 weeks (fundus at or below the level of patient's umbilicus) suggests spontaneous abortion. Dilatation and suction curettage should be performed.

- ◊ Ectopic pregnancy uncommonly presents with acute hemorrhage, but should be considered if the patient has an acute abdomen or if scant tissue is obtained on curettage.

♦ **In the pregnant patient** with uterine size consistent with a third trimester gestation (>4 cm above the umbilicus in a singleton pregnancy), vaginal hemorrhage is usually an indication of placental abruption or placenta previa.

- ◊ Emergent cesarean section will be necessary if the uterine hemorrhage does not spontaneously resolve within several minutes.
- ◊ After delivery of the fetus and placenta, persistent hemorrhage unresponsive to more conservative measures may require hysterectomy (see Emergency Cesarean Section and Uterine Atony).
- ◊ Pregnant patients with acute vaginal hemorrhage who have Rh– blood type, or if their Rh status is unknown, should be given RhoGAM 300 mg IM. Additional doses may be needed if there is a positive Keihauer-Betke (KB; fetal bleed screen) test or concern for significant feto-maternal hemorrhage.

Precipitous Vaginal Delivery

- **Preparation.**
  - Supplies needed for the delivery include povidone-iodine sponges, a 10-mL syringe, lidocaine, two Kelly clamps, ring forceps, dry towels, a bulb syringe, and scissors.
  - The mother should be placed on her left side for labor.
  - The fetal heart rate should be determined every 15 minutes prior to pushing and following each contraction during the pushing phase using a vascular Doppler. **Normal fetal heart rate is between 110 and 160 beats per minute**. The heart rate often drops with the contraction, but should recover to normal prior to the next contraction.

If the fetal heart rate drops below 100 and stays low for more than 2 minutes, a cesarean section should be considered.

  - When the patient presents, the cervix should be examined to determine dilation and fetal position. Before the woman begins pushing, the cervix should be completely dilated (10 cm), and no cervix should be felt on either side of the fetal head. If the baby's head is not presenting (ie, foot or fetal buttocks palpated), move to cesarean section immediately. If there is any question, and ultrasound is available, it should be used to determine the presentation.
- **Delivery.**
  - Once the patient begins pushing, flex the hips to optimally open the pelvis. The patient may be on her back or tilted slightly to the left. Assistants should support the legs during pushing and relax them between contractions.
  - Clean the perineum with sterile Betadine solution. If this is the patient's first delivery, the perineum may be anesthetized with lidocaine in case an episiotomy is needed. There is no evidence to support prophylactic episiotomy.
  - The fetal head delivers by extension. Pushing upward on the fetal chin through the perineum can assist this process. Additionally, it is extremely important to control the rate of delivery of the head with the opposite hand.

- If an episiotomy is needed (in the event of a difficult delivery such as a shoulder dystocia), the incision begins at the posterior midline at the vaginal opening and extends half the length of the perineum and about 2–3 cm into the vagina. A mediolateral episiotomy may be considered in lieu of a midline incision to reduce the risk of anal sphincter and rectal injury. The mediolateral episiotomy is directed approximately 45–60 degrees away from the midline toward the ischial tuberosity.
- After delivery of the head, the mouth and nose may be suctioned and the neck palpated for evidence of a nuchal cord. If present, the cord can be reduced by looping it over the fetal head or by clamping twice and cutting between the clamps.
- Next, the operator's hands are placed along the parietal bones, and the patient is asked to push again to allow delivery of the anterior shoulder. Gentle downward traction should allow the anterior shoulder to clear the pubis, and the fetus should be directed anteriorly to allow delivery of the posterior shoulder. The remainder of the body will normally follow rapidly.
- Wrap infant in dry towels.
- Once the fetus delivers, the cord should be doubly clamped and cut. The placenta usually delivers within 15 minutes of delivery, but may take up to 60 minutes. Delivery of the placenta is heralded by uterine fundal elevation, lengthening of the cord, and a gush of blood. While waiting, gentle traction may be placed on the cord; however, vigorous uterine massage and excessive traction can lead to complications including cord avulsion which can require manual extraction of the placenta.
- Following delivery of the placenta, the patient should be started on an infusion of lactated Ringer solution with 20 units of oxytocin (Pitocin). Oxytocin can also be given 10 units IM if there is no IV access. If no oxytocin is available, alternatives include administering misoprostol (Cytotec) 800-1000 μg PR or 400 μg sublingual (can also be given orally, but there are more side effects with PO administration); methylergonovine maleate (Methergine)

0.2 mg IM; or allowing the patient to breastfeed the infant. Methergine should be avoided in mothers with hypertension > 140/90.

- **The placenta should be inspected for evidence of fragmentation that can indicate retained products of conception.**
- **If the placenta does not deliver spontaneously within 20-30 minutes, it should be manually removed.** Manual extraction is best accomplished by using one hand on the abdomen to push the uterine fundus down, and inserting the second hand into the uterus to grasp the placenta and extract it. It may be necessary to create a plane between the placenta and the uterine wall to aid the separation**.**

- **Inspection and repair.**
  - Following delivery of the placenta, the vagina and cervix should be inspected for lacerations. Downward digital pressure on the posterior vagina and fundal pressure (by an assistant, if available) will facilitate visualization of the cervix. A ring forceps is then used to grasp and visualize the entire cervix.
  - The vagina should be inspected, with special attention to the posterior fornix. The perineum and periurethral areas should also be inspected. Vaginal and cervical lacerations may be repaired with 3-0 Vicryl or an equivalent suture in running or interrupted layers.
  - If the anal sphincter is lacerated, it should be reapproximated with 0 to 2-0 absorbable interrupted single or figure-of-eight sutures.
  - If the tear involves the rectum, the rectal-vaginal septum should be repaired with interrupted sutures of 3-0 Vicryl. A second layer imbricating the underlying tissue will decrease the risk of breakdown. Care should be taken to preserve aseptic technique. If a large tear is noted, a saddle block or spinal anesthetic may be necessary and repair performed in the operating room to facilitate exposure.
  - Patients with a periurethral tear may require urethral catheterization. In addition to lacerations, hematoma in the vulva, vagina, or retroperitoneum may occur. See Gynecological Trauma for management.

Emergency Cesarean Section

- Indications.
  - Fetal heart rate drops below 100 and stays down for more than 2 minutes.
  - Acute uterine hemorrhage persisting for more than a few minutes (suggestive of placental abruption or previa).
  - Breech (complete or incomplete) or transverse fetal lie.
- The patient should be placed in the left tilt position with an IV bag or towel displacing the uterus to the left. She should undergo a quick prep from just below the breasts to the midthigh. A major abdominal equipment set should have most of the instruments you will need.
- **Basic steps to performing an emergency C-section** (Fig. 19-4).
  - Direct the anesthetist to administer 2 g cefazolin (Ancef).
  - Enter the abdomen through the lower midline vertical or transverse pfannenstiel incision.
  - Identify the bladder and retract out of the field with a bladder blade. An optional maneuver to create a bladder flap is performed by incising the peritoneal reflection of the bladder transversely and creating a bladder flap to retract the bladder out of the field.
  - Using a scalpel, carefully incise the uterus transversely across the lower uterine segment (where the uterine wall thins above the bladder reflection or bladder flap).
  - Once the amniotic membranes are visible or opened, extend the incision laterally, either bluntly by pulling, or by **carefully** using bandage scissors. **Avoid the uterine vessels laterally.** If necessary, the incision can be extended at one or both of its lateral margins in a J-fashion by vertical incision.
  - Elevate the presenting fetal part into the incision, with an assistant providing fundal pressure.
  - Upon delivery of the fetus, suction the nose and mouth and clamp and cut the cord. Hand the infant off for care.
  - Allow the placenta to deliver by providing gentle traction on the cord and performing uterine massage.
  - Begin oxytocin, if available, as previously described.
  - Using a sponge, clean the inside of the uterus.
  - Vigorously massage the fundus to help the uterus contract.

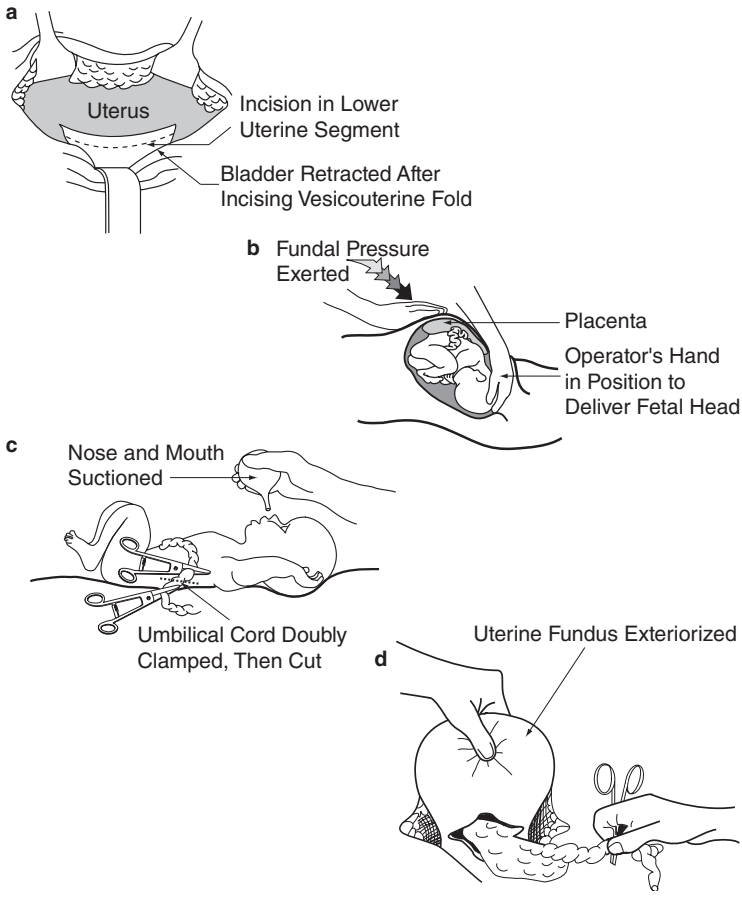

Fig. 19-4. Emergency C-section. (**a**) Uterine incision. (**b**) Delivery of fetus. (**c**) Delivered infant on abdomen. (**d**) Uterine fundus exteriorized.

- Quickly close the incision with 0 VICRYL. A single layer (running, locking) is adequate, if hemostatic, for transverse incisions. Take care to avoid the lateral vessels. If the incision has a vertical extension, close it in two or three layers. A second layer can be used if hemostasis is not adequate with one layer.
- Once hemostasis is ensured, close the fascia and abdomen in the usual fashion.

- In the rare case of continued uterine hemorrhage, evaluate and treat as outlined in Uterine Atony.

Postpartum Hemorrhage – Uterine Atony

- The majority of postpartum hemorrhage is secondary to uterine atony (failure of uterine contracture).

When the uterus fails to contract following delivery of the placenta, bleeding may be torrential and fatal.

- Initial management should include manual uterine exploration for retained placenta. Without anesthesia, this procedure is painful. An opened sponge is placed around the examiner's fingers. Place the opposite hand on the patient's uterine fundus and apply downward pressure. Gently guide your fingers through the open cervix and palpate for retained placenta. The inside of the uterus should feel smooth, and the retained placenta will feel like a soft mass of tissue. This may be removed manually or by using a large banjo curette if available.
- If no tissue is encountered, use both hands to apply vigorous uterine massage/compression to improve the uterine tone.
- Medications should also be used if available. Oxytocin may be given by IV bolus using 20–40 units in 1,000 mL, or up to 10 units IM, but never by IV push. Although unlikely to be available, other medications that can be considered are methylergonovine maleate (Methergine), dinoprostone (Prostin), and misoprostol (Cytotec).
- Tranexamic acid (TXA) may also be used for the treatment of postpartum hemorrhage, and is likely more readily available in an operational setting. Additionally, TXA will treat all causes of postpartum bleeding regardless of the source (eg, atony, laceration, or retained placenta). The dosing is TXA 1 vial consisting of 1,000 mg/10 mL, which is added to 100 mL normal saline and then administered IV over 10 minutes (pump set to 600 mL/h); it may also be administered via slow IV push over 10 minutes. A second repeat dose of TXA can be repeated in 30 minutes if bleeding has not resolved, or if the bleeding stops but restarts within 24 hours of delivery. The only major contraindication to TXA use is presence of venous thromboembolism (PE or DVT).

- If no medication is available, the patient should be encouraged to breastfeed the infant or to perform nipple stimulation to increase endogenous oxytocin release.
- A uterine tamponade device called the Bakri balloon is available commercially but less likely found in an operational setting. Uterine packing and other uterine tamponade options (compression) may be considered to reduce bleeding but should not delay proceeding to laparotomy in the event of an unresolved class 2 (1,000 mL EBL) or class 3 hemorrhage (1,500 mL EBL).
- Massive transfusion protocol should be initiated for an obstetrical patient when estimated blood loss reaches 1,500 mL or if the patient displays signs or symptoms of hypovolemia.

If conservative measures fail to arrest the postpartum hemorrhage, laparotomy (if the hemorrhage is occurring postvaginal delivery) should be performed.

- While initiating laparotomy, direct the anesthesia provider to infuse 2 g Cefazolin (Ancef) for infection prophylaxis.
- Once abdominal entry is completed, intraoperative massage of the uterine fundus may be attempted. Intramyometrial injection of Methergine can be considered (0.20 mg IM).
- **If the massage fails to improve uterine tone, the uterine arteries should be ligated in a stepwise fashion (O'Leary sutures).** Begin with the ascending branch at the junction of the upper and lower uterine segment. Using 0 or no. 1 chromic, place a stitch through the myometrium medial to the artery from front to back. The stitch is then brought out through the adjacent broad ligament and tied. If bilateral ligation of the ascending branch does not control bleeding, the descending branch should be ligated at the level of the uterosacral ligament.
- **Uterine tourniquets** using penrose drains or urinary catheters may be placed around the lower uterine segment, which can help reduce acute blood loss as a temporizing measure.
- Consider **uterine compression sutures** such as **B-Lynch sutures** or **Hayman uterine compression sutures** (Figs. 19-5 and 19-6). Compression sutures are performed using a large Mayo needle with no. 1 or 2 chromic catgut/absorbable suture.

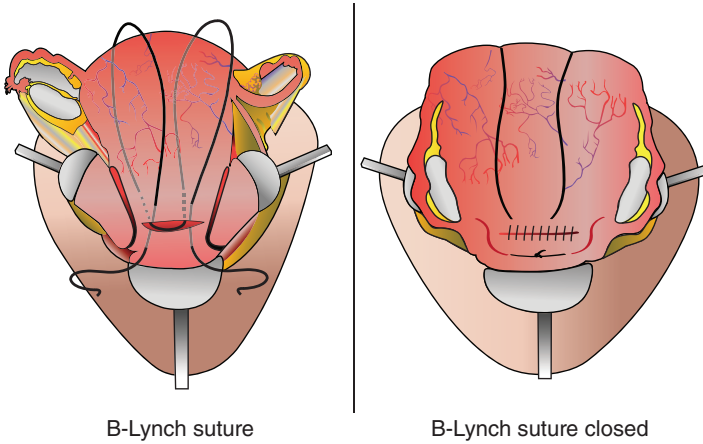

Fig. 19-5. B-Lynch compression sutures.

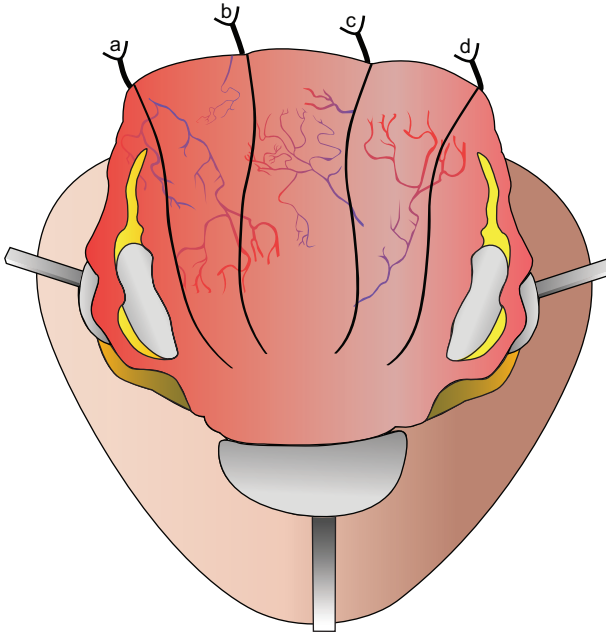

Fig. 19-6. Hayman compression sutures.

- **Bilateral hypogastric artery ligation** should be considered only by surgeons experienced with this procedure. An enlarged, gravid uterus makes visualization and access challenging. **Consider proceeding to hysterectomy** as outlined in the gynecological portion of this chapter.
- **Manual aortic compression** can be considered for temporary control during the threat of severe hemorrhage and is performed via compression of the aorta against the vertebrae several centimeters superior to the sacral promontory or below the renal arteries. However, evidence of safe use of intraaortic balloon catheters in this population is limited to a few case reports.
- **The Pressure Pelvic Pack** (Fig. 19-7) can be used post-hysterectomy in the rare case of continued bleeding despite hysterectomy. A sterile bag (eg, an x-ray cassette bag) is

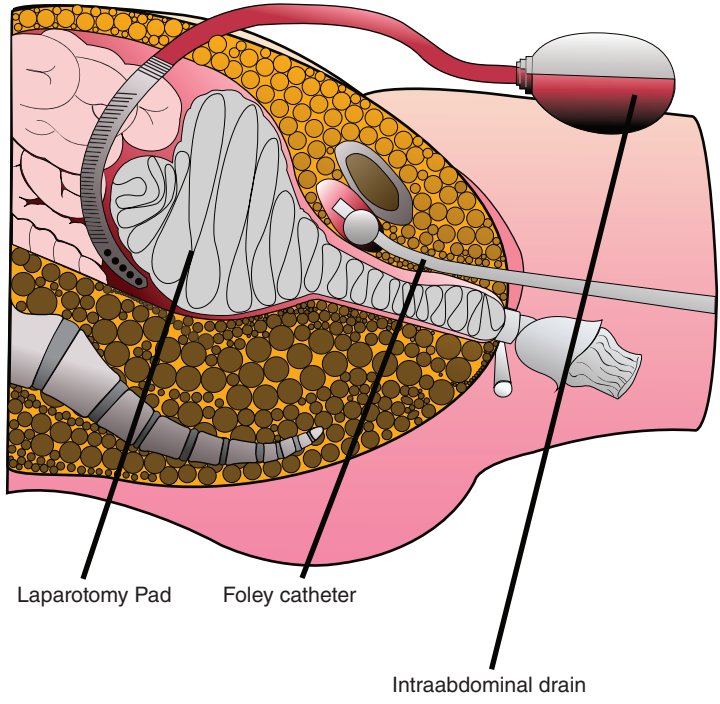

Fig. 19-7. Pressure pack for severe pelvic hemorrhage.

filled with an appropriate amount of gauze. The neck of bag is passed through the vagina from the abdomen. IV tubing connected to 1 L of IV fluids is tied to the neck of the bag and suspended to apply traction and pressure to tamponade bleeding.

Other Sources of Bleeding

- After ruling out uterine atony, other sources of bleeding include retained placenta, genital lacerations, and thrombophilia.
- Examination of the placenta post-delivery can help determine the risk of retained tissue. Manual sweeping of the uterus should be performed if retained placental fragments or membranes are suspected. Additional anesthesia (IV sedation or nitrous oxide) may be required to facilitate manual extraction of the placenta (consider transfer to the OR if patient does not tolerate manual attempt at the bedside). If palpated fragments cannot be extracted manually, sharp curettage with a large banjo curette may be required in the OR which can be facilitated by ultrasound guidance.
- Actively bleeding lacerations on the cervix, vagina, or vulva should be repaired under direct visualization to control hemorrhage.

Neonatal Resuscitation

- **Immediately following delivery, every infant should be assessed for need for resuscitation.** Equipment that may be needed includes warm towels, bulb syringe, stethoscope, flow-inflating or self-inflating bag with oxygen source (with oxygen blender preferred but it may not be available in an operational setting), neonatal cardiac heart rate monitor (if available), laryngoscope and blade, suction catheter, and endotracheal tube. Epinephrine 1:10,000 may be required during neonatal resuscitation.

If the baby is <36 weeks, or if there is meconium in the fluid at delivery, the baby will need to be observed more closely.

- Nearly 90% of term babies are delivered without risk factors and with clear fluid, requiring only that they be dried, stimulated, suctioned (if needed), and observed.

- In the first 30 seconds after delivery, dry and stimulate the baby, position it to open the airway, and clear secretions if needed.
- Non-vigorous newborns with meconium-stained fluid do not require routine intubation and tracheal suctioning; however, meconium-stained amniotic fluid is a perinatal risk factor that requires presence of one resuscitation team member with full resuscitation skills including endotracheal intubation.
- Current evidence suggests that cord clamping should be delayed for at least 30 to 60 seconds for most vigorous term and preterm newborns. If placental circulation is not intact, such as after a placental abruption, bleeding placenta previa, bleeding vasa previa, or cord avulsion, the cord should be clamped immediately after birth. There is insufficient evidence to recommend an approach to cord clamping for newborns who require resuscitation at birth.
- **Oxygen Use (if oxygen blender available)**
  - Resuscitation of newborns ≥35 weeks' gestation begins with 21% oxygen (room air). Resuscitation of newborns < 35 weeks' gestation begins with 21%–30% oxygen.
  - If a baby is breathing but oxygen saturation (Spo_2) is not within target range, free-flow oxygen administration may begin at 30%. Adjust the flowmeter to 10 L/min. Using the oxygen blender, adjust oxygen concentration as needed to achieve the Spo_2 target.
  - Free–flow oxygen cannot be given through the mask of a self-inflating bag; however, it may be given through the tail of an open reservoir.
- If the newborn has labored breathing or Spo_2 cannot be maintained within target range despite 100% free-flow oxygen, consider a trial of continuous positive airway pressure (CPAP).
- **Positive-Pressure Ventilation (PPV)**
  - After completing the initial steps, PPV is indicated if a newborn is apneic or gasping or the heart rate is < 100 beats/min. A trial of PPV may be considered if the baby is breathing and the heart rate is > 100 beats/min but Spo_2 cannot be maintained within target range despite free-flow oxygen or CPAP.
  - For PPV, adjust the flowmeter to 10 L/min.

- Initial ventilation pressure is 20–25 cm H_2O. When positive end-expiratory pressure (PEEP) is used, the recommended initial setting is 5 cm H_2O.
- If PPV is required for resuscitation of a preterm newborn, it is preferable to use a device that can provide PEEP. Using PEEP (5 cm H_2O) helps the baby's lungs remain inflated between positive pressure breaths.
- When PPV is begun, consider using an electronic cardiac monitor for accurate assessment of heart rate.
- The most important indicator of successful PPV is a rising heart rate. If the heart rate does not increase, PPV that inflates the lungs is evidenced by chest movement with ventilation. After intubation or laryngeal mask placement, inflation of the lungs is assessed by chest movement ***and*** bilateral breath sounds with ventilation.
- When PPV begins, the assistant listens for increasing heart rate for the first 15 seconds of PPV.
- If you are attempting PPV but the baby is not improving and the chest is not moving despite performing each of the ventilation corrective steps ("MR. SOPA," below), including intubation, the trachea may be obstructed by thick secretions. Suction the trachea using a suction catheter inserted through the endotracheal tube or directly suction the trachea with a meconium aspirator.

Ventilation Corrective Actions

M Adjust **MASK** to ensure good seal on the face.
R **REPOSITION** airway by adjusting head to "sniffing position."
S **SUCTION** nose and mouth for secretions, if present.
O **OPEN** mouth slightly and move jaw forward.
P Increase **PRESSURE** to achieve chest rise.
A Consider **AIRWAY ALTERNATIVE** (endotracheal intubation or laryngeal mask airway).

- If the heart rate increases to at least 100 bpm with PPV, continue PPV until there is spontaneous respiratory effort.

- If the heart rate is < 60 bpm despite corrective steps and 30 seconds of effective PPV, insert an alternate airway, switch

to 100% oxygen, and initiate **chest compressions** using the 2-thumb technique at 90 compressions/min, compressing one-third the anterior-posterior diameter.

- **Epinephrine** is indicated if the newborn's heart rate remains < 60 beats/min after at least 30 seconds of PPV that inflates the lungs (moves the chest), preferably through a properly inserted **endotracheal tube or laryngeal mask**, ***and*** another 60 seconds of chest compressions coordinated with PPV using 100% oxygen. Epinephrine is ***not*** indicated before you have established ventilation that effectively inflates the lungs.
- One endotracheal dose of epinephrine may be considered while vascular access is being established. If the first dose is given by the endotracheal route and the response is not satisfactory, a repeat dose should be given as soon as emergency umbilical venous catheter (UVC) or intraosseous access is obtained (do not wait 3-5 minutes after the endotracheal dose).
- The recommended solution for acutely treating hypovolemia is 0.9% NaCl (normal saline) or type-O Rh-negative blood. Ringer lactate solution is no longer recommended for treating neonatal hypovolemia.
- The UVC is the preferred method of obtaining emergency vascular access in the delivery room, but the intraosseous needle is a reasonable alternative. All medications and fluids can be infused into an intraosseous needle in term and preterm newborns.
- Sodium bicarbonate should not be routinely given to babies with metabolic acidosis. There is currently no evidence to support this routine practice.
- There is insufficient evidence to evaluate safety and efficacy of administering naloxone to newborns with respiratory depression due to maternal opiate exposure. Animal studies and case reports cite complications from naloxone, including pulmonary edema, cardiac arrest, and seizures.

Refer to the American Academy of Pediatrics Algorithm for the Neonatal Resuscitation Algorithm at: https://www.aap.org/en-us/continuing-medical-education/life-support/NRP/Pages/NRP.aspx.

For Clinical Practice Guidelines, go to
http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 20

Wounds and Injuries of the Spinal Column and Cord

Introduction

Combat injuries of the spinal column, with or without associated spinal cord injury, differ from those encountered in civilian practice. These injuries are often open, contaminated, and usually associated with other organ injuries.

Following the ABCs (airway, breathing, circulation) of Advanced Trauma Life Support, management principles include:

- Initial spine stabilization to prevent neurological deterioration.
- Diagnosis.
- Definitive spinal stabilization.
- Functional recovery.

In complete injuries, the likelihood of neurological recovery is minimal and is not influenced by emergent surgical intervention. Incomplete injuries with neurological deterioration, however, may benefit from emergent surgical decompression. One must assume, until spinal shock has abated, that patients with a significant spinal column injury have the potential for a concomitant neurological deficit, and should be treated and transported accordingly.

Classification

Four discriminators must be considered in the classification and treatment of spinal injuries.

- Is the injury open or closed?
- Neurological status: complete vs incomplete vs intact.

- Complete injury demonstrates no neurological function **below the level of injury** after the period of spinal shock (usually 48–72 hours, evidenced by the return of the bulbocavernosus reflex).

- Location of the injury: cervical, thoracic, lumbar, or sacral.
- Degree of bony and ligamentous disruption: stable vs unstable.

Pathophysiology of Injury to the Spinal Cord

- Injury to the spinal cord is the result of both primary and secondary mechanisms.
  - **Primary:** The initial mechanical injury due to local deformation and energy transmission (primary injury cascade). This phase of the injury is most often unpreventable.
    - High-velocity missile wounds in the paravertebral area can cause injuries even without direct trauma. Stretching of the tissue around the missile's path during formation of the temporary cavity, or fragmentation of the projectile and bone resulting in secondary missiles, causes injury without any direct destruction of the spinal column.

The destructive nature of high-velocity wounds explains the futility of decompressive laminectomy in the management of these wounds.

  - **Secondary:** The cascade of biochemical and cellular processes initiated by the primary process that causes cellular damage and even cell death (secondary injury cascade).

Critical care of spinal cord injury patients includes attempts to minimize secondary injury from hypoxia, hypotension, hyperthermia, and edema.

Mechanical Integrity of the Vertebral Column

The vertebral column is composed of three structural columns (Table 20-1):

- Anterior.

- Middle.
- Posterior.

Table 20-1. Support of the Spinal Column

Column	Bony Elements	Soft-Tissue Elements
Anterior	Anterior two-thirds of vertebral body	Anterior longitudinal ligament Anterior annulus fibrosus
Middle	Posterior one-third of vertebral body Pedicles	Posterior longitudinal ligament Posterior annulus fibrosus
Posterior	Lamina Spinous processes Facet joints	Ligamentum flavum Interspinous ligaments

- Injuries occur by either direct penetrating forces or a combination of flexion, axial loading, rotation, and distraction forces.
- Spinal instability is related to both fracture morphology and the integrity of the spinal ligamentous complex. CT is the most effective means of evaluating spinal fracture morphology.
- Instability may occur from either blunt injury of the vertebral column or gunshot/fragmentation wounds. The incidence of instability is significantly higher in explosion-related injuries.
- Cervical stability can be assessed by flexion-extension lateral radiograph (must include the C7/T1 junction). Instability is suggested by:
  - 3.5 mm or greater sagittal displacement or translation.
  - Angulation of 11° or more on the lateral view.
  - The accuracy and, therefore, the role of flexion and extension lateral radiographs to assess for cervical stability are limited in the acute injury setting. If cervical stability remains in question following initial assessment, the safest course of action is to provide external cervical immobilization until stability can be definitively established.

Instability must be presumed (and the spine stabilized) in any patient with:

- **Complaints of a sense of instability (holds head in hands).**
- **Vertebral column pain.**
- **Tenderness in the midline over the spinous processes.**
- **Neurological deficit.**
- **Altered mental status.**
- **SUSPECTED, but NOT PROVEN, injury.**

Patient Transport

On the battlefield, preservation of the life of the casualty and medic is of paramount importance. In these circumstances, EVACUATION TO A MORE SECURE AREA TAKES PRECEDENCE OVER SPINE IMMOBILIZATION. Data do not support the use of cervical collars and spine boards for PENETRATING spine injuries on the battlefield.

Extrication

- Cervical spine.
  - The neck should never be hyperextended.
  - If an airway is needed: If appropriate, attempt endotracheal intubation with in-line neck stabilization.
    - Cricothyroidotomy may be necessary if intubation fails.
  - The head should be maintained in alignment with the body.
    - Requires several people, including one designated to stabilize the neck.
    - Log roll, with the most experienced person stabilizing the neck.
  - A stiff cervical collar and sandbags provide stabilization of the neck during transport. The head and body should be secured to the extrication device.
- Thoracic and lumbar spine.
  - Use the log roll or two-man carry.
    - The two-man carry alone does not protect the cervical spine. Ensure C-spine protection.

- In the absence of a spine board, makeshift litters can be fashioned from local materials.

Anatomical Considerations

Cervical Spine

- All potentially unstable cervical spine injuries should be immobilized in a cervical collar.
- Certain fracture patterns may be better stabilized with halo immobilization. The decision to place a halo makes medical evacuation more challenging and should be made by a spine surgeon.
- Fracture-dislocations of the cervical spine such as those involving jumped or perched facets require reduction. This is especially relevant in incomplete spinal cord injuries where the deformity may be contributing to ongoing spinal cord compression. Closed reduction of C-spine deformities is done using Gardner-Wells tongs (Figure 20-1, Table 20-2).

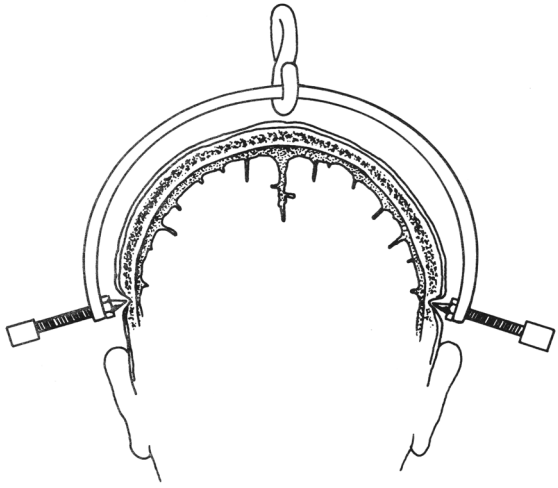

Fig. 20-1. Gardner-Wells tongs.

Thoracic and Lumbar Spine

- Although the thoracic rib cage contributes considerable rotatory stability, it does not protect completely against injuries.

Table 20-2. Application of Gardner-Wells Tongs

Steps	Procedure	Comment
1	**Inspect Insertion Site:** 1 cm superior to pin in line with the external auditory meatus.	Rule out depressed skull fracture in this area.
2	**Shave and Prep Pin Insertion Site**	
3	**Inject Local Anesthetic:** Inject 2–3 cc of 1% Xylocaine or equivalent agent 1 cm above each ear in line with the external auditory meatus.	May omit if patient is unconscious.
4	**Advance Gardner-Wells Tong Pins:** Insert pins into skull by symmetrically tightening the knobs.	A spring-loaded device in one of the two pins will protrude when the pins are appropriately seated. (A data plate on the tongs provides additional information.)
5	**Apply Skeletal Traction:** Use a pulley fixed to the head of the litter or frame to direct horizontal traction to the tongs.	Use the 5-lb rule (ie, 5 lbs of weight for each level of injury). High cervical fractures usually require minimal traction to reduce. Monitor with series radiographs. The tong-pin site requires anterior or posterior positioning to adjust for cervical spine flexing or extension as indicated.
6	**Elevate Head of Litter:** Use blocks to provide body weight counter traction.	The knot in the cord should not be permitted to drift up against the pulley. Should this occur, traction is no longer being applied.
7	**Decrease Traction Weight:** When radiographs confirm that reduction is adequate, decrease traction to 5–15 lbs.	Unreducible or unstable fractures should be maintained in moderate traction until surgical intervention. If neurological deterioration occurs, immediate surgical intervention must be considered.
8	**Daily Pin Care**	Cleanse tracts with saline and apply antibiotic ointment to the pin sites. Maintain pin force (see step 4) by tightening as necessary to keep spring-loaded device in the protruded position.

(Table 20-2 *continues***)**

Table 20-2 *continued*

9	**Turn Patient Appropriately:** Use Stryker, Foster, or similar frame and turn patient every 4 hours.	When initially proned, obtain radiographs to ensure that the reduction is maintained. If reduction is not maintained when the patient is proned, rotate the patient only between the 30° right and left quarter positions. Use of a circle electric bed is contraindicated with injuries of the spinal cord or column.
10	**If Satisfactory Alignment Cannot Be Obtained, Further Workup Is Necessary**	Consider myelogram, CT scan, tomograms, and neurosurgical/orthopaedic consultations.

- The vascular supply of the spinal cord is most vulnerable between T4 and T6, where the canal is most narrow. Even a minor deformity may result in cord injury.

When complex wounds involving the head, thorax, abdomen, or extremities coexist with vertebral column injuries, lifesaving measures take precedence over the definitive diagnosis and management of spinal column and cord problems. During these interventions, further injury to the unstable spine must be prevented by appropriate protective measures.

- The most common place for compression injuries is at the thoracolumbar junction between T10 and L2 in the civilian population. However, a very high preponderance of low lumbar burst fractures (L3 and below) occurs in the military population. These injuries are quite distinct in that the pelvic brim connotes "inherent" stability for these fractures.
- Most burst fractures result from an axial load and occur at the thoracolumbar junction. These fractures are associated with compromise of the spinal canal and progressive angular deformity. They are often associated with significant neurological injury.
- Evaluation for surgical stabilization and spinal cord decompression should be done with advanced imaging, such as CT and/or MRI.

Emergent Surgery

Emergent spine surgery for penetrating or closed injuries of the spinal cord is potentially indicated for incomplete neurological injuries with ongoing spinal cord compression, to repair an open CSF leak, or in the case of neurological deterioration. Spine surgery done in theater carries a higher risk of infection and need for reoperation.

- **Penetrating spine injuries.**
  - Injuries associated with a hollow viscus should undergo appropriate treatment of the viscus injury without **extensive** debridement of the spinal injury, followed by appropriate broad-spectrum antibiotics for 1–2 weeks. Inadequate debridement and irrigation may lead to meningitis.
  - Removal of a fragment from the spinal canal is indicated for patients with neurological deterioration.
  - In neurologically stable patients with fragments in the cervical canal, delaying surgery for 7–10 days reduces problems with dural leak and makes dural repair more straightforward.
  - Casualties not requiring immediate surgery may be observed with spine immobilization and treated with 3 days of IV antibiotics. Surgical stabilization can be performed following evacuation.

General Management Considerations

Neurogenic Shock

- Traumatically induced sympathectomy with spinal cord injury.
- Symptoms include bradycardia and hypotension.
- Treatment:
  - Volume resuscitation to maintain systolic blood pressure >90 mm Hg.
  - May use phenylephrine (50–300 mg/min) or dopamine (2–10 mg/kg/min) to maintain blood pressure. (First treat with fluid resuscitation and oxygen before starting pressor support.)

Gastrointestinal Tract
- Ileus is common and requires use of a nasogastric tube.
- Stress ulcer prevention using medical prophylaxis.
- Bowel training includes a schedule of suppositories and may be initiated within 1 week of injury.

Deep Vein Thrombosis
- Start mechanical prophylaxis immediately.
- Initiate chemical prophylaxis after acute bleeding has stopped (see Chapter 11, Critical Care).

Bladder Dysfunction
- Failure to decompress the bladder may lead to autonomic dysreflexia and a hypertensive crisis.
- The bladder is emptied by intermittent or indwelling catheterization.
- Antibiotic prophylaxis for the urinary tract is not advised.

Decubitus Ulcers
- Skin breakdown begins within 30 minutes in the immobilized hypotensive patient.
- For prolonged transport, the casualty should be removed from the hard spine board and placed on a litter.
- Frequent turning and padding of prominences and diligence on the part of caretakers are essential to protect the insensate limbs.
- All bony prominences are inspected daily.
- Physical therapy is started early to maintain range of motion in all joints to make seating and perineal care easier.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 21

Pelvic Injuries

Introduction

- Injuries of the pelvis are an uncommon, but potentially lethal, battlefield injury.
- Blunt injuries may be associated with major hemorrhage and early mortality. Death within the first 24 hours of injury in these patients is most often due to hemorrhage. Civilian mortality rates have ranged from 18% to 40%.
- Penetrating injuries to the skeletal pelvis are usually associated with abdominopelvic organ injury.
- Key issues in the management of pelvic fractures are to identify if the patient is hemodynamically stable and if the pelvic fracture is mechanically stable.
  - If the patient is not hemodynamically stable, it is imperative to identify all sites of hemorrhage, because pelvic fractures often occur in conjunction with other life-threatening injuries.
  - Appropriate evaluation of the abdomen, chest, and other potential sites of injury and hemorrhage cannot be overstressed.
- Additionally, a thorough examination of the pelvis and perineum is required to rule out associated injuries to the rectum and genitourinary/gynecological systems, which may render the fracture open.
- Open injuries require early recognition and prompt treatment to prevent high mortality due to early hemorrhage and late sepsis. The mortality rate of open pelvic fractures is >50%.
- **Diagnosis.**
  - Leg-length discrepancy, scrotal or labial swelling/ecchymosis, or abrasions over the pelvis raise suspicion for pelvic ring injury.

- Particular injury patterns, such as complex dismounted blast injury with bilateral lower extremity amputations, have a high association with clinically significant pelvic fractures and concomitant life-threatening hemorrhage.
- The perineum, rectum, and vaginal vault must be evaluated for lacerations to rule out an open injury.
- Assess pelvic stability by applying a posteriorly directed force to the iliac crests at the level of the anterior superior iliac spine. If the symphysis opens >2.5 cm, or the hemipelvis shifts posteriorly, the pelvis is unstable. This examination should be completed only once by the most experienced provider available, because additional manipulation can exacerbate hemorrhaging.

Bladder and urethral injuries are suspected when blood is present at the meatus or in the urine, or when a Foley catheter cannot be passed. Retrograde urethrogram and cystography confirm the diagnosis.

  - Radiographs (anterior-posterior pelvis and, when possible, inlet and outlet views) confirm the diagnosis. CT defines the location and extent of injury more accurately, but is not necessary in the immediate evaluation of these patients.

Blunt Injuries

- Patterns and mechanisms are the same as those seen in civilian blunt trauma.
  - Lateral compression injuries are marked by internal rotation or midline displacement of the hemipelvis. By definition, these injuries maintain an intact pelvic floor and are at least partially stable. Radiographic hallmarks include oblique ramus fractures anteriorly and vertically congruent sacroiliac joints posteriorly. Closed-head injuries are associated with this mechanism. Generally, these injuries infrequently require significant transfusion.
  - Vertical shear injuries have cephalad displacement of the hemipelvis and are mechanically unstable. Radiographic hallmarks include a widened symphysis or vertical ramus fractures anteriorly and a vertically disrupted sacroiliac

joint posteriorly. These injuries have a high incidence of retroperitoneal hematoma formation and consumptive coagulopathy. These injuries have a predilection for hemorrhage and may require significant transfusion of blood and blood products for resuscitation.

- Anterior-posterior (open book) injuries demonstrate external rotation of the hemipelvis. Radiographic hallmarks include a widened symphysis or vertical ramus fractures anteriorly and wide but vertically congruent sacroiliac joint(s) posteriorly. These injuries are associated with hollow viscus and solid organ injury and life-threatening hemorrhage. These injuries have a predilection for hemorrhage and may require significant transfusion of blood and blood products for resuscitation.

Combined mechanisms can occur.

- Increasing degrees of displacement in any direction are associated with greater risk of hemorrhage.
  - Anterior-posterior injuries with complete disruption of all sacroiliac ligaments represent an internal hemipelvectomy and have the greatest potential for hemorrhage.

<u>Immediate</u> pelvic stabilization (pelvic binders, sheets, external fixation) can control hemorrhage and reduce mortality. This is particularly true in an austere environment with limited blood replacement products and other treatment resources.

- Treatment.
  - Hemorrhage control.
    - When pelvic fractures cause hemorrhage, the bleeding originates from three major sources: arterial, venous, and cancellous bone. In more than 70% of cases, hemorrhage associated with blunt pelvic trauma causing pelvic fracture is venous and may be controlled with maneuvers that stabilize the pelvis.
    - Mechanical stabilization can be obtained by:

- ◊ Tying a sheet or placing a binder around the pelvis at the level of the greater trochanters.
- ◊ Manually reducing the pelvis and placing bean bags or sandbags at the level of the trochanters.
- ◊ Positioning the patient in lateral decubitus with the affected side down.
- ◊ Tying the ankles together in internal rotation may provide additional stabilization.

Pelvic binders or sheets are the most expeditious way to control hemorrhage and provide pain relief through pelvic stabilization and reduction of intrapelvic volume. External fixators can provide longer term stabilization, but are difficult to place and have a higher incidence of complications. Skin necrosis can occur with long-term application of pelvic binders and sheets.

- ♦ 20% to 30% of pelvic fractures are associated with bleeding from an arterial source and may require procedural interventions, such as surgical packing and/or embolization.

- Angiography is a useful adjunct, but is not usually available in the deployed environment. When available, angiographic exploration with early embolization for the hemodynamically unstable patient with intrapelvic hemorrhage may be beneficial.
- Given that this capability is rarely available outside of a Role 3 facility, the next most beneficial maneuver is retroperitoneal packing via a suprapubic incision.
- Opening a retroperitoneal pelvic hematoma (as a result of a pelvic fracture) from inside the abdomen is highly discouraged and should be attempted only as a last resort.
- None of these interventions should delay the necessary acute surgical treatment for concomitant hemorrhagic injuries.
  - Open blunt injuries require:
    - ♦ Immediate hemorrhage control by packing.
    - ♦ Aggressive and thorough debridement.
    - ♦ Pelvic stabilization by external fixation.
    - ♦ Diverting colostomy in the presence of wounds at risk for fecal soilage.

- Definitive internal pelvic stabilization (plates, screws, etc) is performed outside of the combat zone.

Missile and fragmentation wounds can cause pelvic fractures.

- **The pelvis usually remains mechanically stable.**
- **The colon, small intestine, rectum, and the genitourinary tracts must all be assessed for associated injury.**
- **Major hemorrhage can result from injury to the iliac vessels.**

Penetrating Injuries

- **Evaluation.**
  - Diagnosis of associated injuries may require exploratory laparotomy.
  - Fractures should be assessed with radiographs and CT scans, when available, to rule out extension into the hip and acetabulum.
- **Treatment.**
  - Control hemorrhage and resuscitate with blood and blood products.
  - Control hollow viscus injury.
  - Thoroughly debride wounds and fractures.

For combined hollow viscus and acetabulum/hip joint injuries, the joint is contaminated and must be explored and treated as described in Chapter 9, Soft-Tissue and Open Joint Injuries.

- **Technique of sheet or pelvic binder application.**
  - Slide the folded sheet (30–40 cm wide) or binder under the supine patient, centered at the level of the greater trochanters.
  - With a second individual on the opposite side of the table, overlap the ends of the sheet (or Velcro straps of the binder) circumferentially, applying compression across the pelvis.
  - Secure the sheet in place with large Kelly clamps, or, alternatively, tighten the draw string on the binder.

- Binders can be left in place for 24–48 hours, but require frequent skin checks for longer periods of use.
- Confirm reduction of the pelvis with an anterior-posterior pelvis X-ray.

- Technique of pelvic external fixator placement (Fig. 21-1).
  - Prep the iliac crests.
  - Place a 2-cm horizontal incision over the iliac crest, 2–3 cm posterior to the anterior-superior iliac spine.

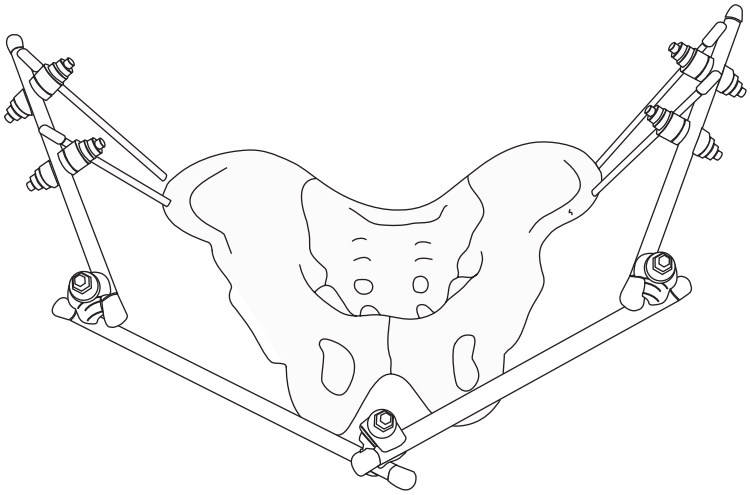

Fig. 21-1. Pelvic external fixator placement.

  - Bluntly dissect to the iliac crest, taking care to identify the intermuscular plane between the external oblique and iliacus, which will lessen bleeding.
  - To determine the angle of the pelvis, first slide a guide pin between the muscle and the bone along the inner table of the iliac wing no deeper than 3–4 cm.

Failure to properly determine the angle of the iliac wing leads to inadequate fixation and may cause significant complications.

- Locate the junction of the middle and medial thirds of the thickness of the iliac crest with the tip of a 5-mm external fixator pin.
- Paralleling the guide pin, begin drilling the pin into the crest.
- Drill between the inner and outer tables to a depth of about 4 cm, aiming generally toward the greater trochanter. Only gentle pressure should be applied once the pin threads have engaged to allow for the pin to guide itself between the tables.
- A second pin is inserted 1–2 cm more posteriorly on the crest.
- Check the stability of each pin. If unsatisfactory, attempt reinsertion by aiming between the tables.
- Place pins in the contralateral iliac crest in the same manner.
- Reduce the pelvis by applying pressure on the pelvis (**not the pins!**) and connect the external fixator pins with bar(s) across the abdomen and pelvis to maintain reduction.

- **Technique for retroperitoneal packing.**
  - Prep the abdomen and make an 8-cm midline incision extending proximally from the level of the symphysis pubis toward the umbilicus. Alternatively, if a prior laparotomy incision has been made, one can extend the incision distally to the symphysis.
  - Divide the fascia of the rectus abdominus at its midline, taking care to avoid penetrating the underlying bladder.
  - Retract the bladder to one side with the use of a malleable retractor, and identify the pelvic brim beginning at the level of the symphysis pubis and extending posteriorly.
  - To the greatest extent possible, quickly identify whether the bulk of the bleeding encountered is venous or arterial in nature. If arterial, consider subsequent embolization procedures.
  - Taking care to avoid disruption of common vascular connections between the obturator and iliac systems (corona mortis), identify the pelvic brim and place the first of three laparotomy sponges with the aid of a sponge stick posteriorly to the level of the sacroiliac joint, below the level of the pelvic brim (true pelvis).

- A second sponge is packed at the midportion below the pelvic brim, with the third sponge placed below the bladder anteriorly into the space of Retzius.
- The bladder is retracted to the other side, and the procedure is repeated for the opposite hemipelvis.
- The rectus fascia is closed, with a single layer running suture and the skin is closed with staples.
- Exploratory laparotomy, if required, should follow closure of the retroperitoneal fascia to allow for the continued tamponade of the vessels in the retroperitoneum.
- Packing should be carefully removed within 24–48 hours.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 22

Extremity Fractures

Introduction

This chapter discusses two techniques for safe transportation of wounded service members with a long bone fracture: **splinting** and **temporary external fixation**. Both of these methods are acceptable for initial treatment of a casualty who will be evacuated out of theater.

Both splints and external fixators are acceptable methods for the initial management of long bone fractures. In the end, the choice of initial fracture stabilization must be made on a case-by-case basis by the treating surgeon.

External fixators are of benefit when soft tissue access is necessary, such as with a vascular injury; when other injuries make use of splinting impractical, such as with a femur fracture and abdominal injury; or with extensive burns. A splint and bulky dressing may be used to augment a limb that has been externally fixated for better soft-tissue support.

Although standard in civilian trauma centers, intramedullary nailing of major long bone fractures is contraindicated in combat zone hospitals because of a variety of logistical and physiological constraints. This method may be used once a patient reaches a Role 4 or other site where more definitive care can be provided. Intramedullary nailing has been performed successfully at Role 3 facilities on local nationals after appropriate initial damage control surgeries, however these should be placed with caution. Local national surgeons must be able to care for patients with orthopaedic implants, particularly in the event they become infected. Historically, infected intramedullary devices have posed a significant management problem in developing countries.

General Considerations of Wound Management

- Initial management.
  - Treat by debridement and irrigation as soon as feasible to help prevent infection.
  - Biplanar radiographs should be obtained when possible.
  - Neurovascular status of the extremity should be documented and checked repeatedly.
  - Internal fixation is contraindicated in the face of gross contamination.
  - Begin IV antibiotics as soon as possible and maintain throughout the evacuation chain. Use a broad-spectrum cephalosporin (Cefazolin 1-2 grams q8h).
- Wound incision/excision.
  - Guidelines as per Chapter 9, Soft-Tissue and Open Joint Injuries.
  - Use longitudinal incisions to obtain exposure.
  - The fascia is incised longitudinally to expose underlying structures and facilitate **compartment release.**
  - All foreign material in the operative field must be removed, along with devitalized bone and nonviable muscle (Fig. 22-1).
  - Bone fragments should be retained only if they have a viable soft-tissue attachment or constitute a large portion of the joint.
  - Detached bone fragments are discarded.
  - Copious irrigation is essential (Fig. 22-1d).
  - Pulsatile lavage is not necessary.
- Closure of wounds.
  - Primary closure is **NOT** indicated in these contaminated wounds. Loose approximation of tissues with one or two retention sutures **MAY BE** appropriate to cover nerves, vessels, and tendons; but, there must be a provision for substantial free drainage.
  - Skin grafts, local flaps, and relaxing incisions are contraindicated in the initial management.
  - Delayed primary closure may be attempted, as described in Chapter 9, Soft-Tissue and Open Joint Injuries. This should be accomplished in a stable wound environment following acceptable serial debridement.
  - Negative pressure wound therapy is a useful adjunct in soft-tissue wound management.

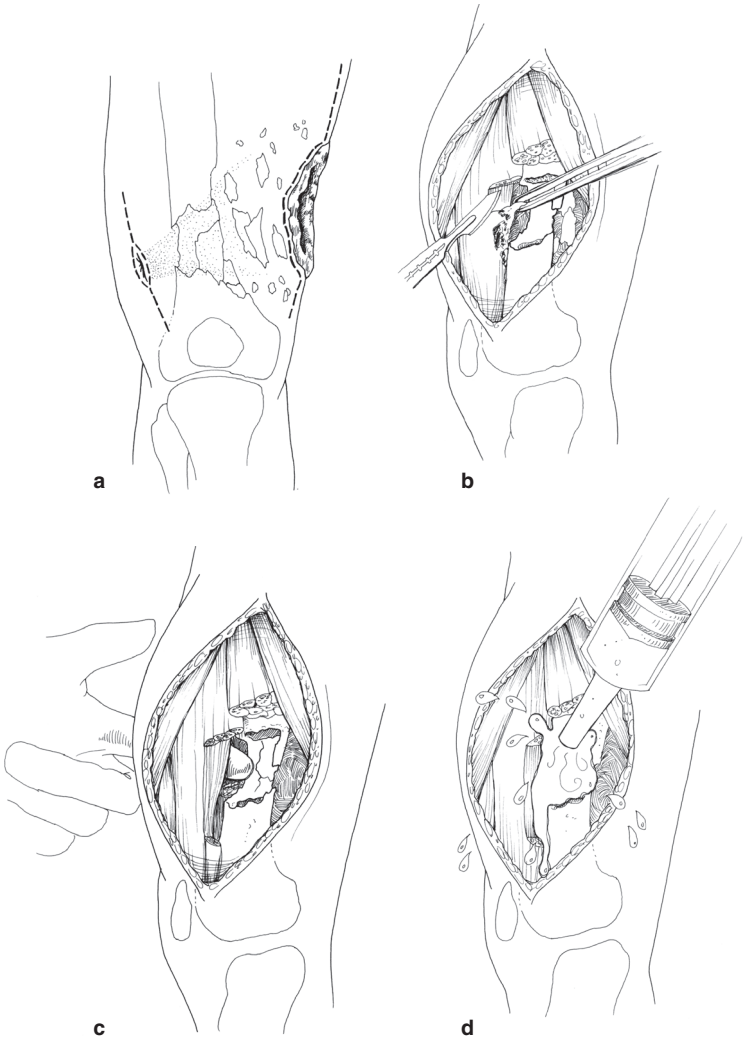

Fig. 22-1. Wound incision/excision.

External Fixation

- General technique: the surgeon should be familiar with four standard constructs of external fixation for use in the initial care of bone and joint injuries: femur, tibia, knee, and ankle.

External fixation can also be applied for humerus and ulna fractures, although these are seldom required.

- A thorough understanding of the anatomy of the extremities is essential for safe insertion of fixator pins.
- The external fixator for military purposes should be modular and allow for modification as healing progresses.
- Application of the external fixator may be done without the use of plain films or fluoroscopy.
- Pins can be inserted without power instruments.
- Enough pins should be placed to adequately stabilize the fracture for transport. This is usually two per multipin clamp, but three may occasionally be required.
- Most external fixation systems allow for the use of either single pin clamps or multipin clamps. Both clamps are acceptable to use in standard constructs.

- Femur diaphyseal fracture technique.
  - The entire limb is prepared for surgery, from the anterior superior iliac spine to the toes.
  - A standard OR table or portable fracture table may be used.
  - An assistant should apply counter pressure while pins are inserted.
  - Precise reduction is not necessary; however, one should reestablish appropriate length to optimize distal limb perfusion and to facilitate future reduction. A padded "bump" under the thigh will help reduce the fracture (Fig. 22-2).

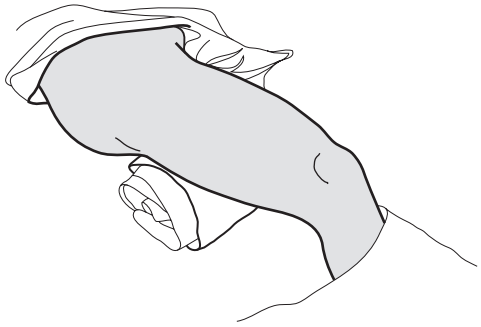

Fig. 22-2. Placing a towel underneath the thigh helps to reproduce the bow of the femur.

- The position of the proximal femur should be identified by palpation. A 1-cm longitudinal stab incision is made over the midaxis, or midlateral axis, of the femur (Fig. 22-3). Anteromedial pins place the neurovascular structures at risk and should be avoided. The pin closest to the fracture should be outside of the fracture hematoma and at least 3 fingerbreadths from the fracture (Fig. 22-4).

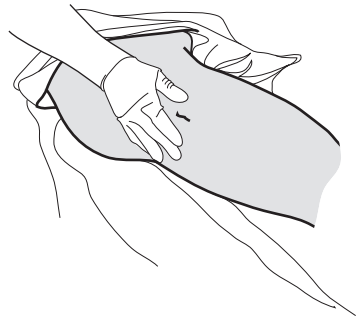

Fig. 22-3. Place a 1-cm longitudinal incision in line with the midlateral axis of the femur.

- Spread soft tissue bluntly down to the bone. Insert a pin through this opening and when reaching the bone, assess its midpoint by sweeping the pin anteriorly and posteriorly (Fig. 22-5). Your assistant should provide stability and counter pressure. Pins are placed by hand or power. Use 5 or 6-mm half-pins for the femur. Insert the pin in the midportion of the bone and advance through both the near and far cortices. (Fig. 22-6). The pin will move easier as it enters the intramedullary canal and become more difficult to drive as it enters the far cortex.

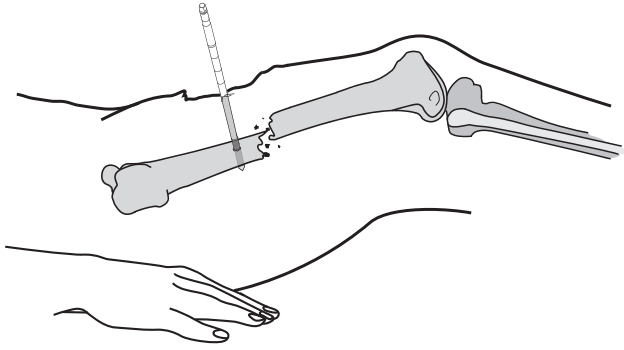

Fig. 22-4. Pins should be placed outside of the fracture hematoma and at least 3 fingerbreadths from the fracture.

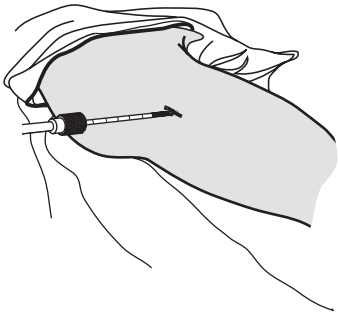

Fig. 22-5. Femoral pin placement.

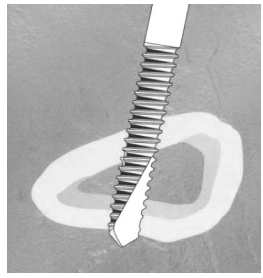

Fig. 22-6. Bicortical placement of 5-mm half-pin.

- Place a multipin clamp over the inserted pin. Ideally, the pin should occupy one of the end positions (Fig. 22-7).
- Using the clamp as a guide, insert a second pin through the clamp. An assistant should hold the clamp. Ensure that the clamp is aligned with the bone and that bicortical purchase is obtained. The second pin must be parallel to the first pin. To ensure they are parallel, it can be helpful to use the clamp as a guide for placing the second pin. Use the pin sites that are the farthest apart on the clamp as possible for biomechanical stability (see Fig. 22-7). A third pin may be inserted if needed for additional clamp stability.

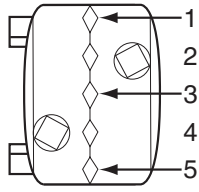

Fig. 22-7. Multipin clamp showing positions 1–5.

- Repeat this technique when inserting pins and applying the multipin clamp to the distal femoral fracture fragment.
- Connect the two clamps with elbows, bar-to-bar clamps, and two longitudinal bars placed parallel to each other (Fig. 22-8).
- Reduce the fracture with longitudinal traction. Manipulating the fracture fragments using the clamps may be helpful. Once adequate reduction is achieved, tighten all of the connections. Precise reduction is not necessary.

- Tibia shaft fracture technique.
  - Place a 1-cm longitudinal incision over the anteromedial face of the tibia (Fig. 22-9). The pin closest to the fracture

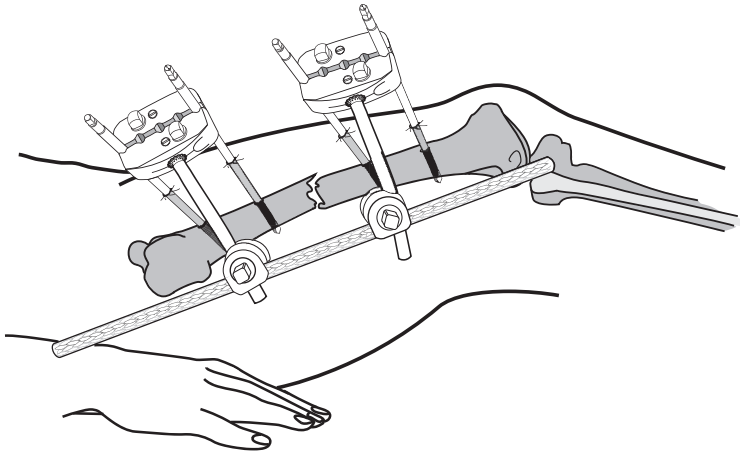

Fig. 22-8. Frame applied and fracture grossly reduced. Anterolateral or anterior placement of stabilizing rod is preferred. Consider use of multiple rods for increased stability.

site should be outside the hematoma and at least 2–3 fingerbreadths away from the fracture site (Fig. 22-10).

- Insert the first pin into either the proximal or distal fragment. Place the pin perpendicular to the subcutaneous border of the tibia and centered across the width of the tibia. Ensure that pins engage both cortices (Fig. 22-11).

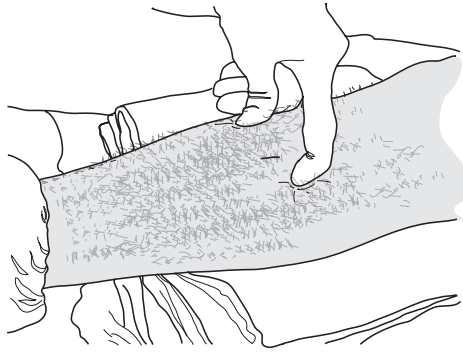

Fig. 22-9. Palpation of the anterior and posterior margins of the medial face of the tibia where a 1-cm incision has been made midway between these two points.

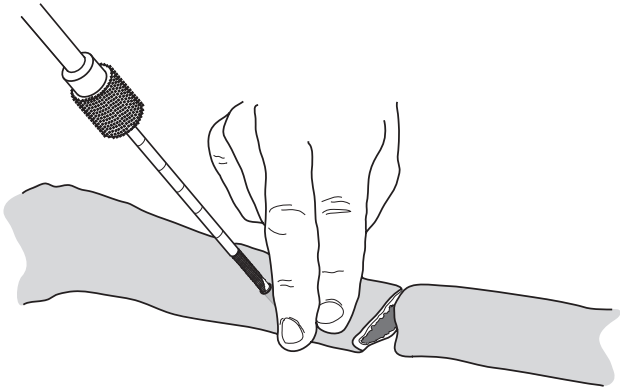

Fig. 22-10. The anteromedial surface is the safest location for tibial pins. Pins should be a minimum of 2 or 3 fingerbreadths from the fracture site.

- Using the clamp as a guide, insert a second pin through the clamp. An assistant should hold the clamp. Align the clamp with the bone and advance the pin through both cortices. The second pin **must** be parallel to the first. Use the pin sites as far apart on the clamp as possible for biomechanical stability (see Fig. 22-7).
- Apply a second multipin clamp and two pins in the same manner to the other main fracture fragment (Fig. 22-12). Connect the two clamps via two elbows, bar-to-bar clamps, and a single bar (Fig. 22-13).
- Most combat-related fractures are comminuted. Therefore, a second bar may be added for increased fracture stabilization (Fig. 22-14).

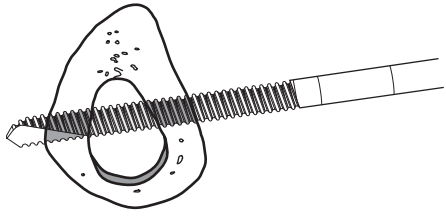

Fig. 22-11. Bicortical placement of tibial pins.

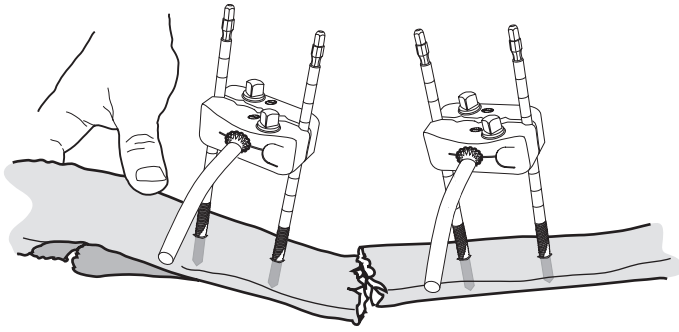

Fig. 22-12. Application of the second multipin clamp and two pins. Add 30-degree elbows to the two sets of multipin clamps. Point the elbows in a direction that will position the bar(s) away from open wounds and allow for the best access.

- Technique to span knee.
  - Indications are proximal tibia fractures, distal femur fractures or extensive knee injuries, or vascular repairs in the popliteal fossa.
  - Check the distal vascular status of the limb prior to and after the procedure. If there is a vascular injury, refer to Chapter 25, Vascular Injuries.

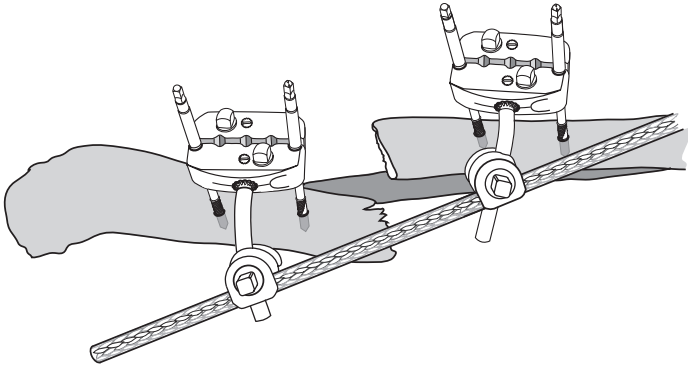

Fig. 22-13. Addition of the cross-bar and two bar-to-bar clamps. Apply longitudinal traction to reduce the fracture and then tighten the frame in alignment.

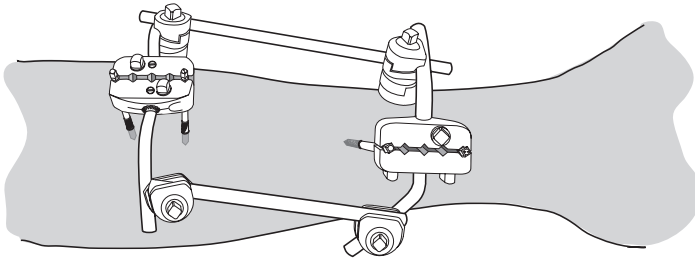

Fig. 22-14. The two-bar apparatus is a more stable construct for typical, unstable tibial fractures.

- General reduction maneuver should be longitudinal traction with slight (10°–15°) flexion at the knee.
- Pins are placed anteromedial on the proximal tibia and anterolateral on the distal femur. Pin placement should be outside the zone of injury, at least 3 fingerbreadths from a fracture site and outside the knee joint. A longitudinal stab incision is made over the mid-anterolateral aspect of the femur and the pin inserted at a 45-degree angle to the long axis of the bone. Depending on the fracture configuration, it may also be placed directly anteriorly, although it is generally better to avoid pin placement through the quadriceps tendon.
- Blunt dissection is used to create a corridor to the bone.
- A single pin is inserted by hand or power through both cortices of the bone.
- A multipin clamp is used as a guide for a second pin. The second pin **must** be parallel to the first pin and also be bicortical—care should be taken to maintain pin alignment. The proximal tibia should be palpated on the anteromedial surface, and pins should be placed in a similar fashion as described above for the placement in tibial fractures.
- The two pin clusters (femur and tibia) should be connected via 2 elbows, 2 bar-to-bar clamps, and 1 bar. The knee should be aligned.
- A second bar may be added in the manner described previously.

- Technique to span ankle.
  - An assistant will be required to help apply the frame and reduce the ankle.
  - General indications are for open distal tibia fractures and open ankle wounds.
  - Pins should be inserted on the anteromedial surface of the tibia and on the medial aspect of the calcaneus.
  - Check the distal vascular status prior to and after the procedure. Mark where the posterior tibial and dorsalis pedis artery pulses can be felt.
  - Palpate the anteromedial border of the tibia. Make a 1-cm longitudinal incision midway between the anterior-posterior border of the tibia. Insert the most distal pin on the tibia outside the zone of injury, at least 3 fingerbreadths from the fracture site.
  - Using a multipin clamp as a guide, insert a second pin in the tibia proximal to the first pin. The pin **must** be parallel and aligned with the longitudinal axis of the first pin.
  - Palpate the medial border of the calcaneus. Make a longitudinal incision over the calcaneus **avoiding the posterior neurovascular structures**: dissect to the bone with a blunt instrument and insert the pin. When available, insert a centrally threaded pin from medial to lateral. The pin insertion point should be the junction of posterior and middle one-third distance between medial malleolus and posterior calcaneus tuberosity. If using two half pins, then apply in the posterior half of this line.
  - Using a multipin clamp as a guide, insert a second pin in the calcaneus.
  - Connect the 2 clamps via 2 elbows, 2 bar-to-bar clamps, and 1 bar.
- Skeletal traction.

As skeletal traction is incompatible with the evacuation of patients on most standard military aircraft, its use in theater is generally discouraged.

- Care in the evacuation chain.
  - When planning procedures, consider the potential for complications during air evacuation.
  - Consider medication supply for transport (see Chapter 4, Aeromedical Evacuation).
  - Skeletal traction should **not** be used for transportation.
  - Casts should not be used. **Casts may act as tourniquets due to tissue swelling**. Even a bivalved cast can create the same effect if the ace wrap is applied too tightly.
  - All documentation, including radiographs, should accompany the patient.
  - Well-padded splints can be used with and without external fixation with large open wounds, such as blast injuries.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 23

Amputations

Introduction

Battle casualties who sustain amputations have the most severe extremity injuries.

- Historically, 1 in 3 patients with a major amputation (proximal to the wrist or ankle) died, usually of exsanguination.
- Although complete and near-complete traumatic amputations are visually dramatic, attention must be focused on the frequently associated life-threatening injuries, including control of ongoing hemorrhage from the damaged limb(s).

Goals for initial care are to preserve life, prepare the patient for evacuation, and leave the maximum number of options for definitive treatment.

Indications for amputation following trauma:

- Partial or complete traumatic amputation.
- Irreparable vascular injury or failed vascular repair with an ischemic limb.
- Life-threatening sepsis due to severe local infection, including clostridial myonecrosis.
- A patient in extremis with severe soft-tissue and bony injuries to the extremity precluding functional recovery.

The surgeon must balance the realistic likelihood of ultimate reconstruction of a functional extremity against the risk of death associated with attempts to preserve a limb. It is always desirable to secure the opinion of a second surgeon before amputating. The tactical situation or the patient in extremis may require amputation in cases where the limb might otherwise have been salvaged.

- Battlefield amputations are unique.
  - Most commonly due to explosive munitions, with penetration and blast effects (see Chapter 1, Weapons Effects and War Wounds).
  - Involve a large zone of injury with a high degree of contamination, which may affect the level of amputation and/or reconstructive options.
  - Require staged treatment, with evacuation out of the combat zone prior to definitive closure.

Amputations should be performed at the lowest viable level of soft tissues, in contrast to traditional anatomical amputation levels (eg, classic above the knee, below the knee, etc) to preserve as much limb as possible. In general, a longer residual limb is desirable for final prosthetic fitting, and initial preservation of all viable tissues maximizes the reconstructive and coverage options available at higher levels of care.

The open **length preserving amputation** procedure has two stages: initial and reconstructive.

- **Initial**—Complete the amputation at the lowest possible level of bone and prepare the patient for evacuation to the next level of care.
- **Reconstructive**—Involves final healing of the limb to obtain the optimal residual limb.
- **NOTE: The final level of amputation and definitive treatment of the residual limb should occur in the stable environment of a CONUS hospital, not in the combat zone hospital.** In the case of host nation casualties or enemy combatants, wherein evacuation is not an option, several debridement and irrigation procedures are generally indicated prior to attempting definitive amputation and closure to prevent high wound failure and infection rates.

  - All viable skin and soft tissues distal and proximal to the indicated level of bone amputation should be preserved for use in subsequent closure of the amputation stump.

These tissues may be considered "flaps of opportunity" and can add length to the stump. This is especially true for amputations below the knee. Short tibia limbs can be saved with posteriorly based flaps because the gastrocnemius and soleus are frequently preserved following blast injury. To save length, any shape or form of a viable muscle or skin flap should be preserved. Preservation of even oblique or irregular soft-tissue flaps or viable bone lacking distal soft-tissue coverage maximizes the reconstruction options at higher levels of care. Late free tissue coverage can sometimes salvage functional joint levels. Therefore, residual viable tibia (if distal to the tibial tuberosity) should be preserved initially, even if the remaining soft tissues would not initially permit wound closure.

Technique of Amputation

- Perform surgical preparation of the **entire** limb to facilitate full evaluation, including the extent of the full zone of injury and the need for proximal vascular control.
- Tourniquet control is mandatory. If a tourniquet was placed in the prehospital setting for hemorrhage control, it is prepped entirely within the surgical field.
- Excise nonviable tissue.
  - Necrotic skin and subcutaneous tissue or skin without vascular support.
  - Muscle that is friable, shredded, grossly contaminated, or noncontractile. (This muscle is usually at the level of the retracted skin.)
  - Bone that is grossly contaminated or devoid of soft-tissue attachment for blood supply. Bone is transected at its lowest viable level, regardless of the residual soft-tissue coverage.
- Identify and securely ligate major arteries and veins to prevent hemorrhage in transport.
- Identify nerves and transect them at the level of available muscular coverage to minimize patient pain due to dressing changes. More proximal traction neurectomy is best reserved for the definitive closure procedure at higher levels of care. Initial traction neurectomy may preclude further reconstructive options at definitive closure as the final level

of amputation may be well proximal to the initial level of viable tissue debridement. Ligate the major nerves if they are bleeding (eg, sciatic); tagging of major nerves with colored suture is reasonable, but not mandatory.

- Preserved muscle flaps should not be sutured, but should be held in their intended position by the dressing.
- Flaps should not be constructed at the initial surgery to facilitate later closure.

In blast injuries, particularly landmine injuries, the blast forces drive debris proximally along fascial planes. It may be necessary to extend incisions proximally parallel to the axis of the extremity to ensure adequate surgical debridement of the wound. Each successive debridement should explore all intermuscular and fascial planes to avoid missing areas of purulence or necrosis, without devascularizing the remaining skin flaps.

The residual limb is never closed primarily.

- **Special considerations.**
  - Primary Symes (ankle disarticulation) has a high failure rate due to heel pad necrosis during transport. The wound should simply be debrided, retaining the clean hindfoot (talus and calcaneus).
  - Primary knee disarticulation is problematic due to skin and tendon retraction necessitating reamputation at a higher, often less functional level. It is preferable to leave even a very short (1–2 cm), clean transtibial stump—even though nonfunctional—to prevent retraction, as well as to preserve as much patellar tendon, gastrocnemius, and distal skin as possible.
  - Fractures, when present proximal to the mangled segment, should not determine amputation level, but must be treated appropriately (splint, external fixator) to preserve maximal length and salvage functional joint levels.
  - Plan the initial amputation solely on the qualities of the wound and surrounding tissues, never on the hope

of achieving a particular level or flap pattern as a final result. The combat surgeon's goals are patient survival, hemostasis, and a thorough and complete debridement. Trying to preserve marginal tissue in the hope that a better stump can be constructed may lead to subsequent infection and a more proximal amputation level.

- For high transfemoral and more proximal amputations (ie, hip disarticulation or hemipelvectomy), particularly when bilateral injuries are present, proximal vascular control via exploratory laparotomy and temporary clamping of the common iliac vessels and/or infrarenal aorta and inferior vena cava can be lifesaving. When this is performed for bilateral proximal amputations, complete proximal fecal diversion with distal colonic washout should be strongly considered concurrently, independent of abdominal injuries, to prevent fecal contamination of wounds.

Dressings

Because amputations must be left open, skin retraction is likely, causing the loss of usable limb length and making definitive closure difficult. This is particularly true of a patient who is in the evacuation chain for a prolonged period.

Negative pressure wound therapy (NPWT) dressings may be placed prior to evacuation only if reliable maintenance of suction can be expected during transport and on arrival at the next level of care. If an NPWT wound dressing is used, skin traction and countertraction can be achieved using a running vessel loop in a laced fashion, secured to the skin edges over the reticulated foam and held in place with staples. Monitor output on NPWT device for excess output that could indicate ongoing bleeding.

After initial completion of amputation a temporary dressing can be fashioned by applying gauze sponges to the end of the stump and loosely approximating the flaps over the gauze. This aids with hemostasis and prevents skin retraction and folding of loose flaps and compromising their blood supply. This is intended as a short-term dressing to facilitate transport.

Postoperative Management

- Prevention of contracture.
  - Below-the-knee amputations are at risk for knee flexion contractures. These contractures are preventable by using a knee-spanning splint. Splinting in extension requires closer monitoring and meticulous cast padding placement and cutouts over the patella. Pillows should never support the knee because of the increased risk of flexion contractures.
  - Above-the-knee amputations are at risk for hip flexion contractures. Prone positioning, when feasible, and active hip extension exercises will reduce the likelihood of this complication.
- Prevention of hemorrhage: a tourniquet should be readily available at bedside or during transport for the first week following injury.
- Pain control: patient comfort is paramount following amputation, particularly if dressing changes are required. Adequate analgesia should be available, and the patient should be counseled regarding phantom limb pain/sensations.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 24

Injuries to the Hands and Feet

Introduction

Combat injuries to the hands and feet differ from those of the arms and legs in terms of mortality and morbidity. The hands and feet have an important commonality: an intricate combination of many small structures that must function smoothly together. Because these terminal appendages are extremely specialized and represent the interface of the person to the outside world, a minor wound—causing no lasting impairment if inflicted, for example, on the thigh—can result in life-long disability when it occurs on a hand or foot.

Types of Injury

- Nonbattle injuries resulting in laceration, contusion, or sprain of the hand and foot.
- Crush injuries involving either the hands or feet from heavy equipment are common. Such crush injuries may result in compartment syndrome.
- Missile, blast, and high-energy ordnance injuries involving the hands and feet are common in combat and may result in mutilating injuries with a permanent loss of function, innervation, or distal extremity tissue (amputation).

The Hand

Even apparently minor wounds distal to the wrist crease may violate tendon sheaths and joints, resulting in a serious deep space infection. Such wounds require a high index of suspicion for injury and a low threshold for operative exploration.

Evaluation and Initial Management

- The casualty's upper extremities should be exposed.
- Rings, watches, and other potentially constrictive material must be removed immediately.
- A preliminary neurological examination should be performed and documented.
- Vascular status of the hand should include an assessment of radial and ulnar pulses, and perfusion to each fingertip as assessed by color, warmth, and capillary refill.

Treatment of Hand Compartment Syndrome

- The hand has 10 separate fascial compartments (4 dorsal interossei, 3 palmar interossei, the thenar muscles, the hypothenar muscles, and the adductor pollicis; Fig. 24-1).

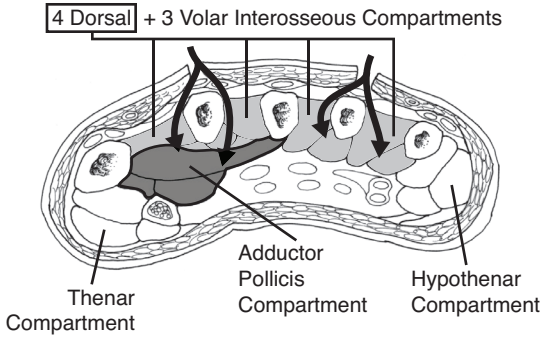

Fig. 24-1. Compartments of the hand.

  - A complete hand fasciotomy consists of four incisions (shown in Fig. 24-2):
    - The **first incision** is placed along the thumb metacarpal at the radial aspect of the hand to release the fascia of the thenar muscles.
    - The **second incision** is centered dorsally on the index metacarpal. On the radial side of this bone, the fascia of the first dorsal interosseous and the adductor pollicis is incised. On the ulnar side of this bone, the fasciae of the dorsal and palmar interossei is incised.

- The **third** incision is centered dorsally on the ring metacarpal. From this wound, the fascia of the dorsal and palmar interossei is released on both sides of this bone.
- The **fourth incision** is placed along the small metacarpal on the ulnar aspect of the hand to release the fascia of the hypothenar muscles.

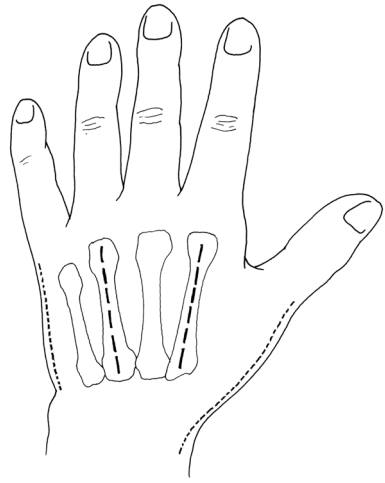

Fig. 24-2. Hand fasciotomy incisions.

- Although compartments are not well defined in the fingers, fingers that are severely swollen may require release of dermal and fascial constriction; care should be taken to place the skin incision away from the neurovascular bundles (Fig. 24-3).

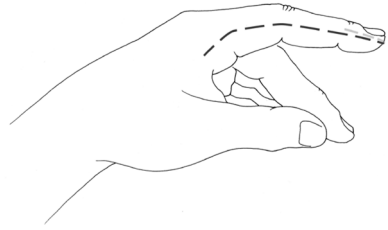

Fig. 24-3. Incision for finger fasciotomy.

Surgical Technique

Do not blindly clamp bleeding tissues because nearby nerves may be injured. If unable to control the bleeding with pressure, isolate the vessel under tourniquet control and tie off or clamp under direct vision.

- General or regional (block) anesthetic is required; local infiltration of anesthetic is inadequate. Epinephrine should not be injected into the hands or fingers.
- Either the radial or ulnar artery may be ligated if necessary. Never ligate both.

- Debridement removes embedded foreign matter and dead tissue.
- Tissue, including skin, with marginal or questionable viability is left for subsequent evaluation to improve chances for optimal outcome.
- The fingers are not amputated unless irretrievably mangled.

Viable tissue, but potentially nonfunctional, is retained and stabilized for later reconstruction to include other locations.

Specific Tissue Management

- **Bone:** Provisional stabilization of fractures with Kirschner wires (K-wires), when skillfully done, may enhance patient comfort. Do not compromise future reconstructive efforts with overzealous initial management. A plaster splint may be the best option.
- **Tendon:** Minimal excision of tendons should be performed. No attempt at repair should be made in the field.
- **Nerve:** Do not excise nerve tissue. No attempt at repair should be made in the field.
- One may tag the cut ends of nerves and tendons to facilitate later repair. Monofilament nonabsorbable suture (6.0 or smaller) should be placed through the epineurium only of cut nerve ends.

Closure of wounds is delayed. However, exposed tendon, bone, and joint should be covered with viable skin, if possible, to prevent desiccation.

Dressing and Splinting

Splint the hand in the safe position (Fig. 24-4). The wrist is extended 20°, the metacarpophalangeal joints are flexed 70°–90°, and the fingers (proximal and distal interphangeal joints) are in full extension.

- Fine-mesh gauze is first laid on the wounds and covered with a generous layer of fluffed gauze.

- The entire wound should be covered, but the fingertips left exposed, if possible, to monitor perfusion.
- A splint is applied, immobilizing all injured parts and extending one bone or joint beyond. A palmar plaster slab is routine, but a dorsal one may be added for additional stability.

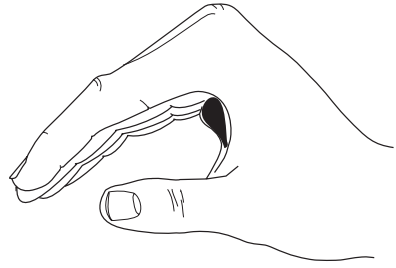

Fig. 24-4. Hand splint position.

The Foot

Penetrating injuries of the foot frequently result in prolonged morbidity and disability. Crush injuries and injuries from blast are more likely to result in an unsatisfactory result than are wounds made by low-velocity bullets or isolated fragments. This is especially true when there is loss of the heel pad, significant neurovascular injury, or when the deep plantar space has been contaminated. The ultimate goal of treatment of these injuries is a relatively pain-free, plantigrade foot with intact plantar sensation.

Evaluation and Initial Management

- The zone of injury in both open and closed injuries of the foot is often more extensive than is apparent with the initial inspection, and a low threshold for extensile debridement using longitudinal incisions should be observed.
- All clothing and boots should be removed and the entire foot exposed.
- The vascular status of the foot should be assessed by palpation of the dorsalis pedis and posterior tibial pulses or with use of a Doppler device if available. An assessment of capillary refill in the toes should also be made to assess peripheral perfusion.
- Transected major blood vessels to the foot should be double suture ligated to include plantar and dorsal pedal arteries and veins. Transected nerves may be tagged with suture for subsequent identification.

- At the time of debridement, small, contaminated, nonarticular bone fragments without soft-tissue attachment should be removed and discarded.
- High-volume, low-pressure irrigation for all open wounds is important as an adjunct to thorough surgical debridement. Vessel loop tissue tensioning technique may be used to prevent wound expansion during transport.

All wounds should be left open.

Sterile wet-to-dry dressings or negative pressure wound dressings should be placed for transport.

Injuries to the Hindfoot

- Severely comminuted, open fractures of the talus may require talectomy; but this decision should be left to higher levels of care.
- The talus is best debrided through an anterolateral approach to the ankle extended to the base of the fourth metatarsal.
- Penetrating wounds into the plantar aspect of the heel pad can be approached through a heel-splitting incision to avoid excessive undermining of this specialized skin.
- Transverse gunshot wounds of the hindfoot are best managed by medial and lateral incisions, with the majority of surgery performed laterally to avoid medial neurovascular structures.

Injuries to the Midfoot

- Tarsal and metatarsals are best approached through dorsal longitudinal incisions. Dorsal incision interosseous fasciotomies do not improve outcomes from potential compartment syndromes.
- Contamination of the deep plantar compartments of the foot is best managed through a plantar medial incision that begins 1 inch proximal and 1 inch posterior to the medial malleolus and extends across the medial arch ending on the plantar surface between the second and third metatarsal heads. The medial neurovascular structures must be identified during this approach. A full compartment release can also be performed through this incision.

Injuries to the Toes

- Every effort should be made to preserve the great toe.
- Amputation of the lateral toes is generally well-tolerated.

Foot Compartment Syndrome

- There are nine compartments in the foot.
  - The four interosseous compartments are bounded by the metatarsals medially and laterally by the dorsal interosseous fascia and the plantar interosseous fascia.
  - The lateral compartment is bounded by the fifth metatarsal shaft dorsally, the plantar aponeurosis laterally, and the intermuscular septum medially.
  - The central compartment is bounded by the intramuscular septum laterally and medially, the interosseous fascia dorsally, and the plantar aponeurosis plantarly.
  - The medial compartment is bounded by the inferior surface of the first metatarsal dorsally, the plantar aponeurosis extension medially, and the intramuscular septum laterally.
  - The calcaneal compartment contains the quadratus plantae muscle.
- There is no evidence that a double dorsal incision and interosseous compartment release alters outcomes, and, in fact, this may increase the risk of complications secondary to infection or chronic pain.
- To spare the dorsal soft tissue and reduce subsequent risk for infection and complex regional pain syndrome, a single incision medial fasciotomy may be used.
- A medial approach to the foot is made through the medial compartment, reaching across the central compartment into the interosseous compartment dorsally and lateral compartment releasing all the way across the foot (see description in this chapter's section on Injuries to the Midfoot; also see Fig. 24-5).
  - As with all battle wounds, the fasciotomy is left open and is covered with a sterile dressing. Jacob's ladder vascular loops may be used to avoid wound expansion during transport.

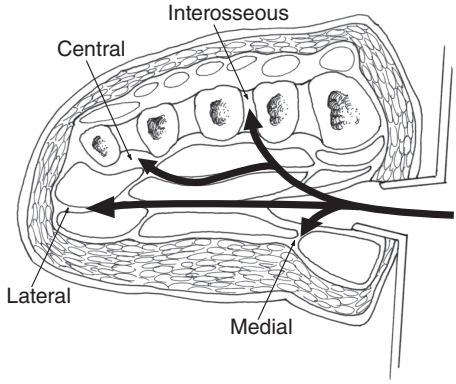

Fig. 24-5. Central compartment releases through medial approach.

Stabilization

- K-wires can be used for temporary stabilization following reduction. Alternatively, for larger segmental involvement, a spanning external fixator may be placed to regain overall anatomical length and alignment. Plate or screw fixation should usually be deferred to Role 4 facilities.
- A splint is usually adequate for transport to a site of more definitive care.

Take care to avoid iatrogenic pressure sores by providing adequate padding. External fixation "kickstands" are useful, but only when external fixation is used for stabilization and not as a primary treatment.

Reference

Fuenfer MM, Creamer KM, eds. *Pediatric Surgery and Medicine for Hostile Environments*. Washington, DC: Department of the Army, Office of The Surgeon General, Borden Institute; 2010.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 25

Vascular Injuries

Introduction

- History.
  - **World War II:** Ligation of popliteal arterial injuries was associated with amputation rates as high as 73%.
  - **Korean War:** The efficacy of repair of arterial injuries was demonstrated.
  - **Vietnam War:** With refinements in arterial repair, amputation rates for popliteal artery injuries were reduced to 32%, and the Vietnam vascular registry was established.
  - **Iraq and Afghanistan:** Hemorrhage control and vascular injury repair is required at a rate at least 5 times greater than in previous conflicts. Widespread tourniquet use is adopted (in the field and during Role 1 care).
  - Vascular shunts are established for initial management of proximal vascular injuries in forward settings (Role 2 care). The Joint Theater Trauma System (JTTS) advances recording of injury.
- Various injury patterns are seen in combat.
  - Penetrating injury due to low-velocity projectiles/fragments cause direct injury to vessels in their path.
  - High-velocity projectile wounds often cause a more extensive zone of vascular and soft-tissue injury due to the greater amount of kinetic energy. Either high or low velocity projectile/fragment may be associated with blast injury, burns, or blunt injury mechanisms.
  - Blunt injury patterns include vascular stretch or compression across bony prominences. These injuries can result in arterial dissection, thrombosis, psuedoaneurysm, or rupture. Blunt injury patterns are most often the result of motor vehicle collision and falls.

- Popliteal artery injuries are commonly associated with posterior knee dislocations. This injury pattern occurs more commonly outside high-intensity combat.

Epidemiology of Vascular Injury

- 1 in 5 (20%) battle injuries (nonreturn to duty) is coded with hemorrhage control not otherwise specified.
- Rate of vascular injury in modern combat is 12%, which is higher than the 1%–3% reported in World War II, Korea, and Vietnam. Rate of operative vascular injury is 9%, with half being ligations and half requiring repair.
- Extremity vessels account for 70%–80% of vascular injuries, whereas 10%–15% are in the cervical region and 5%–10% are in the torso.

Roles of Care and the Management of Vascular Injury

Role-specific capabilities dictate the appropriate management of vascular injury at each level of care:

- **Role 1.**
  - Hemorrhage control (direct pressure, tourniquet, or topical hemostatic agent) and other lifesaving interventions followed by evacuation.
- **Role 2.**
  - Operations at forward operating locations are abbreviated (preferably <1 hour).
  - Intervention on extremity vascular injury is important and may increase the rate of meaningful limb salvage.
  - Primary amputation or ligation is also an acceptable damage control technique when other life-threatening injuries are present.

Regarding amputations, NEVER close a stump primarily. Debride what is clearly not viable (you will need tissue for the eventual closure) and splint the extremity. See Chapter 23, Amputations.

  - If limb salvage is to be attempted, tourniquet removal, exploration and control of vascular injury, thrombectomy, and administration of heparinized saline through the inflow and outflow vessels, with consideration for placement of vascular shunts, are recommended.

- Restoration of flow can then be established using a vascular shunt followed by fasciotomy and MEDEVAC (medical evacuation). Definitive repair at this level can be considered with caution, depending on available equipment and the tactical situation.

- **Role 3.**
  - Definitive diagnosis and management of vascular injury.
  - Removal of tourniquets and/or vascular shunts is followed by definitive repair.
  - Saphenous vein is the preferred conduit for repair of extremity vascular injuries.
  - Soft-tissue coverage is essential to prevent graft exposure and potential catastrophic hemorrhage. Use of local flaps, prosthetic conduit, and extraanatomical bypass may need to be considered.
  - Extremity evaluation will be difficult during AIR EVAC (air evacuation) out of theater, and Role 3 must ensure hemorrhage control, adequacy of perfusion, fasciotomy, debridement, and coverage of the repair.
  - Primary amputation or ligation is an acceptable damage control technique when other life-threatening injuries are present.
- **Role 4 (Safe Haven).**
  - Surveillance of repair, including an assessment of soft-tissue wounds and tissue coverage, prior to continuing AIR EVAC.
- **Role 4 (CONUS).**
  - Surveillance of vascular repair with duplex or CTA (computed tomography angiography) and assessment of soft-tissue wounds and adequacy of tissue coverage.
  - Revision of repairs with stenosis or inadequate tissue coverage; prevention of ischemic complications, infection, and/or subsequent blowout of the repair.
  - Delayed revascularization of viable but poorly perfused extremities in which ligation was chosen as the initial method of care.

Evaluation and Diagnosis

- Hard signs.
  - Active hemorrhage or expanding hematoma.
  - Bruit or thrill.

- Ischemia—defined as the absence of Doppler signals in the extremity after resuscitation and reduction of any associated fractures.
- Hard signs require exploration in the operating room.
- There is limited need for other diagnostic tests (eg, CTA or angiography) that take time and often provide unclear findings.

- Soft signs.
  - Proximity to vessel, fracture/injury pattern (eg, knee dislocation), adjacent nerve deficit, history of hemorrhage, hematoma, or question regarding palpable pulse.
  - Require another diagnostic test, such as continuous wave Doppler with or without calculation of the injured extremity index.
  - CTA or angiography is useful as a diagnostic adjunct in the presence of soft signs of vascular injury.
- The injured extremity index.
  - Similar to the ankle–brachial index and is calculated using a manual blood pressure cuff and a continuous wave Doppler.
  - First step is to determine the pressure at which the arterial Doppler signal returns in the injured extremity (numerator).
  - Cuff and Doppler moved to uninjured extremity and the pressure at which the Doppler signal returns is recorded (denominator).
  - Injured extremity index >0.90 is normal and has a high specificity for excluding extremity vascular injury in the absence of hard signs.
- Angiography.
  - Utility limited by the capabilities of the imaging systems/equipment available in the expeditionary environment.
  - In the diagnosis of wartime extremity vascular injury, the presence of hard signs mandates exploration and repair.
  - Extremity vasoconstriction with shock and hypothermia in young troops may lead to confusing or false-positive findings.
  - Angiography has the greatest utility in the setting of multiple penetrating wounds at various levels of the same extremity and in circumstances with extensive metallic soft-tissue foreign bodies that limit the utility of CTA.

- Angiography may be done via cut-down using a small gauge needle or catheter to inject contrast minimizing complications.

- CTA.
  - Increasingly available in a mature theater of war and has the greatest utility in the diagnosis and triage of torso and neck wounds.
  - CTA is often used as a screening tool for suspected vascular injury in the absence of hard signs.
  - This modality takes additional time, contrast, and technical expertise to provide accurate and meaningful images.

Management Aspects: Extremity Vascular Injury

Upper Extremity

Consider prophylactic distal fasciotomies in all patients with prolonged ischemia times.

- **Subclavian artery.**
  - Recommendations: Shunt or ligate as damage control or definitive repair. If endovascular capability and expertise are available, stent grafting for initial or definitive repair is an option.
  - Utility of shunt is **high**, but technically challenging due to difficulty of exposure and placement.
  - Method/conduit: Interposition graft/6–8 mm ePTFE (expanded polytetrafluoroethylene) or Dacron.
  - Utility of endovascular repair is high as well since endovascular approach can limit the risk and morbidity of surgical exposure.
  - Usual approaches:
    - Innominate and proximal right subclavian vessels are approached through a median sternotomy.
    - The proximal left subclavian artery can be approached using a high (third intercostal space) anterolateral thoracotomy. Alternatively it can be approached through a supraclavicular incision through the clavicular head of the sternocleidomastoid. Division of sternothyroid/hyoid muscles to the scalene fat pad with retraction of

the phrenic nerve, and division of the anterior scalene is required for exposure. The clavicular head may require resection.
- ♦ The mid- and distal subclavian arteries on both sides can be exposed through combination supra- and infraclavicular incisions.
- ♦ Avoid injury to the phrenic nerve, internal mammary, thyrocervical trunk, and vertebral arteries.

- **Axillary artery.**
  - Recommendations: Shunt or ligate as damage control, or definitive repair if stable. If endovascular capability and expertise are available, stent-graft for initial or definitive repair is a good option.
  - Utility of shunt: High.
  - Method/conduit for open repair: Interposition graft/reversed saphenous vein (preferred conduit).
  - Utility of endovascular repair: High, because endovascular approach can limit the risk and morbidity of surgical exposure.
  - Suggestions:
    - ♦ Supra- and infraclavicular incisions allow proximal control and distal exposure. Proximal control may also be achieved with an occlusion balloon.
    - ♦ Prep neck, anterior chest, shoulder, axilla, arm, and hand into operative field.
    - ♦ Infraclavicular exposure includes division of the clavipectoral fascia and the pectoralis major muscle.
    - ♦ The proximal axillary artery is then visible under the pectoralis minor muscle, which can be retracted laterally or divided.
    - ♦ Avoid the brachial plexus, which will be deep or lateral to the axillary artery.
    - ♦ Endovascular repair can be facilitated by a combination of antegrade (femoral) and retrograde (brachial) approach.
- **Brachial artery.**
  - Recommendations: Shunt or ligate as damage control, or definitive repair if stable.
  - Utility of shunt: High.

- Method/conduit: Interposition graft/reversed saphenous vein (preferred conduit).
- Suggestions:
  - Medial approach: adjacent to the median nerve in brachial sheath in biceps/triceps groove.
  - Elastic artery with redundancy: flex arm slightly for interposition grafts to avoid kinking.
  - Ligation may be tolerated if collaterals are intact.

- **Radial/ulnar arteries.**
  - Recommendations: Selective repair (maintain at least one vessel flow to hand).
  - Utility of shunt: Low patency rate.
  - Method/conduit: Ligation or interposition graft/reversed saphenous vein (preferred conduit).
  - Suggestions:
    - Perfusion to the hand should be assessed with Doppler before and after occlusion or ligation.
    - The presence of an arterial Doppler signal in the hand obviates the need for arterial repair. Repair with saphenous vein in instances where there is persistent absence of an arterial signal.
    - The majority of individuals have ulnar-dominant perfusion; when possible, repair/reconstruct the ulnar artery.

Lower Extremity

Prophylactic distal fasciotomies are recommended in all injuries with prolonged ischemia times.

- **Common femoral artery.**
  - Recommendations: Shunt as damage control, or definitive repair if stable.
  - Utility of shunt: High.
  - Method/conduit: Interposition graft/saphenous vein or 6–8 mm prosthetic (ePTFE or Dacron).
  - Author's suggestions:
    - Injury to the common femoral artery is often fatal because hemorrhage control in the field is difficult.

- ♦ Expose artery at the inguinal ligament for proximal control (2–3 cm lateral to the pubic tubercle) (Fig. 25-1).

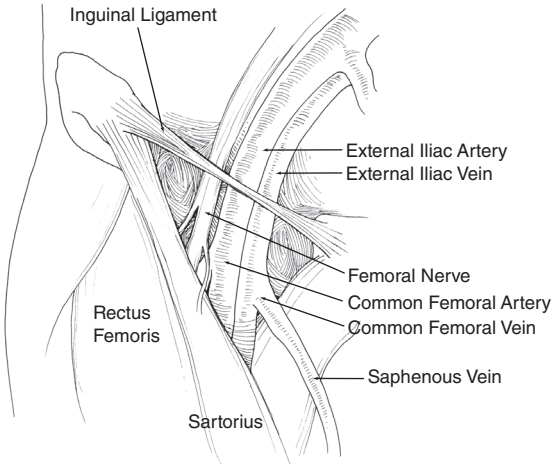

Fig. 25-1. Inguinal anatomy.

- ♦ Proximal control can be obtained in the retroperitoneum (ie, external iliac) through the proximal extension of the groin incision, by using an incision in the lower abdomen, or through use of an occlusion balloon.
- ♦ Attempt to maintain flow in the profunda femorus artery. Cover with tissue (femoral sheath), the sartorius muscle, gracilis, or rectus flap (Role 4).

- Profunda femorus artery.
  - Recommendations: Selective repair.
  - Utility of temporary shunts: Low due to difficult exposure.
  - Method/conduit: Interposition graft/saphenous vein if patient's condition allows, or ligation.
  - Suggestions:
    - ♦ Exposure of proximal profunda is the same (distal extension) as the common femoral.
    - ♦ Proximal profunda injuries should be repaired with reversed saphenous vein interposition.
    - ♦ If superficial femoral is injured, repair of the profunda is necessary to heal amputations.

- If superficial femoral is patent, ligation of mid- to distal profunda injuries is acceptable.

- Superficial femoral artery (SFA).
  - Recommendations: Shunt as damage control, or definitive repair if stable.
  - Utility of shunts: High.
  - Method/conduit: Interposition graft/contralateral reversed saphenous vein is the conduit of choice.
  - Suggestions:
    - Medial incision with "bump" under calf.
    - Exposure of the proximal third of the SFA is medial to the sartorius, and the distal third of the SFA is anterior and lateral to the sartorius.
    - Be wary of the adjacent vein (may be adherent to artery) and geniculate branches at the distal artery (Hunter's canal).
- **Popliteal artery.**
  - Recommendations: Shunt as damage control, or definitive repair if stable.
  - Utility of vascular shunts: High.
  - Conduit: Contralateral reversed saphenous vein is the conduit of choice.
  - Suggestions:
    - Medial incision with "bump" under calf for above-knee exposure and under the distal thigh for below-knee exposure.
    - Natural dissection planes exist in exposing the above-knee popliteal artery (ie, popliteal space) with the exception of the requirement for dividing the fibers of the adductor magnus, which envelopes the distal superficial femoral artery (Hunter's canal) (Fig. 25-2).
    - To completely expose the popliteal space, the medial attachments of the sartorius, semitendinosis, semimembrinosis, and gracilis to the medial condyle of the tibia can be divided. Distal exposure by division of the gastrocnemius and soleus from the tibia allows dissection to the anterior tibial origin and the tibioperoneal trunk. Extraanatomical bypass can also be performed without the need to expose the injured

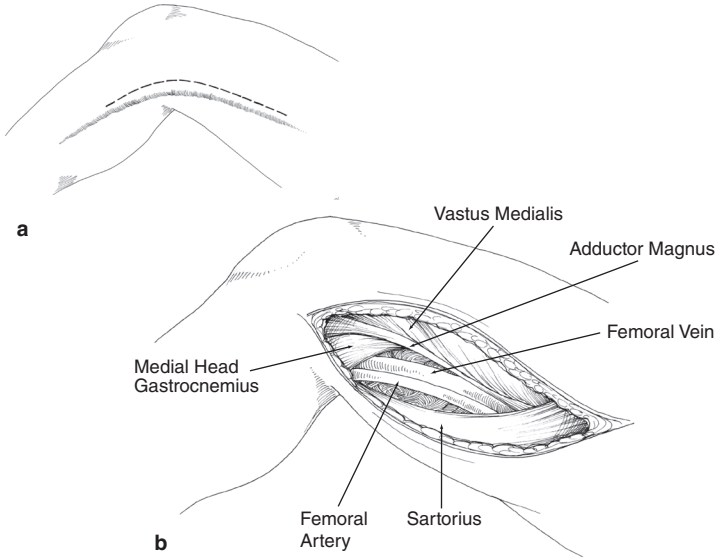

Fig. 25-2. Exposure of distal femoral and popliteal vessels.

segment (Fig. 25-3). Posterior approach (Fig. 25-4) can be considered for isolated popliteal artery injuries where prone positioning can be safely tolerated, such as injuries associated with posterior knee dislocation.

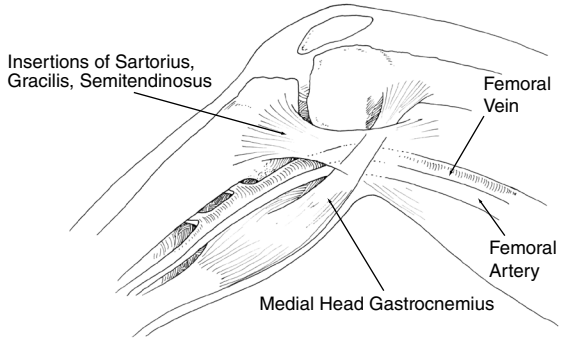

Fig. 25-3. Medial approach to popliteal vessels.

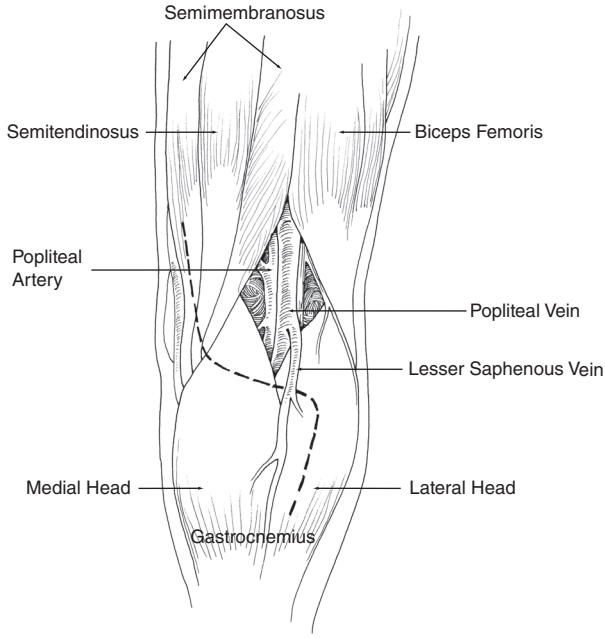

Fig. 25-4. Posterior approach to popliteal vessels.

- **Tibial arteries.**
  - Recommendations: Selective repair.
  - Utility of vascular shunts: Low due to difficult exposure, small caliber, and low patency rates.
  - Method/conduit: Ligation or interposition graft with saphenous vein.
  - Suggestions:
    - Ligation is recommended as long as there is at least one patent tibial vessel remaining.
    - If a Doppler signal is present at the ankle, this indicates that one or more tibial arteries are patent, and additional tests or repair are likely unnecessary.
    - Doppler exam should be repeated after reduction of fractures and as patient is resuscitated and warmed.
    - Repair at least one tibial with vein if three tibial arteries are injured and the limb is felt to be salvageable.

- Exposure of the posterior tibial artery in the deep compartment of the leg is through a medial incision with a lift or "bump" under the knee or thigh.

- **Extremity venous injury.**
  - Recommendations: Selective repair.
  - Utility of temporary vascular shunts: Moderate for large vessels.
  - Method/conduit: Ligation, repair, or saphenous interposition graft.
  - Suggestions:
    - Repair of extremity venous injuries should only be considered in the stable patient.
    - Repair of proximal veins is indicated to reduce venous hypertension and congestion.
    - Shunts in proximal veins will usually remain patent until formal repair can be performed.
    - Lateral venorrhaphy is acceptable, although patch angioplasty or an interposition graft using saphenous vein from the uninjured limb is often necessary.
    - Consider removing thrombus from the distal venous segments with compression (eg, ACE wrap or Esmark bandage) prior to repair.
    - Use a pneumatic compression device on distal extremity to augment venous flow after repair.
    - Limb salvage benefit of vein repair compared with ligation has been shown 2 years after injury.

Management Aspects: Torso Vascular Injury

- **Aorta.**
  - With small penetrating injuries to the aorta of the chest or abdomen, primary repair can be attempted.
  - When not amenable to repair, a shunt can be placed (eg, chest tube).
  - Recognize that penetrating injury may involve entrance and exit wounds to the aorta that may not be obvious.
  - Management of *penetrating injury* to the aorta is very rare, given the prehospital lethality of this injury.
  - Management of *blunt injury* to the thoracic aorta (partial transection or pseudoaneurysm) is rare.

- Most survivors can be initially managed medically with control of heart rate and blood pressure using beta-blockers and permissive hypotension.
- Endovascular repair is preferred and can be attempted where capability and expertise are available (some Role 3 facilities).

- **Vena cava**.
  - Establish resuscitation lines above the diaphragm for abdominal vena cava injuries.
  - Vena cava injuries should be exposed using the Cattell-Braasch and Kocher maneuvers.
  - Lateral repair is acceptable, understanding that the lumen may be compromised.
  - If occlusion of the cava results in hypotension, aortic occlusion (clamp or balloon) can be used to support central perfusion.
  - Retrohepatic and retroperitoneal hematomas should not be disturbed if not actively bleeding or expanding.
  - Attempt to identify large lumbar veins feeding the injured segment that can bleed profusely.
  - Patch angioplasty or resection and interposition graft using ePTFE are reconstructive options.
  - Ligation of the cava is acceptable as a damage control maneuver. If air transport will be utilized, then prophylactic bilateral lower extremity fasciotomies should be performed.
- **Portal vein and hepatic artery.**
  - Pringle maneuver should precede exploration of the portal triad.
  - Ligation of hepatic artery injuries is acceptable, if the portal vein is patent.
  - Lateral venorrhaphy is preferred.
  - Damage control ligation of the portal vein is an option; however, it may result in hepatic ischemia, splanchnic congestion, and systemic hypervolemia.
- **Mesenteric arteries.**
  - Present as supramesocolic zone I hematoma.
  - Repair proximal mesenteric artery and vein injuries, including portal vein.

- Repair options: primary repair, vein patch angioplasty, or replacement of the injured segment with interposition saphenous vein graft.
- Ligation can be performed for distal artery and vein injuries or as damage control.

- **Renal arteries.**
  - Explore zone II hematomas from penetrating injury; 90% of explored kidneys result in nephrectomy.
  - Establish status of contralateral kidney by contrast study or manual palpation prior to nephrectomy.
  - Damage control may require early nephrectomy. Devascularized kidney that is not bleeding may be left in situ.
- **Iliac arteries.**
  - Recommendations: Ligate or shunt as damage control, or definitive repair.
  - Utility of vascular shunts: High.
  - Method/conduit: Interposition graft with ePTFE, Dacron, or saphenous vein.
  - When appropriate expertise and capabilities are available (Role 3 or Role 4), the utility of endovascular repair is high. An endovascular approach can limit the risk and morbidity of surgical exposure.
  - Suggestions:
    - Explore zone III hematoma from penetrating wound after establishing aortic control.
    - Distal control is obtained at the inguinal ligament (for external iliac arteries).
    - If there is primary injury to, or back bleeding from, the internal iliac artery (hypogastric), it may be ligated. Try to avoid ligating both internal iliacs due to risk of gluteal ischemia/necrosis.

Management Aspects: Cervical Vascular Injury

- **Carotid artery.**
  - Recommendations: Ligate or shunt as damage control or definitive repair.
  - Utility of vascular shunts: High.
  - Method/conduit: Vein patch or vein interposition graft.

- Utility of endovascular repair: High, especially for zones I and III injuries because endovascular approach can limit the risk and morbidity of surgical exposure.
- Suggestions:
  - Zone I injuries are best approached with median sternotomy for ample proximal exposure.
  - Early control of common carotid.
  - 3 Fr Fogarty catheter with three-way stopcock is useful to occlude internal carotid back bleeding.
  - During carotid repair, consider temporary shunt and augmentation of mean arterial pressure.
  - When patient status allows, CTA aids in triage for urgent operation, improves operative planning, and images the brain as a baseline.
  - A selective approach to exploration of zone II neck wounds is acceptable in a patient without hard signs of vascular injury or aerodigestive involvement.
  - Penetrating neck wounds that are not selected for exploration should undergo CTA to further evaluate for **vascular, tracheal, or esophageal injury.**
  - Exposure of the carotid artery is through a standard anterior sternocleidomastoid neck incision.

- **Vertebral artery.**
  - Recommendations: Ligate.
  - Utility of vascular shunts: None.
  - Method/conduit: Not applicable.
  - Suggestions:
    - Bleeding vertebral artery injuries are ligated; there is no role for reconstruction in theater.
    - Vertebral artery occlusions are managed with anticoagulation, if it is not contraindicated.
    - Endovascular embolization is an option if injury is not accessible by standard exposure.
    - **Exposure usually requires a rongeur to open vertebral foramen; temporary occlusion with bone wax can be helpful.**
- **Jugular vein.**
  - Recommendations: Ligation or selective repair.
  - Utility of temporary vascular shunts: None.

- Method/conduit: Lateral venorrhaphy, vein patch, or saphenous vein.
- Suggestions:
  - Significant jugular vein injuries can be ligated without adverse effects.
  - Repair of jugular injuries should be considered in the setting of traumatic brain injury with elevated intracranial pressure.

- **Large vein injuries.**
  - Initial control can be accomplished by one or more fingers on the bleeding segment.
  - **Use of clamps for control may injure the vein further.**
  - Avoid too small of a needle and suture, which are difficult to maneuver in blood. 4-0 PROLENE on an SH needle is a practical suture on a needle large enough to see.
  - Manual direct pressure can be replaced with a small sponge stick or Kittner.
  - Hemorrhage control with ligation is preferable to patency with death from exsanguination.
  - **Be wary of the risk of air embolism with large vein injuries.**
- **Ligation of vessels.**
  - Acceptable damage control maneuver, especially for small, more distal arteries and veins (Table 25-1).

Table 25-1. Vessels Amenable to Ligation

Veins That Can Be Ligated Routinely	Arteries That Can Be Ligated Routinely
Internal/external jugular	Digital
Brachiocephalic	Radial or ulnar, but not both; preserve ulnar when possible
Infrarenal inferior vena cava	External carotid
Left renal	Brachial distal to profundi and adequate wrist; Doppler signal
Internal iliac	Subclavian branches
Subclavian	Internal iliacs
Mesenteric	Profunda femoris
Tibialis	Hepatic

- Vascular shunting to restore perfusion should be considered before ligation.
- Continuous wave Doppler should be checked before arterial ligation to judge perfusion/viability.

- **Fogarty thrombectomy catheters.**
  - Sized at 2–7 Fr catheters; maximum balloon diameter of the 2 and 3 Fr catheters is 4 and 5 mm, respectively.
  - Inflate with saline using a 1-cc tuberculin syringe (0.2– 0.75 cc) while withdrawing from the vessel**.**
  - Goal is clot, not intima, removal, so do not overinflate or "drag" too much.
  - May be used to control bleeding with use of a three-way stopcock to maintain inflation.
  - Proximal and distal thrombectomies should be performed prior to performing repair.
- **Vascular shunts.**
  - Inline shunts rest in the vessel ("in situ"), whereas long external shunts are designed to loop.
  - Inline Argyl shunts come in a cylinder container with sizes 8, 10, 12, and 14 Fr Fogarty catheters.
  - Inline Javid shunts are longer and individually packaged.
  - Sundt shunts are designed with short (15 cm; in-line) and long (30 cm; external) profiles.
  - Equal success has been had with Argyl, Javid, and Sundt shunts without systemic anticoagulation.
  - Secured with silk ligatures and patent for up to 6 hours; reports of longer duration exist.
  - Shunts should be removed with formal repair in-theater prior to AIR EVAC to Role 4.
  - Temporary vascular shunts are effective and should be considered in the management of nearly all extremity vascular injury patterns, including proximal venous injuries. Their main advantage is provision of early restoration of flow and mitigation of the damaging effects of arterial ischemia and venous hypertension. As an abbreviated procedure, compared with formal vascular repair, shunting extends the window of opportunity for limb salvage in some patterns of vascular injury. Although the patency at 3–4 hours is higher in larger, more proximal

vessels (axillary/brachial and femoral/popliteal), shunts have been used effectively in smaller (distal brachial/forearm and tibial) vessels. Outcomes of extremity vascular injury managed with temporary shunts have been recorded, demonstrating no adverse effect of this technique and a limb salvage advantage in the most severely injured limbs (Mangled Extremity Severity Score [MESS] ≥8).

- When inserting a shunt, make sure the shunt is as straight as possible (Fig. 25-5a). Twisted shunts or under tension tends to migrate to one side (Fig 25-5b). The shunt should be inserted into the vessel with a 1-inch (2 cm) overlap in each side and secured with two sutures (2-0 or 3-0 silk). Always put a suture with long tails in the middle of the shunt so you can manipulate the shunt during insertion. This marker will provide you with a visual indication of any migration of the shunt during transport. Regional anticoagulation with heparin saline flush (heparin saline flush is typically 10,000 IU/ L, although other mixtures are available with or without papaverine [60 mg/L]) of the inflow/out vessels should be done before securing the shunt.
- **Consider distal fasciotomies in all revascularizations including reperfusions after shunts. The fasciotomy ideally should be done before the placement of the shunt or the formal revascularization (two teams can do it simultaneously).**

- **Pediatric vascular injuries.**
  - In patients under 10 years old: intervention should be avoided given a propensity for spasm.
  - Ligation is better tolerated in infants and toddlers, given the ability to recruit collaterals.
  - Perform interrupted suture lines (6-0 PROLENE) to allow expansion with growth of the child.
- **Endovascular capability and inferior vena cava filters.**
  - Endovascular techniques and technology are increasingly applied to the management of vascular injury with recognized advantages over traditional open surgical approaches.

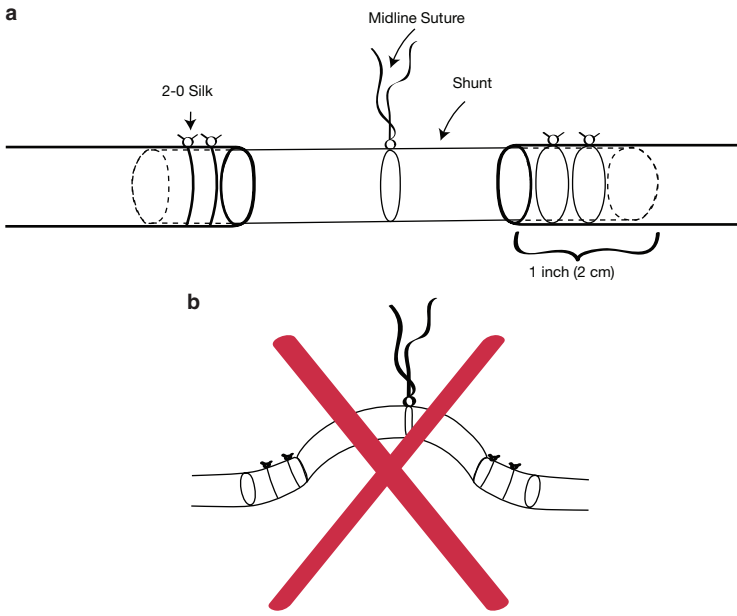

Fig. 25-5. Proper way to insert and secure a vascular shunt.

- Availability and extent of vascular surgery specialty support as well as endovascular capability vary by location and should be determined during initial preparation to receive casualties.
- Placement of vena cava filters should be considered in patients who have contraindications for anticoagulation.

- **Use of prosthetic graft material.**
  - ePTFE (GORE-TEX) or Dacron used for central torso vascular injuries (aorta, great vessels).
  - Prosthetic conduit acceptable as a last resort in extremities when vein cannot be harvested.
  - If prosthetic used in extremity injury, notify higher levels of care to facilitate surveillance.
- **Harvesting and use of autologous vein.**
  - If possible, use reversed greater saphenous vein from the uninjured extremity.

- Expose at saphenofemoral junction or anterior to medial malleolus (consistent locations). Be sure to mark anatomically distal end as "inflow," ensuring reversal of vein conduit.
- Introduce 18-gauge plastic vein or metallic olive tip cannula to distend the vein with heparin saline.
- Nearly always in the setting of trauma, the vein appears in situ as "too small" or "not adequate" due to vasoconstriction or spasm. Best assessed after hydrodistention.

- **Soft-tissue coverage and anastomotic disruption.**
  - Cover vascular repairs with available, viable local tissue (muscle and adipose).
  - If no soft tissue to cover, route grafts out of the zone of injury.
  - Poorly covered vascular anastamosis can "blow out."
  - Avoid direct placement of negative pressure wound therapy sponge on vascular structures.

If no tissue is available to cover the vascular repair, route an interposition graft out of the zone of injury through another myocutaneous or even subcutaneous path.

- **Anticoagulation.**
  - Heparin saline is typically 10,000 IU/L, although other mixtures with or without papaverine (60 mg/L) are acceptable.
  - Systemic anticoagulation is achieved with 50 U/kg of IV heparin (lower than for elective vascular repairs) with 1,000 units repeated at 1 hour. Repeat doses are not recommended, given the propensity for bleeding in wartime injury. Systemic anticoagulation may not be feasible or safe in a multiply injured patient.
  - "Regional anticoagulation" is the use of heparin saline flush in the inflow/outflow vessels.
- **Post-op care.**
  - Palpable pulses obtained in the operating room should remain palpable post-op.
  - Pulse changes, even if Doppler signals remain, may indicate graft thrombosis and should be investigated.

- Consider low-dose heparin as deep vein thrombosis prophylaxis.
- Use heparin with caution in patients with multiple injuries and/or head trauma.
- Slight elevation of injured extremity improves post-op edema.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 26

Burns

Introduction

Burns sustained during conventional military operations constitute 5%-10% of injuries. Even burns to a small surface area can be incapacitating for the casualty and strain the resources of deployed military medical units. It is crucial to remember that burns may represent only one of the casualty's traumatic injuries, particularly when an explosion is the mechanism of injury. Resuscitation of the burn casualty is generally the most challenging aspect of care during the first 48 hours following injury, and optimal care requires a concerted effort on the part of all providers involved during the evacuation and treatment process.

Point-of-Injury Care

Key steps in the initial treatment of burn casualties include:

- **Stop the burning process.** Extinguish flames. Move the patient to a safe location. Remove all burned clothing. Safely separate the patient from the power source related to electrical injury. Remove chemical agents using copious amounts of clean water.
- Provide emergency resuscitative care. Control hemorrhage and protect airway.
- **Remove all constricting articles.** Remove items such as wristwatches, rings, belts, and boots. Remove all contaminated clothing and equipment.
- **Cover the patient.** Do cover the patient with a clean, dry sheet to minimize further contamination during transit. Place saline-soaked dressings over wounds involving *white phosphorus* to prevent ignition of the phosphorus on contact with air.
- **Protect against hypothermia**. Utilize blanket(s) or other warming devices to mitigate hypothermia. Patients with large surface area burns are at increased risk of hypothermia.

- **Establish IV access.** Through unburned skin if possible, through burned skin if necessary, and secure (sew in or staple) IV lines.
- **Begin resuscitation.** Use lactated Ringer (LR) solution or a similar solution, and continue during evacuation. Starting rate: 500 mL/h for adults.

Primary Survey

Do not be distracted by the burn injury itself! The priorities of management for burn casualties are the same as those for other injured patients, with the addition of burn pathophysiology. The burn may not be the most life-threatening injury.

- The primary survey includes hemorrhage control, airway management with protection of the cervical spine as appropriate (based on the mechanism of injury), management of any breathing dysfunction, and rapid circulatory assessment. **In the burn patient, special attention to exposure, removal of materials that may continue to burn the victim, and prevention of hypothermia are very important.**

- **Inhalation injury may be manifested by stridor, hoarseness, cough, carbonaceous sputum, or dyspnea. Airway obstruction may result from plugging of the endotracheal tube and should be suspected if acute changes in pulmonary status occur.**
- **Patients who may have sustained inhalation injury should be closely monitored, without intubation if minimally symptomatic.**
- **Preemptively intubate patients with symptomatic inhalation injury prior to transport.**
- **Endotracheal and nasogastric tubes should be definitively secured with cloth umbilical tape. Securing the endotracheal tube to a premolar tooth using stainless steel wire should be considered in patients with facial burns or other facial trauma.**

- **Airway.**
  - Consider cervical spine injury in patients injured in explosions, falls, or by contact with high-voltage electricity.
  - Burns are a "distracting injury"; pain secondary to burns, and the treatment of pain with narcotics, may make the clinical diagnosis of spinal injury difficult.
- **Breathing.**
  - Inhalation injury occurs in 15% of burned combat casualties. It is more common in patients with extensive cutaneous burns, a history of injury in a closed space (eg, building or vehicle), and facial burns.
  - Patients with major burns and/or inhalation injury require supplemental oxygen, pulse oximetry, chest radiography, and arterial blood gas measurement.
  - Circumferential **full-thickness** burns of the chest may prevent effective chest motion. In such patients, **perform immediate thoracic escharotomy as a life-saving procedure to permit adequate chest excursion** (Fig. 26-1).
  - Definitive diagnosis of lower airway injury requires fiberoptic bronchoscopy.

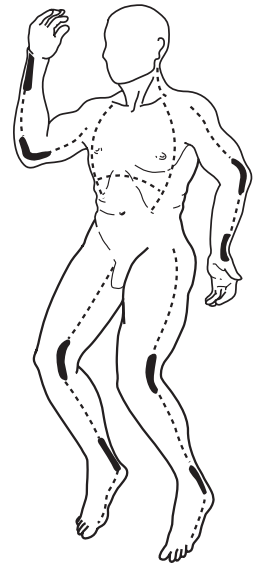

Fig. 26-1. Dashed lines indicate the preferred sites for escharotomy incisions. **Bold lines** indicate the importance of extending the incision over involved major joints. Incisions are made through the burned skin into the underlying subcutaneous fat using a scalpel or electrocautery. For a thoracic escharotomy, begin incision in the midclavicular lines. Continue the incision along the anterior axillary lines down to the level of the costal margin. Extend the incision across the epigastrium as needed. For an extremity escharotomy, make the incision through the eschar along the midmedial or midlateral joint line.

- Carbon monoxide poisoning causes cardiac and neurological symptoms. Patients with carbon monoxide poisoning require 100% oxygen for at least 3 hours or until symptoms resolve.

- **Circulation.**
  - Secure all IV catheters and lines with suture or surgical staples; tape will not adhere to burned skin, and circumferential wrapping may lead to severe constriction, edema, and possible vascular compromise.
  - Manual blood pressure measurements utilizing a cuff may be inaccurate in patients with burned or edematous extremities; therefore, arterial blood pressure is preferred when possible.

Estimation of Fluid Resuscitation Needs for Adults

Initiate resuscitation with LR based on the patient's burn size. Utilize urine output as the primary index of adequacy of resuscitation (see below). It is equally important to avoid both overresuscitation and underresuscitation.

- **Determine the burn size** based on the Rule of Nines (Fig. 26-2). A patient's hand (palm and fingers) is approximately 1% of the total body surface area (TBSA). Only second and third degree burns are included in burn size calculations.
  - Overestimation is common and may lead to overresuscitation.
- **Estimate <u>initial</u> hourly rate for crystalloid resuscitation utilizing the Rule of Tens** and adjust hourly based on response.

Initial Hourly Rate = %TBSA Burn × 10 mL/h
Example: 40% TBSA Burn
Initial Hourly Rate of Lactated Ringer's = 400 mL/h

- **Any formula-based calculation is only an initial estimate of fluid needs.** Patients weighing more than 80 kg or with inhalation injury, predominantly full-thickness burns, and a delay in resuscitation will have higher fluid requirements. The rate of infusion of LR must be adjusted based on physiological response, primarily urine output. Avoid abrupt

changes in rate of infusion; **avoid bolus infusion of crystalloids.** Increase or decrease infusion rate by approximately 25% of current rate as needed, based on response.

- For patients weighing >80 kg, add 100 mL/h for each 10 kg above 80 kg.
- Remember to adjust based on monitored urine output.
- If LR is not available, use other crystalloids such as normal saline. If crystalloid supplies are severely limited, consider starting colloid as early as 12 hours after injury. Resuscitation requires close monitoring of urine output.

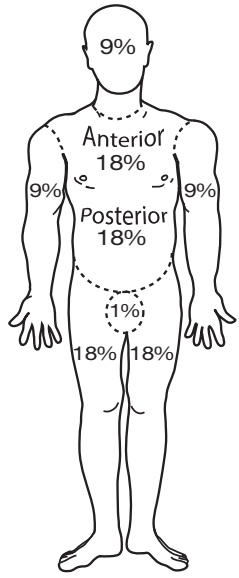

Fig. 26-2. Rule of Nines showing the distribution of body surface area by anatomical part in the adult.

Fluid Resuscitation of Children with Burns

- Fluid resuscitation for pediatric patients with burns involving 20% or more TBSA may be initiated using the modified Brooke formula (2 mL/kg × %TBSA burn × weight [kg] administered over 24 hours, with ½ administered in the first 8 hours).
- Adjust LR based on response as measured by glucose-negative urine output, targeted at 1 mL/kg/h. As with adult patients, frequent monitoring and individual titration are essential.
- Peripheral or intraosseous access may suffice initially; however, central venous access is more reliable and usually required for fluid resuscitation.
- Children with burns over 20% TBSA should have a Foley-type catheter placed (size 6 Fr catheter for infants and size 8 Fr catheter for older children); diapers may be weighed to account for urine output if a Foley is not available.

- Children also require a maintenance rate of either D5½NS or D5LR, calculated in the usual fashion, and not titrated during resuscitation.
- Children with burns under 20% TBSA or those presenting for care 24–48 hours after injury may not require fluid resuscitation; rather, fluid should be administered based on clinical need.
- Children may be provided oral nutrition/hydration if they are able to safely tolerate it; however, gastric decompression with a nasogastric tube during the resuscitation phase must also be considered. Stress ulcer prophylaxis is essential.
- Resuscitation targets include an alert sensorium, full peripheral pulses, and warm distal extremities.
- Serum sodium should be monitored every 8 hours during the first 72 hours if burns are >20%. Hypotonic resuscitation fluid should be avoided.

Monitoring the Burn Patient

- Two IV catheters, a Foley catheter, continuous ECG, pulse oximetry, a core thermometer, and a nasogastric tube are needed for ICU care of a patient with burns of 20% TBSA or greater.
- Vital signs and fluid input/output should be accurately recorded hourly on a flow sheet.
- Nasogastric decompression is essential for all patients with burns over 20% TBSA, due to potential gastric ileus.
- Placement of a Foley-type catheter is an essential part of the resuscitation process. Burns to the penis should not prevent intubation of the urinary meatus. Debridement of eschar and use of a small hemostat may be necessary to facilitate urinary catheter placement. Suprapubic catheter placement is rarely necessary and should be avoided.

Secondary Survey

- Perform a thorough head-to-toe secondary survey, looking for non-thermal injuries, including fractures, dislocations, corneal abrasions, and/or tympanic membrane rupture.
- Ocular examination for corneal laceration and/or globe trauma should be performed early before resuscitation-related edema makes examination more difficult.

- If there is a question of intraabdominal injury, diagnostic peritoneal aspiration, through burned skin if necessary, is appropriate.

Burn Resuscitation—First 24 Hours

Continuously reassess the patient's hourly urine output, which is the single most reliable indicator of the adequacy of resuscitation.

- Target a urine output of 30–50 mL/h in adults or 1 mL/kg/h in children. If urine output is less than the target for 1–2 consecutive hours, increase the LR infusion rate by about 25%; if the response is greater than the target, decrease rate by about 25%.
- Avoid overresuscitation, which may lead to edema-related complications (eg, compartment syndrome or pulmonary edema).
- Other indices of effective resuscitation include a decreasing lactate, improving base deficit, improved tachycardia (a heart rate of 100–130 is normal in adult burn patients), and an improving or normal mental status.
- The use of diuretics is rarely, if ever, indicated in the treatment of burn shock, except when gross pigmenturia is present (see below).
- Glycosuria is common following severe thermal injury and may cause hypovolemia secondary to osmotic diuresis. Check the urine for glucose and treat hyperglycemia with IV insulin as needed.

Burn Resuscitation—Second 24 Hours

At the end of the first 24 hours postburn, decrease use of crystalloid LR and implement use of 5% albumin in normal saline.

- Calculation of 24-hour albumin volume is as follows:

5% albumin volume = (*mL) × (%TBSA burned)
× (preburn weight, kg)

%TBSA burn	30–49	50–69	70+
***mL**	0.3	0.4	0.5

For example, in a burn of approximately 40% in an 80-kg patient:

Albumin volume = (*mL) × (40%) × (80 kg)
= (0.3) × (3,200)
= 960 mL/24 h
= **40 mL/h.**

- Burns <30% TBSA generally do not require infusion of colloid solution.
- It is rarely necessary to adjust the colloid infusion rate.
- If albumin is not available, fresh frozen plasma or synthetic colloid can be used at the same rate used for 5% albumin. If none of these are available, continue utilizing LR while monitoring urine output.
- **Monitor electrolytes**. Burn resuscitation is usually complete by 48 hours after burn injury. However, evaporative water loss replacement is required. **Be watchful for both hypo- or hypernatremia!**
- **Document and communicate**. Accurately document all fluid volumes administered to the patient and communicate this information to providers as the patient is transferred between levels of care. Utilization of the Joint Theater Trauma System (JTTS) Burn Resuscitation Flowsheet is strongly encouraged and demonstrated to improve outcomes following severe burns. Early communication with the burn center is also encouraged.

Burn Wound Care

- The burn wound itself is not immediately life-threatening. However, adequate wound care reduces the risk of infection, which remains the primary complication in burn casualties. Early care of the burn wound should be performed in a clean and warm environment where adequate sedation and analgesia are available.

Early burn wound care includes adequate IV pain management, removal of foreign materials, debridement, cleansing with antibacterial soap, and application of a topical antimicrobial dressing.

- Adequate wound care requires adequate pain control. Small, intermittent boluses of IV morphine or fentanyl are effective for basal pain control. Ketamine is effective for painful wound care (start with an analgesic dose of 0.25 mg/kg IV).
- Prophylactic antibiotics are generally not recommended for burn wounds alone. However, other wounds—such as open fractures, facial injuries, or intraabdominal injuries—may justify use of IV antibiotics and are not contraindicated by the presence of the burn injury.
- Apply a topical antimicrobial agent once or twice daily after thorough cleansing with a surgical detergent such as chlorhexidine gluconate (Hibiclens).
- Use of silver nylon dressings:
  - Burns may be dressed in pliable silver nylon dressings, which provide effective antimicrobial coverage by releasing silver ions. They require a slightly moist environment to remain effective. They should be wrapped with a layer of sterile gauze (eg, Kerlix) and moistened with water to maintain a damp environment. Avoid oversaturation leading to possible hypothermia.
  - Silver nylon dressings may be left in place for extended periods (72 hours), which may offer an advantage during transport.
- Use of topical antimicrobial solution or creams:
  - Aqueous mafenide acetate (Sulfamylon) 5% solution may be prepared and used to moisten sterile gauze and wrapped or laid on burn wounds. Sulfamylon 5% solution should be applied to the dressings approximately every 8 hours to maintain moisture in the dressings.
  - 1% silver sulfadiazine (Silvadene), and/or 8.5% mafenide acetate (Sulfamylon) burn creams may be used. They are applied as a thick layer ($\frac{1}{16}$ to $\frac{1}{8}$ inch thick) on the burn and wrapped with sterile gauze. One 400-g jar covers 20% TBSA.
  - During the period of active wound exudation, it is helpful to place bulky dressings beneath the burned parts to absorb the exudate.
  - Burn cream should be reapplied to open burns as often as needed to keep them covered.

Burn patients must be adequately immunized against tetanus.

- Definitive burn surgery in the combat zone is not advised for patients who can be evacuated to a definitive burn care facility.
- Prevent thermal stress by keeping the environment as warm as possible (>85°F).
- Corneal abrasions in burn patients can lead to full-thickness ulceration and blindness, and require aggressive treatment with antibiotic ointments, preferably gentamicin or a quinolone every 4 hours, alternating with erythromycin every 4 hours.
- Ear burns are prone to chondritis. Avoid placing ties across the ears and apply Sulfamylon cream to burns involving the ear because it will provide better cartilage penetration.
- It is common for patients to develop a sterile chemical cellulitis, manifested by an erythematous rim of normal tissue extending ~1 cm around the wound margin. **Erythema extending beyond this margin, with other clinical evidence of infection, likely represents gram-positive cellulitis (beta-hemolytic streptococcus or staphylococcus).** Consider early use of vancomycin. Treat with appropriate IV antibiotics.
- Invasive gram-negative burn wound infection is heralded by striking changes in the color of the burn wound and a clinical course consistent with sepsis.
  - Antibiotic treatment with an aminoglycoside and a carbapenem is recommended. Apply Sulfamylon cream BID and plan urgent evacuation, if available.
  - If evacuation is not possible, perform surgical excision to fascia.

Daily inspection of the burn wound by a surgeon is essential to identify early infection complications.

Extremity Care

- Carefully monitor the extremities throughout the resuscitation period. Management of the burned extremity can be summarized as follows:

- Elevate.
- Exercise burned extremities hourly.
- Evaluate pulses and neurological status hourly.
- Perform escharotomy as indicated.

- **In extremities with full-thickness, circumferential burns, edema formation beneath the inelastic eschar may gradually constrict the venous outflow and, ultimately, arterial inflow.** Adequate perfusion must be assessed hourly during resuscitation.

Progressive diminution of audible arterial flow by Doppler is a primary indication for escharotomy. Doppler flow should be sought in the palmar arch, not the wrist.

- Pulses may be difficult to palpate in edematous, burned extremities. However, **in the absence of a Doppler flowmeter, and in the appropriate clinical setting, loss of palpable pulses may indicate a need for escharotomy.**
- Patients requiring escharotomy often present with a tight and edematous extremity. They may have progressive neurological dysfunction, such as unrelenting deep tissue pain or paresthesias, and/or distal cyanosis.
- Prior to prolonged transport, strongly consider prophylactic escharotomy.
- Note that loss of the palmar arch Doppler signal, in the presence of adequate radial and ulnar pulses, is an indication for dorsal hand escharotomies. These are performed over the second and fourth metacarpals. Digital escharotomies may be useful in some cases.
- **Following escharotomy, document restoration of normal pulses and continue to monitor the patient.** If the procedure fails to restore pulses, reassess the depth and extent of the incisions, and look for other causes for poor perfusion.
- After escharotomy, cover wounds, including the escharotomy incisions, in burn cream.
- The patient may still develop a true intramuscular, subfascial compartment syndrome requiring fasciotomy.

- Fractures associated with thermal injury are ideally treated with external fixation to permit exposure of the burns and their treatment with topical antimicrobial agents. Plaster, if used, should be bivalved immediately to permit access for wound care and to accommodate edema of the burned limb.

Other Considerations

- After 24-48 hours postburn, patients will develop a hypermetabolic state, with hyperthermia, tachycardia, and hypercatabolism. These changes are proportional to burn size, and may be difficult to distinguish from early sepsis.
- Stress ulcer prophylaxis with IV medication is crucial during the early phases of treatment following severe burns.
- Implement early enteral nutrition once the patient is hemodynamically stable, generally by 24 hours postburn.
- Respiratory care.
  - Soon after injury, patients with subglottic inhalation injury may develop casts composed of fibrinous exudate, blood, mucus, and debris. Inhaled heparin sodium, at a dose of 10,000 units, should be given by nebulization every 6 hours to prevent the formation of casts and help prevent potentially life-threatening obstruction of endotracheal tubes.
  - **Subglottic inhalation injury may persist longer than clinically evident. Extubation must be performed with caution after adequate airway assessment.**
- Patients with large burns are at risk of abdominal compartment syndrome, which is best avoided by keeping the infused volume < 250 mL/kg during the first 24 hours postburn.

Electrical Injury

- High-voltage electrical injury (>1,000 volts) causes muscular damage that often is much greater in extent than the overlying cutaneous injury.
- Examine the extremities for compartment syndrome and perform urgent fasciotomy as needed.
- Gross pigmenturia (myoglobinuria) may result, and fluid resuscitation must be modified to protect against renal injury.
  - Pigmenturia is diagnosed by reddish-brownish urine, with a dipstick test that is positive for blood, but with insignificant numbers of red blood cells on microscopy.

- Elevated blood levels of creatine phosphokinase (CPK) > 5,000 IU/L may assist in trending the severity of myoglobinuria.
- Increase the hourly LR rate until a urine output of 100 mL/h is achieved.
- If increasing hydration fails to result in a progressive clearing of the urinary pigmenturia over a period of 3–4 hours, add 12.5 g mannitol to each liter of LR infused.
- Infusion of sodium bicarbonate in water (150 mEq/L) to alkalinize the urine may be useful.

- Hyperkalemia may occur as a result of rhabdomyolysis, and must be carefully assessed and treated with calcium gluconate infusion, insulin, and glucose.
- Surgical debridement of nonviable muscle is the definitive treatment of persistent myoglobinuria.

High-voltage electric injury requires consideration of deep muscle injury, with resultant rhabdomyolysis, hyperkalemia, acute renal failure, and compartment syndrome. Cardiac monitoring, aggressive fluid and electrolyte management, fasciotomy, and debridement are often required.

- Patients with electrical injuries are at increased risk for multiple fractures, including spinal fractures.

Chemical Burns

- Initial treatment requires immediate removal of the offending agent.
  - Brush any dry materials off the skin surface before implementing lavage with copious amounts of water.
  - In the case of alkali burns, lavage may need to be continued for several hours.
  - Resuscitate and manage chemical burns just as you would a thermal burn.

White Phosphorus Burns

- Most of the cutaneous injury resulting from phosphorus burns is due to the ignition of clothing and is treated as a conventional burn.

- Fragments of this metal, which ignite on contact with the air, may be driven into the soft tissues.
- First-aid treatment of casualties with imbedded phosphorus particles includes **copious water irrigation and placement of a saline-soaked dressing that must be kept continuously wet.**
- Profound hypocalcemia and hyperphosphatemia may result from white phosphorus injury. Check the ECG for prolonged QT interval. Treat with IV calcium and monitor closely.
- Rapid surgical removal of the identifiable particles should be performed; a UV (Wood's) lamp can be used to help locate particles.
  - A dilute (1%), freshly mixed solution of copper sulfate has been used to help identify white phosphorus particles. However, this is no longer recommended because, if the solution is absorbed, it can cause severe hemolysis. If it is used, immediately wash it off with copious saline irrigation; do not apply it as a wet dressing.
- Liberally apply topical antimicrobial burn creams postoperatively.

Triage Considerations

Application of optimal care currently results in survival of approximately 50% of young adults whose burns involve 80% or more of the TBSA. However, treatment options in a battlefield triage situation may be less than optimal, and expectant care may be considered for patients with burns that exceed 80% TBSA when resources are limited. Expectant status (comfort care) should not be implemented based solely on the severity of injury alone, and resuscitation should be implemented for all burn patients, provided resources are available for progressive care, including evacuation to definitive care. Care can be delayed for those patients with burns of 20% or less who are otherwise hemodynamically stable.

Care of Local National Burn Patients

- Treatment of local national patients with burns is frequently encountered by deployed medical units. The basic tenets of burn care apply to any population. However, decisions regarding futility may arise based on the resources available

both at the field facility and among civilian facilities within the region. The inability to evacuate patients for any further definitive care may preclude initiation of aggressive resuscitative or operative interventions and warrant early transition to comfort care measures if there is no potential for evacuation for definitive care.

- Definitive care of burn patients is resource-intensive and affects personnel, supplies, operating room availability, and the blood bank. Careful planning and staging of operations are essential.
- Graft failure enlarges the overall wound burden. Protection of the healing donor site(s) is also crucial. Likewise, it is very important to utilize all donor sites efficiently, including the scalp.

Summary

- Burn patients must be evaluated as trauma patients, searching for other injuries that may be more immediately life-threatening than the burn itself.
- Patients with burns involving 20% or more of the TBSA generally require formal fluid resuscitation and close monitoring.
- The Rule of Tens provides a simplified means of estimating the initial hourly fluid resuscitation rate in adults.
- Placement of a Foley catheter and close monitoring of urine output are essential parts of the resuscitation process.
- Both under- and overresuscitation are associated with undesired effects that must be avoided.
- In most situations, the key factor affecting whether or not a patient's burns are deemed so severe as to warrant implementing comfort care measures is not the extent of burn alone, but rather the availability and access to definitive care, including long-range evacuation if necessary.
- Early communication and consultation with staff at the burn center are encouraged; early discussion of management and transport options ensures optimal coordination along the continuum of care.
- Consultation may be obtained 24/7/365 by contacting the US Army Institute of Surgical Research (USAISR) Burn Center at Fort Sam Houston, Texas, at (210) 222-BURN (2876) or via email at: burntrauma.consult@us.army.mil.

- Updated Clinical Practice Guidelines (CPGs) related to burn trauma may be found at the Joint Trauma System public website.

For Clinical Practice Guidelines, go to
http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 27

Environmental Injuries

Introduction

The successful prevention and control of cold, heat, and altitude injuries depend on vigorous command involvement at every level. The provision of adequate clothing and shoes in conjunction with proper training on an individual and group level will reduce the number and extent of injuries. The medical officer must ensure that he or she understands how military duties impact the occurrence and severity of environmental conditions. His or her involvement is vital when advising the commander on preventive measures.

Cold Injuries

Trench foot and frostbite together have accounted for more than 1 million US casualties in World War I, World War II, and the Korean War. Influencing factors include previous cold injury, fatigue, concomitant injury resulting in significant blood loss or shock, geographic origin, nutrition, tobacco use, activity, drugs and medication, alcohol, duration and exposure, dehydration, environment (temperature, humidity, precipitation, and wind), and clothing.

Nonfreezing Cold Injury

- **Chilblains.**
  - Results from intermittent exposure to temperatures above freezing, usually accompanied by high humidity and moisture; 1–6 hours of exposure.
  - Swelling, tingling pain, and numbness, with pink-to-red flushing of the skin (especially the fingers).
  - Extremities will be pruritic as they warm up.
  - Symptoms usually subside overnight; some superficial scaling may occur.

- Mild joint stiffness may occur acutely, but subsides in a few hours.
- No permanent damage occurs.

- **Pernio.**
  - Continuum of events from chilblains.
  - Exposure for >12 hours to cold and/or wet conditions.
  - Tight-fitting footwear can shorten exposure time and increase severity of injury.
  - Swelling is more severe; pain is more persistent than with chilblains.
  - Thin, partial-skin thickness and necrotic patches (from the dorsum of the hands or feet).
  - Plaques may slough without scarring, but may be particularly painful for months or years.
- **Trench foot**.
  - Epidemiology/clinical appearance.
    - Occurs from prolonged exposure to cold, wet conditions, or prolonged immersion of feet at temperatures as high as 17°C for >12 hours. Shorter duration at or near 0°C results in the same injury.
    - Occurs in nonfreezing temperatures 0°C–12°C.
    - Can occur at higher temperatures from prolonged water immersion.
    - Blunt trauma of marching can produce more serious injury.
    - First symptom is often the feet becoming cold, mildly painful, and numb.
    - Tight footwear increases risk of trench foot.
    - Common symptoms are "cold and numbness" or "walking on wood."
    - Foot may appear swollen, with the skin mildly blue, red, or black.
    - Limb is hot and often hyperhidrotic.
    - On rewarming, pain is excruciating and does not respond to pain medication, including morphine.
    - As time progresses, liquefaction necrosis occurs distally, but more proximal tissue may also be compromised.
    - No sharp line of demarcation of dead tissue from viable tissue.

- ♦ Nerve, muscle, and endothelial cells are most susceptible to this long-term cooling.
- ♦ Microvascular vasospasm with tissue ischemia is the apparent etiology of trench foot.
- ♦ Postinjury sequelae include pain, numbness, loss of proprioception, and cold feet. Hyperhidrosis with subsequent paronychial fungal infections are common.
- ♦ Lifelong, life-changing injury.

o Treatment.

- ♦ Prevent further cold exposure.
- ♦ Do not massage.
- ♦ Dry extremity, warm torso, and allow slow passive rewarming of feet. **Never immerse feet in warm or hot water.**
- ♦ Elevate feet.
- ♦ Rehydrate.
- ♦ If **vesicles** develop, do not debride.
- ♦ Pain medication: The only effective approach is amitriptyline 50–150 mg at bedtime. Other analgesics are either completely ineffective or (as with narcotics) do not actually relieve pain.
- ♦ Blisters should be left intact; ruptured blisters require meticulous antisepsis after unroofing.
- ♦ Systemic antibiotics and tetanus prophylaxis are indicated when there are nonviable tissues, as with any other contaminated wound, or when there is evidence of infection.
- ♦ Debridement of necrotic tissue may be required in trench foot.
- ♦ Macerated or damaged skin requires topical antibacterial precautions.
- ♦ Avoid trauma.
- ♦ Early mobilization is vital to prevent long-term immobility.
- ♦ Recovery is protracted and may require evacuation because trench foot may lead to weeks and months of pain and disability.
- ♦ Long-term sequelae are very common and include sensitivity to the cold (secondary Raynaud's

phenomenon), chronic pain, neurological impairment, and hyperhidrosis.

- **Frostnip.**
  - Exposed skin appears red or minimally swollen.
  - Tissue is not actually damaged.
  - Not true frostbite; freezing is limited to skin surface only.
  - Signals imminent likelihood of frostbite developing.
  - Resolves quickly with warming.
- **Frostbite**.
  - Results from crystallization of water in the skin and adjacent tissues exposed to temperatures below freezing.
  - Depth and severity of injury are a function of temperature and duration—the lower the temperature, the shorter the time required to produce injury.
  - At low temperatures, in the presence of wind, exposed skin can freeze within a few seconds—starts distally and progresses up the finger or toe.
  - Freeze front (line where the ice is formed in the tissues) is where liquefaction and necrosis occur. Tissues immediately proximal to this line may also die, but therapeutic modalities are directed at improving their survival.
  - Clinical appearance**.**
    - Skin initially becomes numb and feels stiff or woody.
    - Mottled, bluish, yellowish, "waxy," or "frozen."
    - Depth of involvement may be difficult to determine until demarcation occurs, which may take an extended period.
  - Frostbite grading**.**
    - Classification into degrees is primarily a retrospective evaluation and has little treatment value.
    - A more clinically useful grading typically divides injuries into superficial or deep.
    - Superficial frostbite.
      - Involves only the skin with swelling, mild pain, and minor joint stiffness.
      - No blisters form.
      - Nonmedical personnel can manage simply by rewarming.
    - Deep frostbite.
      - Involves deeper tissues to include bone.
      - White-hard, anesthetic, blanched, and inflexible.

- ◊ Skin will not move over joints.
- ◊ On rewarming, there is great pain and a blue-gray-to-burgundy color change.
- ◊ Blisters form and are clear, fluid-filled, or hemorrhagic (the latter indicates a more severe, deeper injury). They should be left in place; will slough in 7–10 days without consequence.
- ◊ Failure to form vesicles in an obviously deep-frozen extremity is a grave sign.
- ◊ Postinjury sequelae include Raynaud's phenomenon; pain; paresthesias; hyperhidrosis; loss of proprioception; cold, discolored feet; and gait modification.

- **Field treatment (first-aid)**.
  - Superficial (blanched cheeks, nose, ears, fingertips).
    - ♦ Warm with palm of hand or use warm, wet cloth; warm fingers in armpits.
    - ♦ Emollients may help prevent skin from drying or cracking.
    - ♦ Do not massage, rub with snow, or warm body part by an open fire or high-heat source.
    - ♦ Meticulous skin care is required.
  - Deep frostbite**.**
    - ♦ Prevent further cooling of body part, as well as the patient as a whole.
    - ♦ Apply dry, sterile bandage and elevate involved extremity.
    - ♦ Protect from refreezing during evacuation.
    - ♦ Evacuate promptly to definitive medical care.

Avoid thawing and refreezing; this leads to the greatest damage to tissue and the poorest outcome.

- **Medical treatment facility.**
  - **The outcome of a frozen extremity is not directly related to length of time frozen, but more importantly to the method of rewarming and any subsequent refreezing.**
    - ♦ If the soldier will again be at risk for refreezing, no attempt at rewarming should be initiated; the soldier should ambulate on the frozen extremities until he or she reaches definitive care.

- For transport, the patient's extremity should be splinted, padded with dry dressings, and protected from heat sources that would slowly rewarm the extremity.

- **Rapid rewarming (without the possibility of refreezing) is the treatment of choice.**
  - Immerse in gently circulating water (whirlpool bath) at 40°C (104°F) for at least 30 minutes longer than would be needed to defrost all affected tissues. If deep freezing of the leg or arm has taken place, thorough surgical fasciotomy is mandatory prior to rewarming to prevent compartment syndrome subsequent to the reperfusion of thawing tissue. Extremities are rewarmed until pliable and erythematous at the most distal areas.
  - Twice daily whirlpool baths at 40°C with topical antibacterial added to the water, together with oral ethanol. The alcohol reduces the need for analgesia and may improve outcome. Other drug regimens remain unproven.
  - After rewarming, edema will appear within a few hours and vesicles form within the next 6–24 hours.
  - Intensive mobilization is essential to avoid long-term immobility.
- Vesicles**.**
  - Frostbite vesicles are typically left intact.
  - Debridement is not recommended. Early surgery is only indicated in severely infected cases. Normally, surgery should be delayed for at least 6 months.
- General considerations**.**
  - Ibuprofen or Ketorolac should be given as systemic thromboxane/prostaglandin inhibitors.
  - Systemic antibiotics and tetanus prophylaxis are indicated when there are dead tissues, as with any other contaminated wound, or when there is evidence of infection.
  - Dry, loose dressings may be applied.
  - Cigarette smoking and/or nicotine use are contraindicated during treatment due to their effect on the microvasculature.

- Daily hydrotherapy is recommended. Pain control with nonsteroidal antiinflammatory drugs and narcotics will be needed.
- Sequelae include contractures, cold sensitivity, chronic ulceration, arthritis, and hyperhidrosis.
- Frostbite cases will require prolonged hospital care (9 days on average); therefore, all but those with the most trivial injuries should be evacuated to more definitive care as soon as possible.
- Early surgery is indicated only in the most severe freeze-thaw-refreeze cases, where massive tissue destruction has taken place, and in some more severely infected cases. Normally, surgery should be delayed for at least 6 months ("freeze in January, operate in July").

Due to the inability to reliably predict the outcome in the postthaw period, there is no role for debridement/amputation of necrotic or potentially necrotic tissue in the initial treatment of frostbite.

Hypothermia

Hypothermia is classically defined as whole-body cooling below 35°C. The degree of hypothermia is further defined according to the body's core temperature and the clinical effects seen in a given temperature range.

- **Causative factors and prevention**.
  - Water immersion.
  - Rain and wind.
  - Prolonged exposure to severe weather without adequate clothing. The insulation effect of clothing is markedly decreased with wetness, which increases the conductive heat loss.
  - Stay dry and avoid windy exposure.
  - Shivering can provide 5 times the normal metabolic heat production. Exhaustion and glycogen depletion decrease the time of shivering. Compromise of shivering due to inadequate food intake (skipping meals), exhaustion, heavy exercise, alcohol, and drugs increases the threat of hypothermia.

- **Mild hypothermia:** >33°C (>91°F).
  - Shivering, hyperreflexia.
  - Amnesia, dysarthria, poor judgment, ataxia, apathy.
  - Cold diuresis.
- **Moderate hypothermia:** 28°C–33°C (82°F–91°F).
  - Standard hospital thermometers, mercury as well as digital, cannot measure temperatures below 34°C (93°F).
  - Stupor, loss of shivering.
  - Onset of atrial fibrillation and other arrhythmias.
  - Progressive decrease in level of consciousness, respiration, and pupillary reaction; eventual pupil dilation.
- **Severe hypothermia:** <28°C (<82°F).
  - Increased incidence of ventricular fibrillation, which often occurs spontaneously.
  - Loss of motion and reflexes, areflexic at approximately 23°C (72°F).
  - Marked hypotension/bradycardia.
- **Profound hypothermia:** <20°C (<68°F).
  - Asystole.
  - Lowest known adult survival from accidental hypothermia is 13.7°C (56°F).

Treatment

- **Prehospital (field) treatment**.
  - Awake patients.
    - Remove wet clothing; dry and insulate the patient.
    - Give oral sugar solutions to hydrate.
    - Walk out or transport to medical treatment facility. (This should be attempted if it is the only alternative because it is likely to worsen the condition.)
    - Although walking may deepen hypothermia due to the return of peripheral colder blood to the core, adequate prehydration decreases the postexposure cooling.
  - Comatose patients.
    - Patient should remain horizontal and be handled gently to avoid inducing arrhythmias; do not massage.
    - IV fluids, warmed to 40°C–42°C, if possible.
    - Do not use lactated Ringer solution because the cold liver cannot metabolize lactate; warm (40°C–42°C [104°F–107.5°F]) D5NS is the fluid of choice.

- Remove wet clothes, dry, insulate, and add an outer vapor barrier. Wrap patient in multiple layers of insulation.
- Limit active rewarming principally to the body's center/core only.
  - Heated (40°C–45°C), humidified air/oxygen is the method of choice.
  - Norwegian personal heater pack (charcoal heater), with warming tube placed into insulation wrap.
  - Forced air (Bair Hugger) with rigid chest frame.
  - Hot water bottles in groin/axilla.
- Intubation and heated ventilation may be performed.
- If apneic and asystolic, consider CPR, because the brain may survive longer.

Remember: The patient is not dead until he/she is warm and dead. Continue resuscitation, if possible, until patient has been rewarmed.

- **Medical treatment**.
  - Ventilate; apply CPR if asystolic or in ventricular fibrillation.
  - As the body cools, the peripheral vasculature constricts, causing pooling of cold acidotic blood.
  - Rewarming the periphery of the body rather than the core causes an inrush of this cold acidotic blood into the core, further dropping the core temperature (afterdrop) and worsening cardiac instability.
  - Core rewarming—peritoneal dialysis, thoracic lavage, heated and humidified oxygen, external warm blankets, and warm water torso immersion.
  - For ventricular fibrillation.
    - Bretylium tosylate, 10 mg/kg. Bretylium is the only known effective antidefibrillation drug for hypothermia. It remains functional in a cold heart. Other medications have not proven effective.
    - Warmed IV (lactate and potassium-free).
    - Monitor core temperature via esophageal (preferred) or rectal probes.
    - Careful correction of acid–base balance.

- Rewarm core to 32°C (90°F) and attempt cardioversion (360 J). Continue rewarming and repeat. Defibrillate after every 1°C rise in temperature.
- Monitor potassium, glucose, temperature, and pH.
- Major causes of failure to resuscitate include elevating central venous pressure too fast or too early, attempting defibrillation when core temperature is below 32°C, or continuing to rewarm past 33°C when potassium levels are high and pH is low. If serum potassium levels are high, consider the use of intravenous glucose and insulin.
- Avoid other antiarrhythmics and other medications.
- Patients with core temperature (rectal) above 30°C can generally be rewarmed externally in a variety of methods, including warm blankets and warm water torso immersion. Patients below 30°C rectal should be considered more fragile and will often require internal methods of rewarming (ie, warm gastric, colonic, and/or bladder lavage; warm peritoneal lavage dialysis; warm thoracic lavage; and extracorporeal blood rewarming). Lavage fluids should be warmed to 40°C–42°C (104°F–107.5°F).
- Core temperature will continue to drop after the patient is removed from cold exposure. Continued temperature drop can have grave prognostic implication and increases the likelihood of fibrillation. Post-rewarming collapse of an apparently functional heart often leads to a nonresuscitable heart and death.

- **Cardiopulmonary resuscitation**.
  - If the cardiac monitor shows any electrical complexes, check carefully for apical and carotid pulses before initiating CPR. If any pulse—however thready—is present, **DO NOT INITIATE CPR.**

Trauma patients should be considered to have hypothermia more profound than the core temperature indicates and be warmed more aggressively.

- **Treatment of mild stable hypothermia**.
  - Insulation.

- Heat lamps.
- Warmed IV fluids.
- Warmed forced air (Bair Hugger). Hair dryers have been jury-rigged for this purpose.
- Consider arteriovenous anastomoses warming.
  - Immerse hand, forearms, feet, and calves in water heated to 44°C–45°C (111°F–113°F).
  - Opens arteriovenous anastomoses in the digits causing increased flow of warmed venous blood to the heart and decreases afterdrop.

- **Treatment of severe hypothermia with hemodynamic instability**.
  - Cardiopulmonary bypass with rewarming, when available, is the ideal technique in this circumstance because it provides core rewarming while ensuring circulatory stability.

Heat Injury

In the military setting, heat illness occurs in otherwise healthy individuals and ranges from mild (heat cramps) to life-threatening (heatstroke). Individuals typically present with exertional heat illness and are hot and sweaty, not hot and dry, as seen in classic heatstroke.

Lack of sweating is not a criterion for heatstroke. Some military casualties of heatstroke have profuse sweating, especially with rapid onset of heatstroke.

Minor heat illnesses include heat cramps and heat exhaustion. Major heat injuries include exertional heat injury, exertional rhabdomyolysis, and heatstroke. The diagnostic categories of heat exhaustion, exertional heat injury, and heatstroke have overlapping features, and should be thought of as different regions on the continuum rather than discrete disorders, each with its own distinct pathogenesis.

- **Heat injury prevention**.
  - Easier to prevent than treat.
  - Occurs most commonly in unacclimatized individuals.
    - Acclimatization to heat requires 7–10 days.

- ♦ Predeployment training in artificially warm environments does aid heat acclimatization.
- ♦ One hour of progressively more difficult exercise sufficient to induce moderate sweating each day will maximize acclimatization. (Regular strenuous exercise sufficient to stimulate sweating and increase body temperature will result in a significant degree of heat acclimation.) Aerobic fitness provides cardiovascular reserve to maintain the extra cardiac output required to sustain thermoregulation, muscular work, and vital organs in the face of heat stress.

- o Utilize published work–rest cycle guides (eg, FM 21-10/MCRP 4-11.1D or *Field Hygiene and Sanitation*) or work–rest cycles tailored to the individual's physical capacity by direct medical oversight.
- o **Water restriction/discipline leads to increased heat injury and is contraindicated.**
  - ♦ Acclimatization does not reduce, and may actually increase, water requirements.
  - ♦ Service members will, on average, not feel thirsty until 1.5 L (1%–2%) dehydrated.
  - ♦ Fluid intake should be monitored to ensure urine appears dilute. Additionally, soldiers should be monitored for body weight changes and orthostatic blood pressure changes due to hydration.
  - ♦ The gastrointestinal tract can absorb only 1–1.5 L/h.
  - ♦ Daily rehydration should not exceed 12 L/d orally. **Too much hydration can also be dangerous and lead to water intoxication!**
  - ♦ Leaders must reinforce hydration by planning for all aspects of adequate hydration—elimination as well as consumption. (Soldiers may not drink at night to avoid awakening and having to dress to urinate, or soldiers may not drink prior to a convoy because no rest stops are planned.)
- o MOPP (Mission-Oriented Protective Posture) gear will increase fluid losses and the incidence of heat injuries.
- o In the first few days of acclimatization, sweat–salt conservation will not be fully developed. Salt depletion is

a risk if soldiers are exposed during this time to sufficient heat or work stress to induce high sweating rates (more than several liters/day), particularly if ration consumption is reduced. Salt depletion can be avoided by providing a salt supplement in the form of salted water (0.05%–0.1%). Acclimation should eventually eliminate the need for salt supplementation.

- Salt supplements are not routinely required and are only recommended in rare instances where adequate rations are not consumed.
- Coincidental illnesses increase heat casualty risk through fever and dehydration. Fever reduces thermoregulatory capacity leading to increased risk, even after clinical evidence of illness has disappeared. Requires increased command supervision and moderate work schedule.
- Sunburn and other skin diseases of hot environments reduce the ability of the skin to thermoregulate. Sunburn must be prevented by adequate clothing, shade, and sunscreen. Skin diseases are best prevented by adequate hygiene.
- Medications that affect thermoregulatory adaptations and increase risk of heat injury include anticholinergics, antihistamines, diuretics, tricyclic antidepressants, major tranquilizers, stimulants, and beta-blockers.

Despite preventive measures, service members may suffer from heat illness. One case of heat illness is a warning sign that many others are imminent. The most life-threatening condition is heatstroke. Severity of heat illness depends on the maximum core temperature and duration.

- **Heatstroke**.
  Heatstroke is distinguished from heat exhaustion by the presence of clinically significant tissue injury and/or altered mental status. Degree of injury appears to relate to both the degree of temperature elevation and duration of exposure.

If heatstroke is suspected and temperature is elevated, cooling should not be delayed to accomplish a diagnostic evaluation. Cooling and evaluation should proceed simultaneously.

- Clinical presentation.
  - Heatstroke is a true emergency. It involves components of five organ systems: brain, hemostatic, liver, kidneys, and muscles.
  - Encephalopathy ranges from syncope and confusion to seizures or coma with decerebrate rigidity. Profound neuropsychiatric impairments present early and universally in casualties of advanced exertional heatstroke.
  - Coagulopathy: Thermal damage to endothelium, rhabdomyolysis, and direct thermal platelet activation causes intravascular microthrombi. Fibrinolysis is secondarily activated. Hepatic dysfunction and thermal injury to megakaryocytes slow the repletion of clotting factors. Hepatic injury is common. Transaminase enzyme elevation (values 100 or more times the upper normal limit), clotting factor deficiencies, and jaundice (within 24–36 hours of onset) are also present. Transaminase levels may be transient and reversible; but, if they persist for 48 hours, it is indicative of more severe injury. Hypoglycemia is a frequent complication of exertional heatstroke.
  - Renal failure: Myoglobinuria from rhabdomyolysis in exertional heatstroke, acute tubular necrosis due to hypoperfusion, glomerulopathy due to disseminated intravascular coagulation, direct thermal injury, and hyperuricemia.
  - Muscles are often rigid and contracted: Rhabdomyolysis is a frequent acute complication of exertional heatstroke. Acute muscular necrosis releases large quantities of potassium, myoglobin, phosphate, uric acid, and creatine, and sequesters calcium in exposed contractile proteins.

The patient with heatstroke requires immediate evacuation to medical facilities with intensive care capabilities. Active cooling should be started immediately and continued during evacuation.

- ♦ Prodromal symptoms include headache, dizziness (lightheadedness), restlessness, weakness, ataxia, confusion, disorientation, drowsiness, irrational or aggressive behavior, syncope, seizures, or coma.
- ♦ Collapse is a universal feature of heatstroke.
- ♦ An individual with a core temperature of ≥40ºC (104°F) and CNS dysfunction that results in delirium, convulsions, or coma has heatstroke.

o Casualties who are **unconscious** and have a core temperature of ≥39°C (102.2°F) have heatstroke.

- ♦ Core temperature is often lower on arrival at a treatment area.
- ♦ Seizures:
  - ◊ Occur frequently (>50% of cases) with heatstroke.
  - ◊ Hinder cooling efforts.
  - ◊ Treat with diazepam 5–10 mg.

o Treatment.

- ♦ Rapid cooling can reduce heatstroke mortality anywhere from 50% down to 5%. Cooling by spraying cool water over the body and vigorous fanning can be effective, although not as effective as ice water immersion. Any effective means of cooling is acceptable.
- ♦ A variety of techniques have been used. Although evaporative cooling is less effective, the ice immersion method may prevent safe cardiac monitoring or rapid resuscitation.
- ♦ Cool water immersion (20°C) with skin massage is the classic technique. It provides rapid cooling. Closely monitor patient for, and prevent, shivering.
- ♦ Cooling with cool water-soaked sheets or ice chips and vigorous fanning is highly effective.
- ♦ Do not use alcohol in the cooling solution because freezing of the skin can occur.

The goal of treatment is to effect a rapid lowering of the core temperature to 38°C (101°F), without inducing shivering.

- ♦ Rectal temperature should be closely monitored during cooling. Discontinue cooling efforts when core temperature reaches 38.3°C (101°F) to avoid hypothermia.

- Aspirin and acetaminophen should **NOT** be given to casualties of heatstroke.
- Aggressive fluid resuscitation is not required. Fluid requirements of 1 L in the first 30 minutes, with an additional 2 L or more in the next 2 hours may be sufficient. Because heatstroke patients are frequently hypoglycemic, the initial fluid should include dextrose (chilled IV fluid is of limited benefit).
  - Base further hydration on fluid status/urinary output (Foley required).
  - Overhydration can lead to congestive heart failure, cerebral edema, and pulmonary edema in the heat-stressed lung.
- If shivering develops, treat with diazepam (5–10 mg IV) or chlorpromazine (50 mg IV).
- Patients are frequently agitated, combative, or seizing. Diazepam is effective for control and can be administered intravenously, endotracheally, or rectally, but should be used with caution.
- Airway control is essential. Vomiting is common, and endotracheal intubation should be used in any patient with a reduced level of consciousness or otherwise unable to protect the airway. Supplemental oxygen should be provided when available.
- Hypotensive patients who do not respond to saline should receive inotropic support. Careful titrated use of dopamine or dobutamine is reasonable and has the potential added advantage of improving renal perfusion.
- Pulmonary artery wedge pressure monitoring should be used in patients with persistent hemodynamic instability.
- Management of encephalopathy is supportive in nature and is directed at minimizing cerebral edema by avoiding fluid overreplacement and by ensuring hemodynamic, thermal, and metabolic stability. IV mannitol has been used to treat life-threatening cerebral edema, but is questionable unless renal function is adequate and the patient is fully hydrated. The efficacy of dexamethasone for treating heatstroke-induced cerebral edema is not known.

- Complications.
  - Rhabdomyolysis and secondary renal failure due to myoglobinuria and hyperuricemia; hyperkalemia; hypocalcemia; and compartment syndromes due to muscle swelling.
    - Elevated creatine phosphokinase (in the thousands).
    - Administer IV fluid and possibly furosemide to maintain urinary output >50 cc/h. (Assurance of adequate renal perfusion and urine flow will moderate the nephrotoxic effects of myoglobin and uric acid.)
    - Hyperkalemia can be managed by K^{++}/Na^{+} ion exchange resin (Kayexalate) given orally or rectally as an enema. If available, dialysis may occasionally be indicated.
    - Hypocalcemia does not usually require treatment.
    - Increasing tenderness or tension in a muscle compartment may represent increasing intracompartmental pressures. Direct measurement of intramuscular pressure or fasciotomy should be considered. Pain and paresthesia from a compartment syndrome may not be present until after permanent damage has occurred.
  - Alkalinize urine with sodium bicarbonate IV (2 amps $NaHCO_3$/L D5W). Management of acute renal failure requires exquisite attention to fluid and electrolyte balance. Uremic metabolic acidosis and hyperkalemia require dialysis for control.
  - Coagulopathy due to hepatic injury.
    - Hepatic injury is common, resulting in transaminase enzyme elevation, clotting factor deficiencies, and jaundice. Transaminase levels may be transient and reversible. But, if they persist for 48 hours, then it is indicative of more severe injury.
    - Worst prothrombin time occurs at 48–72 hours postinjury.
    - Thrombocytopenia and disseminated intravascular coagulation peak at 18–36 hours postinjury.
    - Beware of the coagulopathy timeframe when planning evacuation.

- ◊ Subclinical coagulopathy does not require active management. Clinically significant bleeding is an ominous sign. Treatment is directed at reducing the rate of coagulation and replacement of depleted clotting factors. Intravascular coagulation can be slowed by cautious heparin infusion (5–7 units/kg/h), followed in 2–3 hours by fresh frozen plasma and platelets. Successful management leads to a decline in the indices of fibrinolysis (eg, fibrin split products). Heparin is tapered gradually over 2–3 days as directed by laboratory evidence of control.
- ◊ Monitor for hypoglycemia or hyperglycemia.

♦ Prognosis is worse in patients with more severe degrees of encephalopathy. Permanent neurological sequelae can develop after heatstroke, including cerebellar ataxia, paresis, seizure disorder, and cognitive dysfunction.

♦ Neurological deterioration after initial recovery may represent intracranial hemorrhage related to diffuse intravascular coagulation or hematoma related to trauma unrecognized at the time of initial presentation.

♦ Other complications include gastrointestinal bleeding, jaundice, aspiration pneumonia, noncardiogenic pulmonary edema, and myocardial infarction. Immune incompetence and infection are late complications, particularly in patients with severe renal failure.

♦ Hyperkalemia is the most life-threatening early clinical problem. Measurement of serum potassium is an early priority.

- **Heat cramps**.
  - Clinical presentation.

♦ Brief, intermittent, recurring, and often excruciating tonic muscle contractions that last 2–3 minutes. Preceded by palpable or visible fasciculations.

♦ Typically involve muscles of the abdomen, legs, and arms (voluntary muscles of the trunk and extremities). Smooth muscle, cardiac muscle, the diaphragm, and bulbar muscles are not involved.

♦ Occur often with heat exhaustion. (Despite the salt depletion associated with heat cramps, frank signs and symptoms of heat exhaustion are unusual.)

- There are no systemic manifestations, except those attributable to pain.
- Occur in healthy individuals who exercise for prolonged periods in warm environments.
- Occur in salt-depleted patients, generally during a period of recovery after a period of work in the heat.
- Differential diagnosis: tetany due to alkalosis (hyperventilation, severe gastroenteritis, cholera), hypocalcemia, strychnine poisoning, black widow spider envenomation, and abdominal colic.

- Treatment.
  - Mild cases can be treated with oral 0.1%–0.2% salt solutions. Salt tablets should not be used as an oral salt source.
  - Most "sports drinks" (diluted 1:1 with water) effective for mild cases.
  - IV normal saline (NS) provides rapid relief in more severe cases.
  - Patients with heat cramps usually have substantial salt deficits (15–30 g over 2–3 days, usual dietary intake). These individuals should be allowed 2–3 days to replenish salt and water deficits before returning to work in the heat.

- **Heat exhaustion**.
  - Clinical presentation.
    - Thirst, headache, dyspnea, lightheadedness (orthostatic dizziness), profound physical fatigue, anorexia, confusion, anxiety, agitation, mood change, chills, piloerection, nausea, and vomiting. There is no combination of presenting symptoms and signs that is pathognomonic.
    - Often accompanied by heat cramps.
    - Oliguria, clinical dehydration, ataxia, tachycardia, and tachypnea resulting in symptomatic hyperventilation with acroparesthesia and carpopedal spasm.
    - Syncope may occur.
    - Core temperature is <39°C (102.2°F), even at time of collapse.

- Treatment.
  - Oral rehydration (if patient is not vomiting).
  - Parenteral fluids produce more rapid recovery: no more than 250 mL NS bolus without laboratory surveillance; after 2.5 L of plain saline, add dextrose as a source of energy (D2.5½NaCl); subsequent fluid replacement should be D5½NS or D5¼NS. Individuals with significant salt depletion have coincident potassium depletion, often amounting to 300–400 mEq of KCl. To begin restoration of potassium deficit, inclusion of potassium in parenteral fluids after volume resuscitation is appropriate if there is no evidence of renal insufficiency or rhabdomyolysis.
  - Does not require active cooling; however, because symptoms are difficult to distinguish from heatstroke, the **safest course** is to provide active cooling for all casualties who are at risk for heatstroke.
  - Removal from hot environment.
  - Stop exercising, move out of the sun.

- **Minor heat illnesses**.
  - Miliaria rubra, miliaria profunda, and anhidrotic heat exhaustion.
    - Subacute (miliaria rubra) pruritic inflamed papulovesicular skin eruption that appears in actively sweating skin exposed to high humidity. Becomes generalized and prolonged (miliaria profunda); lesions are truncal, noninflamed papular, with less evidence of vesiculation than the lesions of miliaria rubra.
    - Each miliarial papulovesicle represents an eccrine sweat gland whose duct is occluded at the level of the epidermal stratum granulosum by inspissated organic debris.
    - Eccrine secretions accumulate in the glandular portion of the gland and infiltrate into the surrounding dermis.
    - Pruritus is increased with increased sweating.
    - Miliarial skin cannot fully participate in thermoregulatory sweating; therefore, the risk of heat illness increases in proportion to the amount of skin surface involved. Sweat does not appear on the surface of affected skin.

- ♦ Sleeplessness due to pruritus and secondary infection of occluded glands has systemic effects that further degrade optimal thermoregulation.
- ♦ Miliaria is treated by cooling and drying affected skin, avoiding conditions that induce sweating, controlling infection, and relieving pruritus. Eccrine gland function recovers with desquamation of the affected epidermis, which takes 7–10 days.
- ♦ Miliaria profunda causes an uncommon, but disabling, disorder: anhidrotic heat exhaustion (or tropical anhidrotic asthenia). Miliaria profunda causes a marked inhibition of thermoregulatory sweating and heat intolerance similar to that of ectodermal dysplasia. That individual is more at risk for heat exhaustion and at high risk of heatstroke in conditions tolerated by others.
- ♦ Evacuation to a cooler environment until restoration of normal eccrine gland function.

- ○ Heat-induced syncope.
  - ♦ Due to a reduced effective blood volume. (Thermal stress increases the risk of classic neurally mediated [vasovagal] syncope by aggravating peripheral pooling of blood in dilated cutaneous vessels.)
  - ♦ Symptoms range from light-headedness to loss of consciousness.
  - ♦ Typically someone standing in a hot environment.
  - ♦ Greatest risk on first day of heat exposure; subsequent risk decreases daily.
  - ♦ Risk almost 0 after 1 week of heat exposure; however, syncope occurring during or after work in the heat, or after more than 5 days of heat exposure, should be considered evidence of heat exhaustion.
  - ♦ Core temperature is not elevated or only very minimally so.
  - ♦ Patient regains consciousness immediately after syncope.
  - ♦ Clinical evaluation and management should be directed toward the syncopal episode, not potential heat illness. Treatment is oral hydration and continued acclimatization.
- ○ Heat edema.

- ♦ Seen early in heat exposure.
- ♦ Plasma volume expanding to compensate for the increased need for thermoregulatory blood flow.
- ♦ In the absence of other disease, condition is of no clinical significance.
- ♦ Will resolve spontaneously.
- ♦ Diuretic therapy is not appropriate and may increase risk of heat illness.

- ○ Sunburn.
  - ♦ Reduces thermoregulatory capacity of skin.
  - ♦ Systemic effect: hyperthermia.
  - ♦ Preventable.
  - ♦ Affected soldiers should be kept from significant heat strain until the burn has healed.
- ○ Heat tetany.
  - ♦ Rare; occurs in individuals acutely exposed to overwhelming heat stress.
  - ♦ Extremely severe heat stress induces hyperventilation.
  - ♦ Manifestations include respiratory alkalosis, carpopedal spasm, and syncope.
  - ♦ Treatment: removal from heat source and control of hyperventilation (rebreathing into paper bag to reverse respiratory alkalosis).
  - ♦ Dehydration and salt depletion are not prominent features.

Altitude Illness

Exposure of troops to the hypobaric hypoxia of altitude results in a decrement of performance, as well as the possible development of altitude illness. Altitude illness spans a spectrum from high-altitude bronchitis, to acute mountain sickness (AMS), to death from high-altitude pulmonary edema (HAPE), and high-altitude cerebral edema (HACE).

- **Altitude basics**.
  The occurrence of altitude illness is based on altitude and rapidity of ascent. Contributory factors include level of exertion, physiological susceptibility, age, and coexisting medical conditions.
  - ○ Physiological changes due to altitude begin to occur at just over 1,500 m (4,900 ft).

- These changes are the body's attempt to acclimatize to altitude.
- Symptoms occurring below 2,250 m (7,400 ft) are rarely due to altitude illness.
  - Rapid ascent to high altitudes results in a high incidence of altitude illness.
  - Climbing Mt. Rainier brings one from sea level to 14,500 ft (4,400 m) in 36 hours and results in a 70% incidence of altitude illness. An ascent to a similar height over the course of 5 days would only result in a 5% incidence of altitude illness.
  - 10%–20% of soldiers who ascend rapidly (<24 hours) to altitudes between 1,800 to 2,500 m (6,000–8,000 ft) experience some mild symptoms.
  - Rapid ascent to elevations of 3,600 to 4,300 m (12,000–14,000 ft) results in moderate symptoms in more than 50% of the soldiers, and 12%–18% may have severe symptoms.
  - Rapid ascent to 5,300 m (17,500 ft) causes severe, incapacitating symptoms in almost all individuals.

- Descent basics.
  - Almost everything improves with prompt descent.
  - For illness requiring descent, one should try to descend at least 1,000 m (3,300 ft) if not more.
  - A Gamow bag (USA; a portable fabric hyperbaric chamber) or Certec SA bag (Europe) can temporize a patient if evacuation/descent is not possible.
  - Symptoms typically resolve quickly with descent, but may linger for several days.
  - Victims of HACE and HAPE should not reascend until 72 hours after symptoms abate, and then they must ascend much slower than previously.
  - Victims of HACE or HAPE should descend at the earliest sign, before they become moribund and incapable of aiding in their own descent.
  - **There are no reliable predictors of susceptibility to AMS, except prior experience at altitude.**

Incidence and severity of symptoms vary with initial altitude, rate of ascent, level of exertion, and individual susceptibility.

- Vigorous physical activity during ascent or within 24 hours after ascent will increase both the incidence and severity of symptoms.
  - If a soldier became ill previously at a given altitude, he or she will likely become ill at the same altitude unless the ascent is slower to allow for better acclimatization.
  - Physical fitness level has **no effect** on susceptibility to altitude illness.
  - Oral Sildenafil (Viagra) 50 mg qd increases exercise tolerance in healthy volunteers at altitude (5,200 m [17,000 ft]), although it has not been approved for this purpose. The role of this drug in the treatment and/or prophylaxis of AMS and HAPE has not been established.
  - If a rapid ascent to altitude must be made, use prophylaxis against AMS.

- **Acute mountain sickness**.
  - AMS is the most common form of altitude illness.
  - Onset is shortly after arrival at high altitude. Onset occurs 3–24 hours after ascent. Symptoms reach peak severity in 24–72 hours and usually subside over the course of 3–7 days.
  - Further ascent without an acclimation period usually exacerbates symptoms and can result in increased incidence of HAPE and HACE. The majority of AMS cases do not progress to more serious altitude illness without continued ascent.
  - Symptoms.
    - Headache: Symmetric, global in location, and throbbing in character. Most intense during night and shortly after arising in the morning, attributed to increased hypoxemia caused by altitude-induced sleep apnea.
    - Anorexia.
    - Nausea.
    - Fatigue (weakness).
    - General malaise.

- Decreased coordination.
- Dizziness or light-headedness.
- Oliguria.
- Emesis (vomiting).
- Lassitude.
- Insomnia: Sleep disturbances with periodic breathing with recurrent apneic periods during sleep are usually present, but are not necessarily a component of AMS.

- Diagnosis.
  - Occurrence of a headache and at least one other sign/symptom in an individual who ascended from low (1,524 m or < 5,000 ft) altitude to high altitude, or from high altitude to higher altitude in the previous 24–48 hours.
  - Differential diagnosis includes viral gastroenteritis, hangover, exhaustion, dehydration, carbon monoxide poisoning, and HACE.
  - Presence of neurological symptoms—such as incoordination, ataxia, and excessive lethargy or cognitive dysfunction—is indicative of progression to HACE, which requires immediate therapeutic intervention.
- Prophylaxis for AMS.
  - Gradual acclimation.
    - **Staged ascent**: Soldiers ascend to intermediate altitudes and remain there for three or more days before ascending further.
    - **Graded ascent**: Limits daily altitude gain to allow partial acclimation. Sleep altitude is most important. Have soldiers spend two nights at 2,743 m (9,000 ft) and limit the sleeping altitude to no more than 305 m (1,000 ft) per day above the previous night's sleep altitude.
    - **Combined staged and graded ascent**: This is the safest and most effective prevention method.
  - Diet: High carbohydrate diet (<70% of total energy intake as carbohydrates); stimulation of ventilation through increased carbon dioxide produced from the metabolism of carbohydrates.

- ♦ Acetazolamide (250 mg qid or 500 mg bid po), starting 48 hours before ascent and continuing for 48 hours after ascent. Side effects include peripheral paresthesias, fatigue, increased urination (polyuria), and altered taste imparted to carbonated beverages. It prevents AMS in 50%–75% of soldiers and reduces symptoms in most others. Short-term use when changing altitude significantly (400 m). **Contraindicated in sulfa allergy**.
- ♦ Dexamethasone (4 mg qid po) is the prophylaxis of choice in sulfa-allergic individuals. Dexamethasone does not aid acclimatization, and effects are gone when it is stopped. Dexamethasone ± acetazolamide is also the prophylaxis of choice for missions of a rapid, high (more than 4,000 m [13,000 ft]), short-duration profile (raids, rescues).
- ♦ Cyanosis: Oxygen 2–6 L/min. Do not delay descent.

- ○ Treatment.
  - ♦ AMS alone does NOT mandate descent.
  - ♦ Remain at the same elevation; do **not** ascend until symptoms abate.
  - ♦ Acetazolamide (250 mg bid to 500 mg tid po)—do not use in patients with sulfa allergies. (If already receiving a preventive dose of acetazolamide [1,000 mg/d] and still symptomatic, 500 mg can be added with caution.) Diuretic effect may exacerbate AMS.
  - ♦ Dexamethasone in doses of 2–4 mg q6h (has the same potentially serious side effects as when used as a prophylaxis). Symptoms may recur when medication stopped.
  - ♦ Oxygen by nasal cannula 2–6 L/min (severe headache).
  - ♦ Do NOT advance sleeping altitude.
  - ♦ Symptomatic treatment with acetylsalicylate acid (or aspirin); acetaminophen; prochlorperazine for nausea and vomiting 5–10 mg tid–qid, po, or IM; or 25 mg bid PRN also stimulates respiration; ibuprofen for headache.
  - ♦ Minimize utilization of sleeping agents at altitude; they can worsen illness. Acetazolamide for sleep disorders, 250 mg qid or tid po. Temazepam for insomnia, 30 mg qhs po; triazolam for insomnia, 0.125–0.25 mg qhs po. Short-term use only. Possible short-term memory loss.

- **High-altitude pharyngitis and bronchitis**.
  - Common condition occurring after 2–3 weeks at altitude.
  - Common at altitudes over 5,486 m (18,000 ft).
  - Sore throat, chronic cough, and severe cough spasms (severe enough to cause rib fractures).
  - Environmental, from breathing cold dry air.
  - Altitude-induced tachypnea aggravates the problem.
  - Cold-induced vasomotor rhinitis, especially at night, stimulates mouth breathing and also aggravates problem.
  - Usually not caused by infection, although infection can occur.
  - Patient will **not** have dyspnea at rest.
  - Symptomatic treatment with lozenges, mild cough suppressant, and decongestant nasal sprays. Personnel can use a mask or a porous, breathable silk balaclava as a mouth covering to reduce respiratory heat and moisture loss.
  - Maintain hydration.
- **High-altitude peripheral edema**.
  - Altitude-related edema of the hands and face.
  - Hypoxia-induced retention of sodium and water.
  - Not considered related to AMS/HACE edema spectrum or HAPE.
  - Decreased urine output and weight gain of 2.7–5.4 kg (6–12 lbs) over several days; most evident on awakening.
  - Diagnosis based on association of characteristic peripheral edema with ascent to high altitude; recurs consistently with repeat ascents; more common in females.
  - Differential diagnosis includes cardiogenic edema, allergic reactions, and edema of the upper extremities caused by pack straps or binding by tight clothes.
  - Prophylaxis includes salt restriction. The acetazolamide regimen used to prevent AMS is often successful in preventing peripheral edema.
  - Treatment with diuretics (one 20- to 40-mg dose of furosemide or 250 mg of acetazolamide every 8 h for 3 doses) and salt restriction.
- **High-altitude retinal hemorrhage**.
  - Bleeding from retinal vessels during altitude exposure. One of the manifestations of hypoxia-induced retinopathy.

- Caused by blood pressure "surges" within the distended vessels.
- Usually asymptomatic; normally does not adversely affect military operations; however, can affect an individual soldier's vision.
- Hemorrhages are self-limiting and resolve in 1–2 weeks after descent.

- **Thromboembolic events**.
  - Increased possibility of thromboembolic event with ascent to high altitude: thrombophlebitis, deep venous thrombosis, pulmonary embolus, transient ischemic attacks, and stroke.
  - Probably result from hypoxia-induced polycythemia and clotting abnormalities, but also may result from environmental and mission factors—such as dehydration, cold, and venous stasis caused by prolonged periods of inactivity during inclement weather or by constriction of tight-fitting clothing and equipment.
  - Unusual below 4,267 m (14,000 ft). At very high and extreme altitudes (>4,200 m [13,700 ft]), these events are not uncommon; and thrombophlebitis appears to be relatively common.
  - Clinical manifestations are similar to manifestations of thromboembolic events at low altitude, except for their occurrence in young and otherwise healthy personnel.
  - Prevention relies on reducing the risk factors by maintaining adequate hydration and warmth, and by avoiding conditions that might cause venous stasis.
  - Evacuation to lower altitude is required. Treatment follows standard treatment guidelines, including appropriate anticoagulation. In the field setting, fractionated heparin (1 dose of 250 IU/d) can be used prior to and during evacuation.
- **Subacute mountain sickness**.
  - Prolonged deployment (weeks to months) to elevations above 3,658 m (12,000 ft).
  - Common manifestations include sleep disturbances, anorexia, weight loss, fatigue, daytime somnolence, and subnormal mentation.
  - Caused by failure to acclimatize adequately.

- Some relief of symptoms obtained from low-flow oxygen and acetazolamide.
- Evacuate to lower altitude as soon as practical.
- Some degree of immune suppression and poor wound healing occurs in personnel at very high and extreme altitudes. Injuries resulting from burns, ballistics, and physical trauma should be considered more clinically significant at high altitude.

- **High-altitude pulmonary edema**.
  - Potentially fatal, **non**cardiogenic pulmonary edema.
  - Occurs in <10% of personnel ascending above 3,700 m (12,000 ft).
  - Onset 2–4 days after rapid ascent to altitudes greater than 2,438 m (8,000 ft).
  - Repeated ascents and descents above 3,700 m (12,000 ft) increase susceptibility.
  - Risk factors.
    - Moderate-to-severe exertion.
    - Cold exposure.
    - Anxiety.
    - Young age.
    - Male sex.
    - Obesity (possibly).
  - Early symptoms (pulmonary edema).
    - Nonproductive cough.
    - Rales (few).
    - Dyspnea on exertion.
    - Fatigue.
    - Weakness with decreased tolerance for physical activity and increased time for recovery after physical exertion.
    - Resting tachycardia and tachypnea greater than induced by altitude alone.
    - Once symptoms appear, HAPE can progress very rapidly (<12 hours) to coma and death.
    - Nail beds and lips may be more cyanotic than other unit members.
  - Progressing pulmonary edema.
    - Productive cough of frothy and sometimes pink or blood-stained sputum.

- Rales more numerous and widespread.
- Wheezing may develop.
- Lung sounds become audible even without a stethoscope, especially when the individual is supine.
- Orthopnea may occur (<20%).
- Progressive hypoxemia causes dyspnea and cyanosis.
- Arterial blood gas (if available) documents hypoxemia, hypocapnia, and a slight increase in pH.
- Mental status deteriorates with progressive confusion and sometimes vivid hallucinations.
- Obtundation, coma, and death occur without treatment.
- Subfebrile temperature <38°C (100.5°F) and a mild increase in white blood cell count may be present.
- Dyspnea at rest.
- Marked hypoxia by oximetry.
- **Dyspnea <u>at rest</u> and cough should be considered to be the onset of HAPE.**

Delay in the TREATMENT of progressive pulmonary edema at altitude usually results in DEATH.

- Treatment.
  - Depends on severity.
  - Immediate descent is mandatory! Descent of even a few hundred meters (300–1,000 m) can be helpful or even lifesaving in severe cases.
  - Mortality can approach 50% if descent cannot be accomplished rapidly.
  - Oxygen by cannula 2–6 L/min (mild) or by mask 4–6 L/min (moderate and severe). **DO NOT DELAY DESCENT!**
  - Portable fabric hyperbaric chamber may be lifesaving—Gamow bag/Certec SA bag.
  - Nifedipine, 10 mg chew + 10 mg swallow immediately, then 10 mg po q4h. If the patient is comatose, pierce the nifedipine capsule and squirt the liquid into the patient's mouth.

Nifedipine should not be used in lieu of descent, supplemental oxygen, or treatment in a hyperbaric bag. It may be used in conjunction with other therapies.

- ♦ Immediate descent to lower elevation; if symptoms resolve, wait at least 72 hours before attempted return to previous elevation.

Neither furosemide nor morphine sulfate should be used in the treatment of HAPE (high-altitude pulmonary edema), unless other, more effective, treatment options are not available.

- ♦ Treatment after descent, at a medical treatment facility, is directed toward ensuring adequate oxygenation and reducing pulmonary artery pressure; includes bed rest, supplemental oxygen, and nifedipine.
- ♦ Invasive diagnostic procedures, such as bronchoscopy or pulmonary artery catheterization, are **NOT** indicated unless clinical course deteriorates and the diagnosis is in doubt. Endotracheal intubation is seldom necessary.

- o HAPE prophylaxis.
  - ♦ Nifedipine, 20 mg tid po, 24 hours before ascent, continuing 72 hours after ascent.

- **High-altitude cerebral edema**.
  - o Onset following ascent is highly variable and occurs later than either AMS or HAPE. Mean duration of 5-day onset, with a range of 1–13 days.
  - o Incidence lower than AMS or HAPE (<1% of individuals making rapid ascent).
  - o Potentially fatal, uncommon (<2% above 3,700 m). Can occur as low as 2,430 m (8,000 ft), but vast majority of cases occur above 3,600 m (12,000 ft). Untreated HACE can progress to death over 1–3 days or become more fulminant with death occurring in <2 hours.
  - o Exacerbation of unresolved, severe AMS.
  - o **Most often occurs in people who have AMS symptoms and continue to ascend.**
  - o Signs and symptoms.

- ♦ Most signs and symptoms are a manifestation of progressive cerebral edema.
- ♦ **Early signs resemble AMS. (These symptoms are not invariably present.)**
- ♦ Severe headache.
- ♦ Nausea.
- ♦ Vomiting.
- ♦ Extreme lassitude.

- o Progressing signs.
  - ♦ Mental status changes: Confusion, disorientation, drowsiness, and impaired mentation.
  - ♦ Truncal ataxia (swaying of upper body, especially when walking). As the edema progresses, soldier may also exhibit an ataxic gait in addition to the truncal ataxia.
  - ♦ Soldier appears withdrawn, and behavior is mistakenly attributed to fatigue or anxiety.
  - ♦ Cyanosis and general pallor are common.
  - ♦ Symptoms of HAPE.
- o Untreated HACE.
  - ♦ Variety of focal and generalized neurological abnormalities may develop: visual changes, anesthesias, paresthesias, clonus, pathological reflexes, hyperreflexia, bladder and bowel dysfunction, hallucinations, and seizures.
  - ♦ Papilledema may be present in up to 50% of the soldiers, but is **NOT** universal.
- o Coma.

Ataxia at altitude is HACE (or high-altitude cerebral edema).

- o Prophylaxis.
  - ♦ No definitive evidence; however, due to similarity with AMS, prophylactic measures for HACE include use of staged or graded ascent, high carbohydrate diet, and use of acetazolamide.
- o Treatment.
  - ♦ Immediate descent is mandatory. Definitive treatment of HACE is immediate descent. In general, the greater the

descent, the better the outcome. Descent >300 m (1,000 ft) may be required for clinical improvement, and descents to altitudes of <2,500 m (8,000 ft) are optimal.

- If descent is delayed, treatment with a portable cloth hyperbaric chamber may be lifesaving. May require at least 6 hours of pressurization in chamber.
- Oxygen by mask or cannula 2–6 L/m; should not be used as a substitute for descent.
- Dexamethasone, 4–8 mg initially; then, 4 mg qid, po, IV, or IM. **DO NOT DELAY DESCENT!** Few side effects if used only 3–4 days.

High-altitude cerebral edema (HACE) and high-altitude pulmonary edema (HAPE) often coexist. Individuals with HACE will often have HAPE; however, most individuals with HAPE do not have concomitant HACE.

- Loop diuretics and osmotic diuretic agents—such as mannitol, urea, and glycerol—have been suggested, but there is little experience with them in this role. Careful attention is required before diuretics are used. Individual may have altitude-induced decrease in intravascular volume concomitant with cerebral edema.
- Hospital management consists of supplemental oxygen (if needed to maintain arterial oxygen levels), supportive care, and possibly diuretics. Comatose patients may require intubation and bladder catheterization.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 28

Radiological Injuries

The reader is strongly advised to supplement material in this chapter with the following two references:

1. Armed Forces Radiobiology Research Institute. *Medical Management of Radiological Casualties*. 4th ed. Bethesda, MD: AFRRI; July 2013.
2. Waselenko JK, MacVittie TH, Blakely WF, et al. Medical management of the acute radiation syndrome: recommendations of the Strategic National Stockpile Radiation Working Group. *Ann Intern Med*. 2004; 140:1037–1051.

Introduction

Radiological casualties on the battlefield may occur with improvised or conventional nuclear devices or radiological dispersal devices ("dirty bombs") (Table 28-1).

- Conventional nuclear weapons.
  - The relative casualty-causing potential depends primarily on four factors:
    - Yield of the weapon.
    - Height of burst.
    - Environmental conditions in which the detonation occurs.
    - Distribution and shielding of troops in the target area.
  - A nuclear detonation generally causes injuries with the following distribution:
    - Blast injury: 50%.
    - Thermal injury: 35%.
    - Ionizing radiation injury.
      - Initial: 5%.

- ◊ Residual: 10%.

- A radiological dispersal device (RDD) is any device—including any weapon or equipment—other than a nuclear explosive device, specifically designed to spread radiation.
  - RDDs contaminate conventional casualties with radionuclides, complicating medical evacuation.
  - RDDs are ideal weapons for terrorism, and are used to intimidate and deny access to an area by spreading radioactive material.

Table 28-1. Radiological Casualties

Weapon Effect	Weapon Yield (kt)/Distance (m)			
	1 kt	10 kt	100 kt	1,000 kt
Blast (50% casualties)	140 m	360 m	860 m	3,100 m
Thermal radiation (50% deep burns)	370 m	1,100 m	3,190 m	8,020 m
Ionizing radiation (50% immediate transient ineffectiveness)	600 m	950 m	1,400 m	2,900 m
Ionizing radiation (50% lethality)	800 m	1,100 m	1,600 m	3,200 m

kt: kiloton; m: meter.

Triage

- Triage should be conducted on traditional surgical and medical considerations, then modified by radiation injury level.
  - Radiation interacts deleteriously with trauma. Patients with medical or traumatic injury who also have whole-body or significant partial-body irradiation have a substantially worse prognosis and will require a higher triage priority.
  - Make a preliminary diagnosis of radiation injury only for those with exposure symptoms, such as nausea, vomiting, diarrhea, fever, ataxia, seizures, prostration, and hypotension.
  - Radiation patient triage classifications.
    - **Immediate:** Those requiring immediate lifesaving intervention. Pure radiation injury is not acutely life-threatening unless the irradiation is massive. If a

massive dose has been received, the patient is classified as expectant.

- **Delayed:** Casualties with only radiation injury, without gross neurological symptoms (ataxia, seizures, and impaired cognition). For trauma combined with radiation injury, all surgical procedures must be completed within 36–48 hours of radiation exposure, or delayed until at least 2 months after the injury.
- **Minimal:** Buddy care is particularly useful here. Casualties with radiological injury should have all wounds and lacerations meticulously cleaned and then closed.
- **Expectant:** Receive appropriate supportive treatment compatible with resources; large doses of analgesics as needed.

- Table 28-2 provides medical aspects of radiation injuries.

Table 28-2. Medical Aspects of Radiation Injuries

Probability/degree of exposure	Signs and Symptoms						
	Nausea	Vomiting	Diarrhea	Hyperthermia	Erythema	Hypotension	CNS dysfunction
Unlikely	–	–	–	–	–	–	–
Probable	++	+	+/–	+/–	–	–	–
Severe	+++	+++	+/+++	+/+++	–/++	+/++	–/++

CNS: central nervous system.

- The lethal dose (LD) of radiation, which will kill 50% of a population within 60 days of exposure, is called $LD_{50/60}$. The $LD_{50/60}$ is approximately 3–4 Gy for a population with radiation injury alone and with no significant medical care. The $LD_{50/60}$ for a population with radiation injury alone and the best available medical care (including antiemetics, antivirals, antibiotics, hematopoietic cytokines, and transfusion) may be 6 Gy or more. Combined injuries with radiation and trauma and/or burns will markedly lower the LD_{50}.

- Significant medical care may be required at 3–5 weeks for 10%–50% of personnel. Anticipated problems should include infection, bleeding, fever, vomiting, and diarrhea. Wounding or burns will markedly increase morbidity and mortality.
- Treatment.
  - Fluid and electrolytes for gastrointestinal losses.
  - Cytokines for immunocompromised patients (follow granulocyte counts).
  - Restricted duty. No further radiation exposure, elective surgery, or wounding. May require delayed evacuation from theater during nuclear war in accordance with command guidance.
  - If there are more than 1.7×10^9 lymphocytes per liter, 48 hours after exposure, it is unlikely that an individual has received a fatal dose.
  - Patients with low (300–500) or decreasing lymphocyte counts, or low granulocyte counts, should be considered for cytokine therapy and biological dosimetry using metaphase analysis where available.
- Asymptomatic patients with lethal radiation dose may perform usual duties until symptomatic.

Potential Injuries

- **Thermal/flash burns** or thermal pulse burns are caused directly by infrared radiation. Close to the fireball, the thermal output is often so great that everything is incinerated, and even at great distances, thermal/flash burns will occur (see Chapter 26, Burns, for management).
  - Burn mortality rates associated with radiation exposure are significantly higher due to bone marrow suppression and infection (a 50% total body surface area burn associated with radiation exposure has a mortality of 90%).
- **Blast injuries** consist of two basic types of blast forces that occur simultaneously in a nuclear detonation blast wave: (1) direct blast wave overpressure forces, measured in terms of atmospheres of overpressure; and (2) indirect blast wind drag forces, normally measured in the velocities of the winds that cause them. The most important blast effects are those due to the blast wind drag forces.

- **Direct blast wave overpressure forces.** When the blast wave acts directly upon a resilient target such as the human body, rapid compression and decompression result in transmission of pressure waves through the tissues. These waves can be quite severe and will result in damage primarily at junctions between tissues of different densities (bone and muscle) or at the interface between tissue and air spaces (lung tissue and the gastrointestinal [GI] system). Perforation of the eardrums is a common blast injury.
- **Indirect blast wind drag forces.** The drag forces of blast winds are proportional to the velocities and duration times of these winds, which in turn vary with distance from the point of detonation, yield of the weapon, and altitude of the burst. These winds are relatively short in duration but are extremely severe and may reach several hundred kilometers per hour. Indirect blast injuries occur as crush and/or translational injuries and as missile injuries. Casualties are likely to be thrown against immobile objects and impaled by flying debris.

- **Radiation injuries** are due to ionizing radiation released both at the time of the nuclear detonation and for a considerable time afterward. The two types of radiation released are electromagnetic (gamma) radiation and particulate (alpha, beta, and neutron) radiation.
  - Alpha particles can be shielded against by clothing.
  - Beta particles shielding requires solid materials, like a wall.
  - Gamma and neutron radiation are the most biologically active and require lead equivalent shielding for protection.
  - Fission products are the major radiation hazard in fallout because a large number emit penetrating gamma radiation. This can result in injuries, even at great distances.
  - Fallout causes whole-body irradiation from gamma-emitting isotopes because they do not actually have to be on a person's skin to cause damage.
- **Flash blindness** may occur as the result of a sudden peripheral visual observation of a brilliant flash of intense light energy.
- **Retinal burns** may also occur, and result in scarring and permanent altered visual acuity.

Treatment of Combined Injuries

- Following the detonation of a nuclear device, the majority of resulting casualties will have sustained a combination of blast, thermal, and radiological injuries.
- The usual methods of treatment for blast injuries must be modified in those casualties simultaneously exposed to ionizing radiation.

Traditionally, combat wounds are left open. However, wounds left open to heal by secondary intention in the irradiated patient will serve as a nidus of infection. Wounds exposed to ionizing radiation should be debrided and closed at a second-look operation within 36–48 hours.

- Hypotension should always be assumed to be hypovolemia and not due to radiological injury.
- Hyperthermia is common.
- Radiological injuries increase the morbidity and mortality of injuries due to compromise of the normal hematopoietic and immune responses to injury. Surgical procedures may need to be delayed during bone marrow suppression, if at all possible.
- Potassium iodide may be used for prevention of thyroid uptake of radioisotopes after nuclear reactor accidents.
- Chelating agents may be used to eliminate metals from the bloodstream before they reach target organs.
- Mobilizing agents are used to increase the excretion of internal contaminants.
- Prussian blue is used to remove radionuclides from the capillary bed surrounding the intestine and prevents their reabsorption. Delay until patient is stable. Treat ABCs first.

Decontamination

- There are no reports of healthcare provider injury with radiation while performing ABCs on a radiation victim.
- Removal of the casualty's clothing can eliminate as much as 90% of the radiological contamination.
- The first priority of surface decontamination should be to open wounds, then other areas.

- To prevent rapid incorporation of radioactive particles, wounds should be copiously irrigated with normal saline for several minutes.
- The eyes, ears, nose, mouth, and areas adjacent to uncontaminated wounds, hair, and remaining skin surface should be decontaminated with soap and water.
- Personnel providing decontamination must protect themselves from ionizing radiation exposure with:
  - Protective outer clothing.
  - Aprons, gloves, and masks.

- Amputation should be seriously considered when the contamination burden is great and severe radionecrosis is likely.

Logistics of Casualty Management

- **If nuclear weapons are employed within theater, the entire medical evacuation and treatment system will be severely overburdened,** and some system of classification and sorting of casualties must be added to the normal procedures of evacuation and hospitalization.
- Patients entering a medical treatment facility should be routinely decontaminated if monitoring for radiation is not available.
- These two requirements—the sorting of casualties and the holding of excess numbers—must be planned for and drilled as part of the normal organization and operation of the health service support system in a theater of operations where radiation exposure potential is high.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 29

Biological Warfare Agents

The reader is strongly advised to supplement material in this chapter with the following reference:
US Army Medical Research Institute of Infectious Diseases (USAMRIID). *Medical Management of Biological Casualties Handbook*. 8th ed. Fort Detrick, MD: USAMRIID; 2005.

Introduction

Biological warfare (BW) agents infect the body via the same portals of entry as infectious organisms that occur naturally. These include inhalation into the respiratory tract; ingestion into the gastrointestinal tract; and absorption through mucous membranes, eyes, skin, or wounds. Most BW agents will enter the body through inhalation. Usually, the disease produced by a BW agent will mimic the naturally occurring disease, but the clinical presentation can be different if delivery of an agent occurs through a portal that differs from the natural portal.

Detection

- The appearance of a large outbreak of cases of a similar disease or syndrome, especially in a discrete population.
- Many cases of unexplained diseases or death.
- More severe disease than is usually expected for a specific pathogen or failure to respond to a standard therapy.
- Unusual routes of exposure for a pathogen, such as the inhalation route of diseases that normally occur through other exposures.
- A disease case or cases that are unusual for a given geographic area or transmission season.
- Disease normally transmitted by a vector that is not present in the local area.

- Multiple simultaneous or serial epidemics of different diseases in the same population.
- A single case of disease caused by an uncommon agent (smallpox, some viral hemorrhagic fevers, inhalational anthrax, pneumonic plague).
- A disease that is unusual for an age group.
- Unusual strains of variants of organisms or antimicrobial resistance patterns different from those known to be circulating.
- A similar or identical genetic type among agents isolated from distinct sources at different times or locations.
- Higher attack rates among those exposed in certain areas, such as inside a building if released indoors, or lower rates in those inside a sealed building if released outside.
- Outbreaks of the same disease occurring simultaneously in noncontiguous areas.
- Zoonotic disease outbreaks.
- A zoonotic disease occurring in humans, but not animals.
- Intelligence of a potential attack, claims by a terrorist or aggressor of a release, and discovery of munitions, tampering, or other potential vehicle of spread (spray device, contaminated letter).

Diagnosis

The first indication of an attack may be when large numbers of patients present with the same constellation of signs and symptoms, especially for a disease that is not endemic to the area of operations.

Rapid diagnostic tests may be available in forward areas to assist clinicians in early diagnosis:

- Isolation of the etiological agent can occur within 1–2 days for some agents.
- Enzyme-linked immunosorbent assays (ELISAs).
- Genome detection by polymerase chain reaction.
- Antibody detection.

Prevention and Protection

- Immunizations: Anthrax and, in specific scenarios, smallpox and plague.
  - Pre- or postexposure chemoprophylaxis—anthrax, plague, Q fever, and tularemia. Chemoprophylaxis for anthrax is presently approved by the Food and Drug Administration for postexposure only.
    - Investigational new drugs exist for the treatment of Argentine hemorrhagic fever, botulinum toxin, Q fever, Rift Valley fever, Venezuelan equine encephalitis, and tularemia.
- Protective clothing and mask.

Decontamination—Personnel, Equipment, and Clothing

- **Mechanical** decontamination removes, but not necessarily neutralizes, the BW agent.
  - Brushing to ensure loosening of the BW agent from the surface.
  - Filtration and chlorination of drinking water to remove organisms.
- **Chemical** decontamination renders BW agents harmless through the use of disinfectants.
  - Soap and water followed with copious rinsing with water is often sufficient.
  - For patients requiring urgent decontamination, biological agents are neutralized within 5 minutes when contaminated areas are washed with a 0.5 % hypochlorite solution (1 part household bleach mixed with 9 parts water).
  - **Do not use hypochlorite in the eyes, in the abdominal cavity, or on nerve tissue**.
  - A 5% hypochlorite solution (ie, household bleach) may be used to decontaminate clothing or equipment.
- **Physical** decontamination, such as heat and solar ultraviolet radiation.
  - Dry heat for 2 hours at 160°C.
  - Autoclaving at 120°C under 1 atm of overpressure for 20 minutes.
  - Ultraviolet radiation is difficult to standardize.

- Dry biological agents can be a hazard through secondary aerosolization, but adequate liquid decontamination will prevent this hazard. There is no vapor hazard, and special protective masks are generally not required for surgical personnel.

Infection Control

Infection control procedures should be reinforced for situations involving BW agents. Standard precautions are appropriate for BW agents once they have been identified. For an undifferentiated febrile illness following a BW agent attack:

- Place patients together in an isolated setting, such as a designated tent or other structure.
- Surgical masks may be placed on patients when isolation is not possible.
- Employ respiratory droplet precautions along with standard precautions until diseases transmissible by droplet (eg, plague and smallpox) have been excluded.

Medical Evacuation

- If plague, smallpox, and hemorrhagic fevers can be **excluded**, patients may be evacuated using standard precautions and the disease-specific precautions.

Plague and smallpox are internationally quarantinable diseases. Do not evacuate patient across international borders unless authorized by the theater surgeon.

- Isolation precautions should be added to standard precautions.
- Immediately upon diagnosing patients with smallpox, the line and medical chain of command must be notified.
- Observe strict quarantine.
  - Standard and respiratory droplet isolation precautions.
    - **Standard precautions**.
      - Hand washing after patient contact.
      - Use of gloves when touching blood, body fluids, secretions, excretions, and contaminated items.
      - Use of mask, eye protection, and gown during procedures likely to generate sprays of blood, body fluids, secretions, or excretions.

- ◊ Handle contaminated patient-care equipment and linen in a manner that precludes transfer of microorganisms to individuals or equipment.
- ◊ Practice care when handling sharps and use pocket mask or other ventilation device when ventilating the patient.
- ◊ Place patient in private room when possible. Limit the movement or transfer of the patient.

♦ **Droplet precautions**.

- ◊ Standard precautions plus:
  - ■ Place patient in private room or with someone with the same infection. If not feasible, maintain at least 1 m distance between patients.
  - ■ Use a mask when working within 1 m of patient.
  - ■ Mask the patient if he or she needs to be moved.

o All contacts should be vaccinated within 7 days of exposure and quarantined together for at least 17 days following the most recent exposure.

Hemorrhagic Fevers—Hanta, Ebola, Lassa, Rift Valley, and Hemorrhagic Fever With Renal Syndrome

- These viruses pose special challenges for hospital infection control. With the exception of dengue and hantaviruses, viral hemorrhagic fever patients harbor significant levels of potentially infectious virus in blood, body fluids, or secretions. Special caution must be exercised in handling hypodermic needs and other sharps. Strict adherence to standard and contact precautions will prevent nosocomial transmission in most cases.
- When a viral hemorrhagic fever is suspected, additional infection control measures are indicated. The patient should be isolated in a private room with an adjoining anteroom to be used for donning and doffing protective barrier garments, storage of supplies, and decontamination of lab specimen containers.
- Medical evacuation may result in increased morbidity and mortality; thus, treatment at local medical treatment facilities is preferred.
- When necessary, patients may be evacuated using universal and respiratory droplet isolation precautions.

Biological Agents

The four toxins most likely to be used as biological agents are botulinum toxins, ricin, staphylococcal enteroxin B, and T-2 mycotoxins (Table 29-1).

Table 29-1. Symptoms and Medical Management of Biological Toxins

Biological Toxin	Signs/Symptoms	Medical Management
Botulinum	Cranial nerve palsies Paralysis Respiratory failure	Antitoxin/supportive care
Ricin	Fever, cough, shortness of breath Arthralgias, pulmonary edema	Nonspecific/supportive care
SEB	Nausea, vomiting, diarrhea Fever, chills, headache	Nonspecific/supportive care
T-2 mycotoxin	Skin pain, redness, blistering Nasal itching, epistaxis, rhinorrhea Dyspnea, wheezing, cough	Nonspecific/supportive care

SEB: staphylococcal enteroxin B.

Bacterial Agents

The bacteria or rickettsia most often considered to be potential BW threat agents include *Bacillus anthracis* (anthrax), *Brucella* sp. (brucellosis), *Vibrio cholerae* (cholera), *Burkholderia mallei* (glanders), *Yersinia pestis* (plague), *Francisella tularensis* (tularemia), and *Coxiella burnetii* (Q fever) (Table 29-2).

Table 29-2. Symptoms and Medical Management of Bacterial Agents

Bacterial Agent	Signs/Symptoms	Medical Management
Anthrax	Fever, malaise, cough, shortness of breath, cyanosis	Ciprofloxacin
Plague	High fever, chills, headache, cough, shortness of breath, cyanosis	Streptomycin
Brucellosis	Fever, headache, myalgias, sweats, chills	Doxycycline
Cholera	Massive watery diarrhea	Fluid therapy and antibiotics (tetracycline, doxycycline, or ciprofloxacin)
Tularemia	Local ulcer, lymphadenop-, athy fever, chills, headache, and malaise	Streptomycin
Q fever	Fever, cough, and pleuritic chest pain	Tetracycline

Viral Agents

A number of viruses are BW agents, including smallpox, viral hemorrhagic fevers, and the alpha virus that causes Venezuelan equine encephalitis (Table 29-3).

Table 29-3. Symptoms and Medical Management of Viral Agents

Viral Agent	Signs/Symptoms	Medical Management
VEE	Fever and encephalitis	Nonspecific/supportive care
Smallpox	Malaise, fever, rigors, vomiting, headache followed by pustular vesicles	Antiviral under investigation/ supportive care
VHF	Flushing of the face, petechiae, bleeding, fever, myalgias, vomiting, and diarrhea	Nonspecific/supportive care

VEE: Venezuelan equine encephalitis; VHF: viral hemorrhagic fever.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 30

Chemical Injuries

The reader is strongly advised to supplement material in this chapter with the following reference:
US Army Medical Research Institute of Chemical Defense (USAMRICD), Chemical Casualty Care Division. *Medical Management of Chemical Casualties Handbook*. **5th ed. Aberdeen Proving Ground, MD: USAMRICD; 2014.**

Introduction

The use of chemical agents in modern history includes the use of riot control agents, pulmonary agents (chlorine and phosgene), and vesicants (mustard) during World War I through the use of vesicants (mustard) and nerve agents by Iraq on Iran in the 1980s. The chemical agents most likely to be used today on the battlefield include nerve agents and mustard. However, with the implementation of various types of medical defenses, chemical casualties can be saved and returned to duty, and mortality can be minimized.

Personal Protection

- Prevention!
  - Avoid becoming a casualty.
  - Protect yourself and instruct your personnel to do the same.
- Prevent further injury of the casualty by instructing him/her to put on the protective mask and MOPP (Mission-Oriented Protective Posture) ensemble, and administer self-aid. If contaminated, tell the individual to remove clothing and decontaminate potentially exposed body surfaces.
- Provide buddy aid by masking the individual, administering antidotes, and spot decontaminating exposed body areas.

- Ensure completeness of the decontamination process to the greatest extent possible at the co-located patient decontamination station.
  - Potential for vapor exposure from an off-gassing residual agent or inadvertent contact with undetected liquid is a hazard for medical personnel.
  - Avoid contamination of the medical treatment facility.

Initial Treatment Priorities

- There is no single "best" way to prioritize emergency treatment for chemical or mixed casualties, although respiratory insufficiency and circulatory shock should be treated first. One workable sequence is shown below.

1. **Treat respiratory insufficiency (airway management) and control massive hemorrhage.**
2. **Administer chemical agent antidotes.**
3. **Decontaminate the face (and protective mask if donned).**
4. **Remove contaminated clothing and decontaminate potentially contaminated skin.**
5. **Render emergency care for shock, wounds, and open fractures.**
6. **Administer supportive medical care as resources permit.**
7. **Transport the stabilized patient to a contamination-free (ie, clean) area.**

Specific Chemical Warfare Agents and Treatment Considerations

Nerve Agents

- Tabun (GA), sarin (GB), soman (GD), cyclosarin or cyclohexyl sarin (GF), and methylphosphonothioic acid (VX).
- **General:** Nerve agents are among the most toxic of the known chemical agents. They pose a hazard in both vapor and liquid states, and can cause death in minutes by respiratory obstruction and cardiac failure.
- **Mechanism of action:** Nerve agents are organophosphates that bind with available acetylcholinesterase, permitting a paralyzing accumulation of acetylcholine at the myoneural junction.

- **Signs/symptoms:** Miosis, rhinorrhea, difficulty breathing, loss of consciousness, apnea, seizures, paralysis, and copious secretions.
- **Treatment:** Each deployed US service member has three **Antidote Treatment Nerve Agent Autoinjectors** (ATNAAs) for IM self-injection in a pocket of the protective mask carrier. Each kit delivers 2-mg injections of atropine sulfate and 600 mg pralidoxime chloride (2-PAMC). Each US service member also carries a 10-mg diazepam autoinjector to be administered by a buddy.
  - Immediate IM or IV injection with:
    - Atropine to block muscarinic cholinergic receptors (may require multiple doses in much greater amounts than recommended by Advanced Cardiac Life Support doses).
    - 2-PAMC (if given soon after exposure) to reactivate cholinesterase.
- **Pretreatment:** Military personnel may have also received pretreatment prior to nerve agent exposure. In the late 1990s, the US military fielded pyridostigmine bromide tablets as a pretreatment for nerve agent exposure (this **reversibly** binds to the enzyme acetylcholinesterase, enhancing the efficacy of atropine against soman).

Vesicants

- Sulfur mustard (HD or H), nitrogen mustard (HN), Lewisite (L), and phosgene oxime (CX).
- **General:** The vesicants (blister agents) are cytotoxic alkylating compounds exemplified by the mixture of compounds collectively known as "mustard."
- **Mechanism of action:** Mustard is an alkylating agent that denatures DNA, producing a radiomimetic effect; and produces liquefaction necrosis of the epidermis, severe conjunctivitis, and, if inhaled, injures the laryngeal and tracheobronchial mucosa.
- **Signs/symptoms:** Skin blisters, moderate-to-severe airway injury (presentation can be delayed), conjunctivitis of varying severity that causes the casualty to believe he/she has been blinded, and mucus membrane burns. No delay with Lewisite; immediate burning of the skin and eyes.

- **Treatment:** Preventive and supportive. Immediate decontamination of the casualty has top priority. Agent droplets should be removed as expeditiously as possible by blotting with Reactive Skin Decontamination Lotion (RSDL) or flushing with water or 0.5% hypochlorite. RSDL is extremely effective at inactivating mustard.
  - Most military forces carry a decontamination powder or liquid that should be used immediately to remove the vesicant.
  - Because mustard tends to be an oily solution, water may spread the agent. Dimercaprol is used by some nations in the treatment of Lewisite. Dimercaprol must be used with caution because the drug itself may be toxic.

Lung-Damaging (Choking) Agents

- Phosgene (CG), diphosgene (DP), chloropicrin (PS), and chlorine.
- **General:** Lung-damaging or choking agents produce pronounced irritation of the upper and the lower respiratory tracts. CG smells like freshly mowed hay or grass.
- **Mechanism of action:** CG is absorbed almost exclusively by inhalation. Most of the agent is not systemically distributed, but rather is consumed by reactions occurring at the alveolar–capillary membrane.
- **Signs/symptoms:** CG exposure results in pulmonary edema following a clinically latent period that varies, depending on the intensity of exposure. Immediate eye, nose, and throat irritations may be the first symptoms evident after exposure (choking, coughing, tightness in the chest, and lacrimation). Over the next 2–24 hours, the patient may develop noncardiogenic fatal pulmonary edema.
- **Treatment:**
  - Terminate exposure, force rest, manage airway secretions, oxygen; consider steroids.
  - **Triage considerations** for patients seen within 12 hours after exposure:
    - Immediate care in an ICU, if available for patients in pulmonary edema.
    - Delayed: dyspnea without objective signs of pulmonary edema; reassess hourly.

- ♦ Minimal: asymptomatic patient with known exposure.
- ♦ Expectant: patient presents with cyanosis, pulmonary edema, and hypotension. Patients presenting with these symptoms within 6 hours of exposure will not likely survive.

The Cyanogens

- Blood agents: hydrogen cyanide (AC) and cyanogen chloride (CK).
- **General:** AC and CK form highly stable complexes with metalloporphyrins, such as cytochrome oxidase. The term "blood agent" is an antiquated term used at a time when it was not understood that the effect occurs mostly outside of the bloodstream.
- **Mechanism of action:** Cyanide acts by combining with cytochrome oxidase, blocking the electron transport system. As a result, aerobic cellular metabolism comes to a halt.
- **Signs/symptoms:** Seizures, cardiac arrest, and respiratory arrest.
- **Treatment:**
  - o Immediate removal of casualties from the contaminated atmosphere prevents further inhalation.
  - o 100% oxygen.
  - o If cyanide was ingested, perform gastrointestinal lavage and administer activated charcoal.
  - o **Specific antidotal therapy:** Administer sodium nitrite (10 mL of 3% solution IV) over a 3-minute period, followed by sodium thiosulfate (50 mL of 25% solution IV) over a 10-minute period. Sodium nitrite produces methemoglobin that attracts the cyanide; sodium thiosulfate solution combines with the cyanide to form thiocyanate, which is excreted.

Incapacitation Agents

- BZ (3-quinuclidinyl benzilate) and indoles.
- **General:** Heterogeneous group of chemical agents related to atropine, scopolamine, and hyoscyamine that produces temporary disabling conditions with potent CNS effects that seriously impair normal function, but that do not endanger life or cause permanent tissue damage.

- **Signs/symptoms:** Mydriasis, dry mouth, dry skin, increased reflexes, hallucinations, and impaired memory.
- **Treatment:**
  - Immediate removal of firearms and other weapons to ensure safety.
  - Close observation.
  - Physostigmine, 2–3 mg IM every 15 minutes to 1 hour until desired level is attained; maintain with 2–4 mg IV every 1–2 hours for severe cases.

Thickened Agents

- Thickened agents are chemical agents that have been mixed with another substance to increase their **persistency** (persistent agents may remain in the environment more than 24 hours).
- Casualties with thickened nerve agents in wounds are unlikely to survive to reach surgery.
- Thickened mustard has delayed systemic toxicity and can persist in wounds, even when large fragments of cloth have been removed.

Surgical Treatment of Chemical Casualties

- **Wound decontamination**—Initial management of a casualty contaminated by chemical agents will require removal of MOPP gear, as well as initial skin and wound decontamination with available decontaminant before treatment.
  - Bandages are removed, wounds are flushed, and bandages are replaced.
  - Tourniquets are replaced with clean tourniquets after decontamination.
  - Splints are thoroughly decontaminated.

Vesicants and nerve agents are potential wound contamination hazards. Cyanogens are so volatile that it is extremely unlikely they would remain in a wound.

Off-Gassing

- The risk of vapor off-gassing from chemically contaminated fragments and cloth in wounds is very low and insignificant.

Off-gassing from a wound during surgical exploration will be negligible. However, the possibility of thickened agents being in wounds presents a potential hazard. Precautions such as double surgical gloves and using probes to explore wounds instead of fingers may be considered.

Use of RSDL

RSDL inactivates nerve agents and mustard, and can remove an agent that has already begun to penetrate the skin. It is the preferred spot decontaminant for chemical casualties, but is not currently approved for use in eyes or wounds.

Warning: Concomitant use with bleach may result in an exothermic reaction capable of generating sufficient heat to damage tissue.

Use of Hypochlorite Solution

- Household bleach is 5% sodium hypochlorite; hence, mix 1 part bleach with 9 parts water to create a ~0.5% solution.
- Dilute hypochlorite (0.5%) is an effective skin decontaminant, but the solution is **contraindicated** for use in or on a number of anatomical areas:
  - Eye: may cause corneal injuries.
  - Brain and spinal cord injuries.
  - Peritoneal cavity: May lead to adhesions.
  - Thoracic cavity: Hazard is still unknown, although it may be less of a problem.
- Full strength 5% hypochlorite is used to decontaminate instruments, clothing, sheets, and other inanimate objects.

Wound Exploration and Debridement

Surgeons and assistants should wear well-fitting, thin, butyl rubber gloves or double latex surgical gloves. **Gloves should be changed often** while ascertaining that there are no foreign bodies or thickened agents remaining in the wound.

Wound excision and debridement should be conducted using a no-touch technique. Removed fragments of tissue should be dumped into a container of 5% hypochlorite solution. Superficial wounds should be wiped thoroughly with 0.5% hypochlorite and then irrigated with copious amounts of normal saline.

Following the Surgical Procedure

- Surgical and other instruments that come into contact with possible contamination should be placed in 5% hypochlorite for 10 minutes prior to normal cleansing and sterilization.
- Reusable linen should be checked with the chemical agent monitor, M8 paper, or M9 tape for contamination. Soak contaminated linen in 5% hypochlorite.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 31

Pediatric Care

Introduction

The military surgeon must be prepared to address the unique challenges that pediatric patients present, not only in war scenarios, but also in noncombat military operations other than war.

Anatomical and Physiological Considerations

- **Fluid, electrolyte, and nutrition.**
  - Maintenance fluid requirements in children may be estimated using a weight-based nomogram (Table 31-1) or a length-based method, such as the Broselow Pediatric Emergency Tape. There is an increasing realization that hyponatremia caused by hypotonic intravenous fluids is a significant cause of morbidity and mortality in the injured child. Administration of D5½NS with 20 mEq/L of KC1 is acceptable even in infants. Monitoring serum electrolytes serves as is a useful guide in assessing the adequacy of resuscitation. Because infants and small children have limited glycogen stores, administration of glucose early in the resuscitation period (within 6 hours) is critical.

Table 31-1. Hourly Fluid Requirements for Children

Weight (kg)	Hourly Volume	Fluid
Up to 10 kg	4 mL/kg	D5½NS + 20 mEq KCl/L
11–20 kg	40 mL + 2 mL/kg over 10 kg	D5½NS + 20 mEq KCl/L
>20 kg	60 mL + 1 mL/kg over 20 kg	D5½NS + 20 mEq KCl/L

  - Fluid resuscitation is best performed with normal (0.9%) saline at 20 mL/kg boluses. (See Evaluation and Diagnosis.)

- Normal urine output
  -infants: 2 mL/kg/h
  -children: 1 mL/kg/h
  -adults: 0.5 mL/kg/h
- Daily caloric and protein requirements may be estimated based on weight and age (Table 31-2).

Table 31-2. Daily Caloric and Protein Requirements for Children

Age (yrs)	Body Weight (kcal/kg)	Protein (g/kg Body Weight)
0–1	90–120	2.0–3.5
1–7	75–90	2.0–2.5
7–12	60–75	2.0
12–18	30–60	1.5
>18	25–30	1.0

- Breast milk is optimal when initiating oral intake in infants, and offers many advantages over other preparations. Standard infant formulas provide 20 kcal/oz. An estimate of the amount of formula needed to provide 120 kcal/kg/d is:

Infant's weight (kg) × 22-30 =
Amount (in mL) of formula needed q4h.

- If pediatric-appropriate enteral formulas are unavailable, adult preparations may be utilized beyond infancy by diluting them with free water:

100 mL/kg of free water per day for the first 10 kg,
50 mL/kg/day for the second 10 kg,
and then 20 mL/kg/day for every kg over that up to 2.4 L/day.

- Pulmonary.
  - In contrast to adults the most common cause of cardiac arrest in children is respiratory arrest. Hypoxemia can lead to bradycardia with hypoperfusion, followed rapidly by cardiac arrest.
  - Newborns are obligate nasal breathers; thus, nasal airways and nasogastric tubes should be avoided if possible in favor of oropharyngeal airways and orogastric tubes.

- The child's larynx is positioned more anteriorly compared to adults, and a more forward positioning of the head ("sniffing position") will facilitate visualization of the trachea.
- The acceptable range of PaO_2 (60–90 mm Hg) corresponds to an oxygen saturation of 92%–97%. Oxygen saturations in the low 90s are adequate in infants due to increased levels of fetal hemoglobin (Hgb F). Supraphysiologic concentrations of inspired oxygen are unnecessary, and are harmful, especially to preterm infants.
- Infants breathe primarily using their diaphragm; thus, increases in intraabdominal pressure or other problems that limit diaphragmatic movement may significantly impair respiration. An example of this is gastric distension. In the traumatically injured infant or child, gastric decompression is important to preserve respiratory function and prevent vagal stimulation. Children have limited functional residual capacity; therefore, maneuvers such as c-spine and backboard immobilization may impair respiration, especially in the face of gastric distension.

- Cardiovascular.
  - Vital signs by age group are shown in Table 31-3.

Table 31-3. Normal Vital Signs for Age

Age	Weight (kg)	Respiration Rate	Pulse	BP (Systolic)
Premie	<3	40–60	130–150	42 ± 10
Term	3	40	120–140	60 ± 10
1–5 years	~10–20	20–30	100–130	95 ± 30
6–10 years	20–32	12–25	75–100	100 ± 15
Adolescent	50	12–18	70	120 ± 20

  - Cardiac stroke volume in infants is relatively fixed. Therefore, bradycardia or relative bradycardia may be associated with a significant decrease in cardiac output (CO=HR × SV).

Obtaining venous access in a hypotensive child may be extremely difficult and may delay the administration of critically needed fluids or medications. Limit peripheral IV access attempts to two within 90 seconds for the child in shock, then immediately proceed to intraosseous needle access. (See Chapter 7, Shock, Damage Control Resuscitation, and Vascular Access.) NEVER utilize the sternum as a location for IO access in small children. The humerus should be used only as a last resort. In general, the tibial plateau or distal femur are the preferred locations.

- **Burns.**
  - An infant or child's head comprises a greater percentage of the total body surface area, with the lower extremities being a lesser percentage. The area encompassed by the palm of the patient's hand corresponds to approximately 1% of the total body surface area, and may be useful in calculating the total burn surface area (Fig. 31-1).

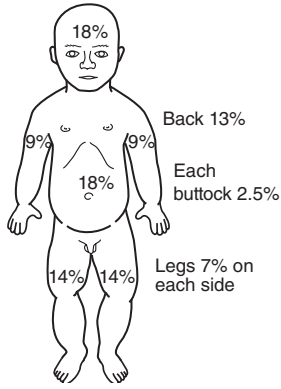

Fig. 31-1. Body surface area percentages for infants and children.

- Gastrointestinal.
  - **Esophageal** reflux is physiologic in the newborn period, and decreases as a child becomes ambulatory, solid food comprises a greater part of the diet, and lower esophageal sphincter tone increases.
  - Upright positioning and institution of thickened feedings often improves symptomatic children.
  - Children (especially infants) are predisposed to hypoglycemia due to their low hepatic glycogen stores. Full-term infants will tolerate NPO status for approximately 5 days (with an appropriate D10 solution). Premature infants will tolerate only 3 days of NPO status prior to the initiation of total parenteral nutrition. Approximately 5–7 mg/kg/min of glucose is necessary to maintain normoglycemia.

- A child's GI tract is very sensitive to insults, including hypoxemia, enteric infection, electrolyte and acid-base abnormalities, and systemic illness. This may be manifest as impaired motility and feeding intolerance.
- Gastroenteritis with diarrhea, often associated with fevers, is also a very common cause of severe dehydration.

- Hematology and blood volume.
  - Infants have a physiologic anemia (hematocrit of 30%–33%) as production of adult hemoglobin (Hgb A) replaces fetal hemoglobin (Hgb F) during the first 3–5 months of life.
  - Estimates of blood volume are as follows:

Age Estimate	Volume (mL/kg)
Newborn	90
Infant	80
School-age child	70

- Renal.
  - Infants and young children have a limited ability to concentrate urine (maximum: 400–600 mOsm/L) and a fixed ability to excrete sodium, and are therefore at risk for hypernatremia if excessive sodium is administered.
  - Maintenance electrolyte requirements:
    1 mEq/kg/day of potassium
    2 mEq/kg/day of sodium
    3 mEq/kg/day of chloride
  - Serum electrolytes should be monitored daily in children who are NPO with significant GI losses or children who are being resuscitated. GI losses such as gastric fluid output should be carefully measured and replaced with the appropriate IV fluids. Bolusing children with potassium-containing fluids can be very dangerous. It is preferable to tolerate mild to moderate hypokalemia while replacing losses very slowly (over 12 hours) while on an EKG monitor, if available. It is much safer to replace ongoing losses as they occur, preferably by the enteral route, than to use an IV bolus for measured deficits.
- **Thermoregulation.**
  - Infants and young children are predisposed to heat loss due to diminished quantities of adipose tissue, and they

compensate poorly for wide fluctuations in ambient temperatures. Children have a higher ratio of body surface area to mass, and therefore are likely to experience increased insensible water loss and become dehydrated more quickly than adults when febrile.

- Reduce exposure to heat loss, and keep infants and children in a regulated warm environment. Active warming measures such as warming IV fluids and using thermal blankets are critical for infants and small children during trauma evaluations and in the operating room. Small children will rapidly become hypothermic if this is not done as part of standard practice.

- **Immune system.**
  - Premature infants have an immature immune system, causing a 60-fold increased risk of sepsis. All elective surgery in infants under 30 days of age requires 48 hours of prophylactic antibiotics (with anaerobic coverage added when appropriate) after the first week of life.
  - Early signs of sepsis may be subtle in infants and may be manifested as lethargy, intolerance to feedings, fever, hypothermia, tachycardia, and irritability before a rise in white blood cell count. Leukopenia and thrombocytopenia in infants and small children may be associated with an overwhelming infectious process.

Evaluation and Diagnosis

- Pediatric cervical spine clearance can be performed with a physical examination in awake children without neurological deficits. If there is no midline tenderness or pain with active motion, the spine can be cleared. Obtunded children, those with focal neurological deficits, and those with tenderness should have further imaging, dictated by imaging modalities available at a given facility. Although children are at higher risk for spinal cord injury without radiographic abnormality (SCIWORA) than adults, most cases may be managed with immobilization alone. Plain films will detect most clinically significant c-spine injuries in children. Unlike in adults, a normal CT of the c-spine in small children will not rule out a ligamentous injury. Pseudosubluxation of C2 on C3 may

be evident on x-ray. If in doubt, continue immobilization of the cervical spine. Because of the larger cranium in infants, the body should be placed on a pad in order to maintain normal anatomic alignment of the airway during backboard immobilization, and sufficient padding should be placed under the occiput to prevent pressure necrosis of the scalp.

- Basic ATLS guidelines should direct the initial assessment and evaluation for all children involved in traumas.
  - Modified Glasgow Coma Scale scores for children < 4 years old:

Verbal Response	Verbal Score
Appropriate words/social smile/fixes/follows	5
Cries, but consolable	4
Persistently irritable	3
Restless, agitated	2
None	1

Treatment

- The treatment algorithm shown here provides the proper sequence for the rapid sequence intubation of the pediatric patient (Fig. 31-2).
  - Avoid succinylcholine in patients with burn or crush injuries, or at risk for increased intracranial pressure.
  - Ketamine may prevent hypotension in patients not in septic shock.

Equipment and Supplies

- Accessory pediatric medical/surgical equipment arranged according to age and weight appears in Table 31-4.
- Surgical instruments.
  - If a pediatric surgical set is not immediately available, a peripheral vascular set will usually contain instruments delicate enough to accomplish most tasks in newborns.

Commonly Used Drugs and Dosages

All doses are IV or IM.

- Phenobarbital: 10–20 mg/kg IV at a rate not to exceed 1 mg/kg/min (maximum dose: 40 mg/kg).
- Diazepam: 0.04–0.3 mg/kg/dose.

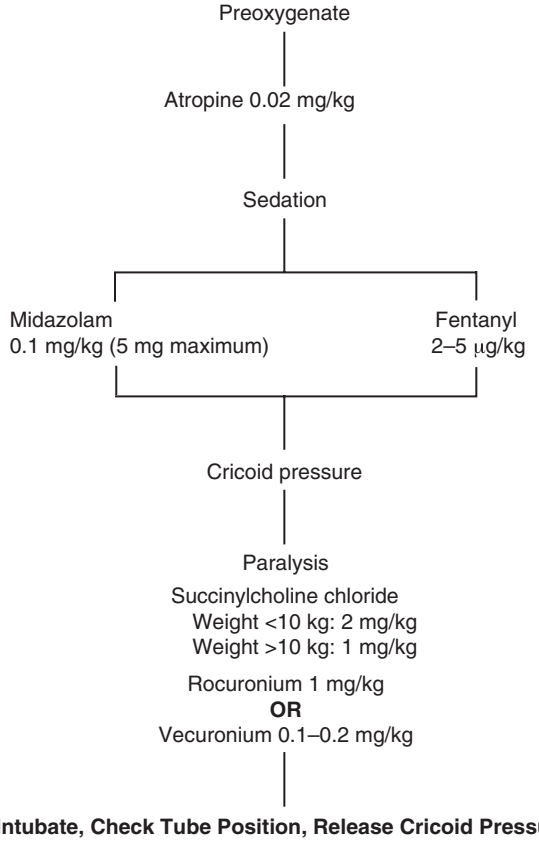

Fig. 31-2. Rapid sequence intubation for the pediatric patient.

- Midazolam: 0.1 mg/kg IV (maximum: 5 mg).
- Atropine: 0.02 mg/kg IV.
- Phenytoin: 15–20 mg/kg IV; administered at 0.5–1.5 mL/kg/min as a loading dose, then 4–7 mg/kg/d IV for maintenance.
- Mannitol: 0.25–1.0 g/kg IV.
- Succinylcholine chloride: 2 mg/kg IV for <10 kg and 1 mg/kg IV for >10 kg.
- Ampicillin: 25–50 mg/kg IV q6h; 100–200 mg/kg/d divided q6h.
- Gentamicin: 4.5–7.5 mg/kg IV qd [once daily dosing (ODD)]; keep doses in manual for q8h dosing.

Table 31-4. Pediatric Resuscitation Equipment and Supplies

	Airway/Breathing							Circulation		Supplemental Equipment			
Age, Weight (kg)	**O_2 Mask**	**Oral Airway**	**Bag Valve**	**Laryngo-scope**	**ET Tube**	**Stylet**	**Suction**	**BP Cuff**	**IV Cath**	**NG Tube**	**Chest Tube**	**Urinary Cath**	**C-collar**
Premie 3 kg	Premie Newborn	Infant	Infant	0 Straight	2.5–3.0 No cuff	6 Fr	6–8 Fr	Premie Newborn	24 gauge	12 Fr	10–14 Fr	5 Fr Feeding	—
0–6 mo 3.5 kg	Newborn	Infant Small	Infant	1 Straight	3.0–3.5 No cuff	6 Fr	8 Fr	Newborn Infant	22 gauge	12 Fr	12–18 Fr	5–8 Fr Feeding	—
6–12 mo 7 kg	Pediatric	Small	Pediatric	1 Straight	3.5–4.0 No cuff	6 Fr	8–10 Fr	Infant Child	22 gauge	12 Fr	14–20 Fr	8 Fr	Small
1–3 yrs 10–12 kg	Pediatric	Small	Pediatric	1 Straight	4.0–4.5 No cuff	6 Fr	10 Fr	Child	20–22 gauge	12 Fr	14–24 Fr	10 Fr	Small
4–7 yrs 16–18 kg	Pediatric	Medium	Pediatric	2 Straight or curved	5.0–5.5 No cuff	14 Fr	14 Fr	Child	20 gauge	12 Fr	20–32 Fr	10–12 Fr	Small
8–10 yrs 24–30 kg	Adult	Medium Large	Pediatric Adult	2–3 Straight or curved	5.5–6.5 Cuffed	14 Fr	14 Fr	Child Adult	18–20 gauge	12 Fr	28–38 Fr	12 Fr	Medium

BP: blood pressure; Cath: catheter; C-collar: cervical collar; ET: endotracheal; Fr: French (gauge); IV: intravenous; NG: nasogastric; O_2: oxygen.

- Metronidazole: 7.5 mg/kg IV q6h.
- Acetaminophen: 15 mg/kg PO q4h.
- Cefazolin: 25–100 mg/kg/d divided q6h–q8h.
- Clindamycin: 15–40 mg/kg/d divided q6h–q8h.
- Hypertonic saline (3%): 5–10 mL/kg.
- Morphine: 0.1–0.2 mg/kg q2h–q4h PRN.
- Ketamine: 0.5–1.5 mg/kg IV over 1 minute >3 months; 2–4 mg/kg IM.

Surgical Management

- Basics.
  - As a general guideline, transverse abdominal incisions should be used in infants. This minimizes the risk of postoperative dehiscence, while still allowing adequate exposure of all areas of the abdomen except the gastro-esophageal junction.
  - Absorbable sutures, such as VICRYL or PDS (2-0), should be used to close the rectus fascia, regardless of the incision. The skin can then be closed using staples or absorbable monofilament suture (eg, MONOCRYL 6-0).
  - Cricothyroidotomy should not be done in children under age 10. If a surgical airway is required, a large-bore IV connected to high flow oxygen can be placed into the cricothyroid membrane or the trachea while preparations are made for an urgent tracheostomy. It is important to allow for passive expiration during this procedure because pneumothoraces can occur if high flow oxygen is administered in the face of an upper airway obstruction. Use of a needle cricothroidomy for more than 45 minutes will result in hypercarbia. Tracheostomy in small children is done as it is in adults. The presence of an esophageal tube is critical to avoid inadvertent injury to the esophagus.
  - The vast majority of thoracic injuries in children can be managed with chest tube alone. Children who present in extremis due to penetrating thoracic injury should undergo a resuscitative thoracotomy similarly to adults. However, for children with blunt trauma, survival after resuscitative thoracotomy is so poor that its use in this setting cannot be justified, particularly in the austere environment.

- When thoracotomy is required in small children, double lumen endotracheal tubes with lung isolation is usually not necessary. Placement of a bronchial blocker or standard endobronchial placement of a single lumen tube will allow for sufficient exposure in small children.

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Tschudy MM, Arcara KM, eds. *The Harriet Lane Handbook: A Manual for Pediatric House Officers*. 19th ed. Philadelphia, PA: Elsevier Mosby; 2012.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 32

Care of Enemy Prisoners of War/Internees

Introduction

Healthcare personnel of the armed forces of the United States have a responsibility to protect and treat enemy prisoners of war (EPWs), retained personnel, civilian internees, and other detainees. For the purposes of this chapter, all such personnel are referred to as **internees**.

The care provided must meet universal principles of medical ethics and standards of care. Internment facility leadership must ensure healthcare providers caring for internees are prepared for the challenges they will face regarding security, politics, ethics, and their own physical and mental health. Healthcare providers have been attacked, injured, bitten, spit on, and in some cases infected with bodily fluids thrown at them (eg, with hepatitis) during examinations or while doing rounds near prison cells.

Department of Defense (DoD) healthcare personnel should make every effort to comply with "Principles of Medical Ethics Relevant to the Role of Health Personnel, Particularly Physicians, in the Protection of Prisoners and Detainees Against Torture and Other Cruel, Inhuman, or Degrading Treatment or Punishment," adopted by the United Nations General Assembly Resolution 37/194, December 18, 1982 (see Appendix 1 in this book), and all applicable DoD policies.

The Geneva Conventions

- Define medical personnel as those individuals "exclusively engaged in the search for, or the collection, transport, or treatment of the wounded or sick, or in the prevention of

disease; and staff exclusively engaged in the administration of medical units and establishments" (**Geneva Convention for the Amelioration of the Wounded and Sick in Armed Forces in the Field [GWS]**).

- Medical personnel of enemy forces are not considered internees, but are classified as "retained" in order to treat other EPWs. Internees are also entitled to the protections afforded under the provisions of the **Geneva Convention Relative to the Treatment of Prisoners of War** (GPW). Detained persons who are not protected under GWS and GPW may be protected under the provisions of the **Geneva Convention Relative to the Protection of Civilian Persons in Time of War**.

The Geneva Convention for the Amelioration of the Wounded and Sick in Armed Forces in the Field states that belligerents must care for the sick and wounded without any adverse distinctions founded on sex, race, nationality, religion, political opinions, or any other similar criteria. Only medical urgency can justify priority in the order of treatment.

Workload

The number of internees and retained/detained personnel requiring medical in-processing and/or medical care can be staggering. Coalition forces captured over 62,000 internees during Operation Desert Storm. During the 1-week ground war, until the end of March 1991, 8,979 internees were treated.

- The most common internee medical condition reported during Operation Desert Storm was dental disease (24%). Other common medical illnesses were unexplained fever, nephrolithiasis, peptic ulcer disease, and malaria.

Wounds in internees may be different than those seen in friendly forces due to differences in personal protective gear, preexisting diseases, malnutrition, and neglect.

Medical Care of Internees

- Healthcare providers have a responsibility to report information that constitutes a clear and imminent threat to the lives and welfare of others.
- **Whenever possible, internees should receive medical care equal to that given to US troops.**
  - Providers should report any suspected abuse or maltreatment of an internee.
  - Providers should inform the theater internment facility chain of command of internee physical limitations. Medical recommendations concerning internee activities are nonbinding. Decisions concerning internee activities are made by the chain of command.
- Healthcare providers charged with the care of internees should **not:**
  - be actively involved in interrogation;
  - advise interrogators how to conduct interrogations; or
  - interpret individual medical records/medical data for the purposes of interrogation or intelligence gathering.
- Healthcare personnel ordered to perform duties they deem unethical should request to be recused through their chain of command. If the situation is not resolved satisfactorily, healthcare providers may contact their Command Surgeon or the Inspector General.
- Requirements for internee care are provided in **AR 190-8/ OPNAVINST 3461.6/AFJI 31-304/MCO 3461.1**. Internees must have an examination upon arrival at the detention facility, as well as a chest radiograph (tuberculin skin test for children up to age 14 years). Sick call must be available daily, and each internee must be weighed at least once per month. Sanitation and hygiene must be maintained at all times (**AR 190-8**).
- **Medical records.**
  - Internee medical records are the property of the US government. Internees are entitled to a copy of their medical records upon release. Original records are retained.
  - The Health Insurance Portability and Accountability Act (HIPAA) does not apply to the medical records of internees (DoD Instruction 6025.18 and DoD 6025.18R). However,

the handling, disposition, and release of all types of medical records are governed by regulation. Commanders and others who have an official need to know can access information contained in internee medical records by following the procedures given in AR 40-66, using DA Form 4254. Patient consent is not required. The medical treatment facility commander or designee, usually the patient administrator, determines what information is appropriate for release. Only specific medical information required to satisfy the terms of a request will be disclosed. Healthcare providers should expect that released medical information would be used by the chain of command, including interrogators.

- Documentation of your encounter with an internee should be very detailed. In many cases the encounter should include pictures or even video, depending on the procedure to be performed or the legal circumstances of the internee. The electronic medical record has improved the continuity of care and, in well-documented cases, has protected US interests. If you have to write a note in a paper chart, make sure your note is legible and complete. **If possible, keep copies**.

- **Medical information**
  - Releasable medical information includes that which is necessary to supervise the general state of health and cleanliness of internees, to detect contagious diseases, and to provide for the safety and security of the facility.

Setup/Planning

- The issue of hunger strikes and force feeding has been debated all the way to the Supreme Court, with the courts siding with force feeding once certain conditions are met. The details of the different rulings are beyond the scope of this chapter but if you find yourself in that situation, familiarize yourself with the criteria to make sure you are participating in something that is both legal and ethical.
- Develop plans for prisoners on a hunger strike and those who refuse treatment.
  - Many patients on a hunger strike will be force fed using an enteral route once is determined that their life is in danger.

  - The procedure is considered by some to be a form of torture and by others to be lifesaving. Healthcare providers may refuse to participate for a variety of reasons.
  - Before participating in the practice of force feeding an internee, make sure there is legal authority in writing for your protection.
  - Once the legal barriers have been cleared, be familiar with "refeeding syndrome" and the protocols required to do the procedure in the most humane way to reduce discomfort to the patient.
  - Recommendations:
    - Numb the nasal cavity and use plenty of lubrication before inserting the feeding tube.
    - Take an X-ray (if available) to make sure the feeding tube is below the diaphragm.
- Enemy forces may have preexisting medical conditions requiring medication.
- Ensure that any internee/retained/detained person evacuated to the medical treatment facility for treatment is escorted by an armed guard, as designated by the nonmedical (echelon) commander. The guard must remain with the patient while in the medical evacuation and treatment chain. When possible, keep internees segregated from friendly forces patients.

It is critical that medical personnel not enter the general EPW holding area, but have patients brought out to them for sick call and any medical treatment.

- **NATO STANAG 2131**, *Multinational Phrase Book for Use by the NATO Medical Services—AMedP-5*, provides basic medical questions in a number of NATO languages.
- Use other retained persons/internees (especially medical personnel) as translators.
- Detainees may feign mental illness to avoid interrogation.
- Internees requiring evacuation will receive an internee identification number upon entry into the detainee reporting system.

Medical personnel, including mental health providers, do not search, guard, or interrogate internees.

Screening

- Guards should ensure internees are screened for hidden weapons and other potentially dangerous materials. **Medical personnel, however, must remain vigilant of these threats and mentally prepared should a threat or attack occur.**
- During transfer, release, and/or repatriation, another medical examination should be performed. Final documentation of any ongoing medical, surgical, or wound care problem is completed and forwarded to the gaining facility or to the appropriate medical records repository.

Supply

- The internment facility must enforce field hygiene and sanitation principles.
- Plan for personal hygiene requirements and protective measures (insect netting, insect repellent, sunscreen).
- Coordinate with the supporting medical headquarters for additional preventive medicine support (pest management, potable water, dining facility sanitation, and waste disposal) and Veterinary Services support for food safety as required.

Medical Staffing

- The facility should be staffed to ensure that detainees receive the same standard of care as US forces.
- Retained medical personnel should be utilized for care of their compatriots in conformity with the Geneva Conventions.

Legal

- When possible, signed permission should be obtained for all surgical or invasive procedures.
- The patient's identity should be absolutely clear in each photograph. Photographs are invaluable should there be a claim of unnecessary surgery or amputation. **In some cases even video of the procedure should be obtained**. Ask your legal representative for advice.
- A high-quality camera is important.

Any patient who requires amputation or major debridement of tissue should be photographed (face as well as wound images).

Internee Advocate

- The military physician is often the commander's advisor for medical ethics. The physician should be alert for potential and actual ethical conflicts, and make efforts to resolve them.
- They must also strive to maintain a "moral distance" from participating in any proceeding potentially adverse to the patient's interest.

Personal safety should never be taken for granted by the medical team, regardless of familiarity with internees and surroundings.

Security

- There is **always** an element of danger to the medical staff in treating internees.
- Before beginning to treat internees, it is a good idea to shadow a provider with experience treating internees for some time to learn the required precautions. **It may save your life!**
- Physical security will be provided by nonmedical personnel designated by the appropriate leadership.
- It is the capturing line unit's responsibility to provide security for EPWs/detainees until arrival at an internment facility.
- Security personnel must accompany all internees whenever they are in a treatment or holding area. In forward areas, it may not be possible to have separate and secure medical treatment/holding areas for internees. When possible, internees should be segregated from allied, coalition, and US forces.
- When possible, avoid taking medical equipment into the patient wards for security reasons (ie, bring the patient to the equipment).
- Following treatment, the provider should alert internment medical personnel of any special needs the internee may have.

For Clinical Practice Guidelines, go to
http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 33

Battlefield Transfusions

Introduction

About 87% of battlefield deaths occur in the prehospital environment. Of these, 24% have been deemed to be potentially survivable, with over 90% of this potentially preventable mortality occurring due to hemorrhage. Prehospital blood transfusion administered within 30-40 minutes of injury has been shown to dramatically reduce combat casualty mortality from hemorrhagic shock. In addition, of the patients dying of wounds after reaching an MTF, about 51% were found on autopsy to have had potentially survivable injuries, and 80% of these died of hemorrhage. Hemorrhage is thus the main cause of potentially preventable death on the battlefield.

Treatment of hemorrhage requires aggressive control of bleeding and blood transfusion. Considering the patients in the prehospital setting who bled to death before reaching an MTF over the course of recent conflicts in Iraq and Afghanistan, as well as the patients arriving directly to MTFs without prior resuscitation who either received a massive transfusion (>10 units of red blood cells and/or whole blood in 24 hours) or who died of hemorrhage in the course of resuscitation, then a total of at least 10% of all casualties were at risk of exsanguination at point of injury and required substantial blood transfusion support beginning as close as possible to point of wounding. Indeed, data from the Joint Trauma System and Armed Services Blood Program indicate that these patients received 90% of all blood transfused in theater.

Another perspective on the need for battlefield transfusion stems from the observation that 13.6% of all casualties admitted to Role 3 combat support hospitals in Iraq and Afghanistan between 2003 and 2012 required transfusion, almost half of these being massive transfusions. Considering that these recent conflicts occurred

with reduced overall battlefield lethality due to weapons systems used and troop protective measures (conditions that have not been prevalent in conflicts since World War II), it is easy to see that need for transfusion may affect up to 20% of casualties.

The 10%-20% of patients likely to require massive transfusion are at high risk of early mortality, generally occurring within the first 6 hours after injury. These patients require immediate resuscitation with blood, preferably starting within 30 minutes of injury, especially in the prehospital setting. In cases of massive blood loss, there is no substitute for the transfusion of blood.

This chapter will briefly address early control of hemorrhage, blood products and their availability by role, ABO Rh matching of blood products, massive transfusion and its specific complications/management, emergency fresh whole blood collection, and transfusion reactions/management relevant to the field.

Early Control of Hemorrhage

- Patients who do not lose large amounts of blood following injury will not likely need blood products. Although this is an obvious statement, it highlights the point that every attempt to control external bleeding should be made during initial care.
- Tourniquets should be applied immediately to extremities with potential for life-threatening blood loss, such as with traumatic amputation, active/ongoing bleeding, or suspected vascular injury (ie, pulsatile bleeding or expanding hematoma formation).
- Advanced bandages or topical hemostatic agents approved for use in theater should be used to help control sites of external bleeding.
- For proximal extremity bleeding (eg, in the groin, axilla, and neck), junctional tourniquets or hemostatic pressure should be applied, and every attempt at hemorrhage control should be made in the prehospital environment while not delaying rapid transport to surgical care.
- Patients with non-compressible torso hemorrhage will likely require rapid surgical intervention to survive; however, adjuncts for hemorrhage control include the anti-fibrinolytic tranexamic acid (TXA) and blood transfusion, preferably whole blood.

- Early control of extremity and external hemorrhage with tourniquets, bandages, and direct manual pressure is essential.
- Patients with suspected thoracic, abdominal, or pelvic bleeding must be evacuated quickly to medical units with surgical capability.

Blood Products Available by Role

- Damage control resuscitation initiated in the prehospital phase of care must include the use of blood products.
- Blood products fielded with Role 2 surgical units are predominantly low titer group O whole blood (LTOWB) (whole blood with low titers of anti-A and anti-B antibodies that can be transfused to any patient), group O stored RBCs and AB or A plasma (fresh frozen plasma [FFP] that is thawed and stored at 1°–6°C for up to 5 days as thawed plasma, or never frozen liquid plasma, or freeze-dried plasma).
- Role 3 combat support hospitals have a much larger inventory of ABO type-specific blood products that also include apheresis platelets (aPLTs) and cryoprecipitate.
- Role 1 through Role 3 facilities must have the ability to perform emergency fresh whole blood drives.
- Availability, storage, and shelf-life of these products are outlined in Table 33-1.

ABO Matching of Blood Products

- Until the ABO type of the casualty is known, **type O RBCs and LTOWB are safe and recommended for emergency transfusion**.
- AB plasma (which contains neither anti-A nor anti-B antibodies) is safe for emergency transfusion. However, AB plasma is a scarce resource because only 4% of the population has this blood type, so AB plasma is frequently unavailable. Reactions against the A antigen tend to be more severe; therefore, A plasma (which does not contain anti-A antibodies) is also recommended for emergency transfusion and is used in patients of all blood types (Table 33-2).
- Once the ABO typing of the casualty is known, type-specific blood products should be used if available.

Table 33-1. Blood Products by Role of Care

Roles	Blood Product	ABO and Rh Groups	Storage Capacity	Storage	Shelf-Life
1	Fresh whole blood	Type-specific or LTOWB	Emergency collection only	Room temp or 1°–6°C	24 hours at room temp / 21 or 35 days at 1°–6°C
2	RBCs	O Rh+/–	50–100 U	1°–6°C	42 days
	Fresh frozen plasma	AB, A	50–100 U	≤–18°C	1 yr/5 days post-thaw
	Fresh whole blood*	Type-specific or LTOWB	Emergency collection only	Room temp or 1°–6°C	24 hours at room temp / 21 or 35 days at 1°–6°C
	LTOWB (stored)	O Rh+/–	2–10 U	1°–6°C	21 or 35 days
	Never frozen liquid plasma	AB, A	10–20 U	1°–6°C	26 or 40 days
3	RBCs	O Rh+/–	50–100 U	1°–6°C	42 days
	Fresh frozen plasma	AB, A	50–100 U	≤–18°C	1 yr/5 days post-thaw

(Table 33-1 *continues***)**

Table 33-1 *continued*

Roles	Blood Product	ABO and Rh Groups	Storage Capacity	Storage	Shelf-Life
	Fresh whole blood*	Type-specific or LTOWB	Emergency collection only	Room Temp or 1°–6°C	24 hours at room temp / 21 or 35 days at 1°–6°C
	LTOWB (stored)	O Rh+/–	2-10 U	1°–6°C	21 or 35 days
	Never frozen liquid plasma	AB, A	10-20 U	1°–6°C	26 or 40 days
	Apheresis platelets	O, A, B Rh+/–	Up to 24 U	20°–24°C	5 days
				or 1-6°C	CCMD-dependent but up to 15 days
	Cryoprecipitate	N/A	50–100 U	≤–18°C	1 yr/4 h

CCMD: combatant command; LTOWB: low titer group O whole blood; N/A: not applicable; RBCs: red blood cells; U: units.
*Type-specific or LTOWB collection is performed when plasma/RBC products are exhausted or when platelets are required. Type-specific or LTOWB collection is performed when blood products are exhausted or in critical shortage (ie, type O RBCs that are needed in reserve for emergency release).

Table 33-2. ABO Matching for Transfused Blood Products*

Recipient Group	Unknown	O	A	B	AB
RBCs					
1st choice	O	O	A	B	A, B, or AB
2nd choice			O	O	O
Fresh frozen plasma					
1st choice	AB	O	A	B	AB
2nd choice	A	A	AB	AB/A	A
Whole blood (emergency collected)†	Type-specific	O	A	B	AB

RBCs: red blood cells
*Low titer O whole blood (LTOWB) may be transfused regardless of recipient ABO type. Platelets and cryoprecipitate do not need to be type-specific.
†Fresh whole blood MUST be type-specific if no group O prescreened donors are available (preferably low titer Group O). If group O, prescreened low titer (anti-A / anti-B) donors are drawn, then see LTOWB for ABO matching guidance.

- At Role 2 surgical units, cold stored LTOWB may be available. RBCs and plasma should be readily available. However, if blood product support is not adequate, emergency collection of **type-specific whole blood or LTOWB** is necessary.
- LTOWB drawn from pre-screened donors may be transfused to a patient regardless of patient's blood type. If pre-screened, low titer group O donors are unavailable, collected whole blood must be an ABO type-specific match with the patient's blood type. If ABO typing and low titer group O donors are unavailable, **type O fresh whole blood (unknown titer levels)** can be used as a last resort.

- LTOWB or type O RBCs are safe for emergency transfusion.
- **AB plasma (or A plasma as the next safest alternative) is used for emergency transfusion.**
- **If fresh whole blood is required:**
  - Group O low titer donors are preferred.
  - If whole blood is not group O (low-titer group O is preferred); then it MUST be ABO type-specific whole blood.

Rh Blood Matching for Female Casualties

- Women, military and civilian, are becoming more frequent victims of conflict. Serious consequences to Rh incompatible blood are rare in men who have no previous history of transfusions.
- Rh– women transfused with Rh+ blood are very likely (approximately 20%) to produce anti-D (Rh+) antibodies. This seroconversion can jeopardize a subsequent pregnancy when this Rh– mother, now sensitized by Rh+ transfusion, conceives an Rh+ fetus. Hemolytic disease of the fetus and newborn (HDFN) may result, which can be fatal to the fetus. With current therapy for HDFN, serious adverse events occur in approximately 6% of affected pregnancies.
- When the supply of group O blood permits, **group O Rh– blood for emergency release should be reserved for women of child-bearing potential** (age <50) until their ABO and Rh types are known. If Rh– blood is not available, Rh+ blood should **NOT** be withheld (saving a life takes precedence over risk of Rh immunization).
- Although there is a risk of Rh seroconversion with apheresis platelets (due to a small amount of RBCs in the unit), Rh incompatibility should not influence transfusion. **If Rh+ platelets are transfused to an Rh– woman, this can be mitigated by use of Rh immunoglobulin (RhoGAM)** within 72 hours of platelet transfusion.
- Rh seroconversion from FFP and cryoprecipitate is rare, and these products are not generally Rh matched.

Under no circumstances should a lifesaving transfusion be withheld because of Rh incompatibility. Saving a life takes precedence over Rh immunization.

Massive Transfusion

- Massive transfusion has been defined in various ways, but the most common definition is the need for **≥10 U of blood in 24 hours.** This definition is far from perfect in that it does not account for the rate of transfusion. For example a casualty receiving 8 units of blood in the first hour of resuscitation will likely have worse anatomic and physiologic insults than a

casualty who receives ½ unit of blood every hour for 20 hours. Therefore, this definition is under scrutiny, but is still widely accepted.

- The massive transfusion definition based on 10 units in 24 hours is based on the estimate of 1 blood volume for an average adult male. Small individuals and pediatric patients have a lower blood volume that should be considered when deciding whether a patient needs a massive transfusion. Massive transfusion in pediatric patients is defined as exceeding 40 mL/kg of combined blood products in 24 hours.
- **Survival in massively transfused combat casualties is higher in patients who are transfused with increased ratios of plasma and platelets in relation to RBCs.** Based on these observations, prior to definitive surgical control of bleeding, massively bleeding patients should be transfused with whole blood or with component therapy aiming at a ratio of **6 RBCs:6 FFPs:1 aPLT**. It is reasonable to consider transfusing 10 U of cryoprecipitate along with this ratio. Whole blood is the preferred therapy.
- **Early recognition (on admission) of need for massive transfusion.**
  - Systolic blood pressure <110 mm Hg.
  - Heart rate >105 beats per minute.
  - Hematocrit <32%.
  - pH <7.25.
  - Patients with three of the above four risk factors have approximately a **70% risk** of massive transfusion.
  - Patients with all four of the above risk factors have an **85% risk** of massive transfusion.
- Laboratory-directed transfusion thresholds should **not** be used in massively bleeding patients **until the patient has been stabilized** (because of the significant time lag between drawing labs and receiving their results).
- The rate and volume of blood products to transfuse should be determined *clinically*, until surgical correction of hemorrhage has been established. Goals include clinical factors supporting adequate perfusion, restoration of hemodynamic physiology, mentation, skin color, and urine output > 0.5 mL/kg/h.

- Massive transfusion protocols (Fig. 33-1) and good communications between providers in the ER, OR, ICU, and blood bank are essential.

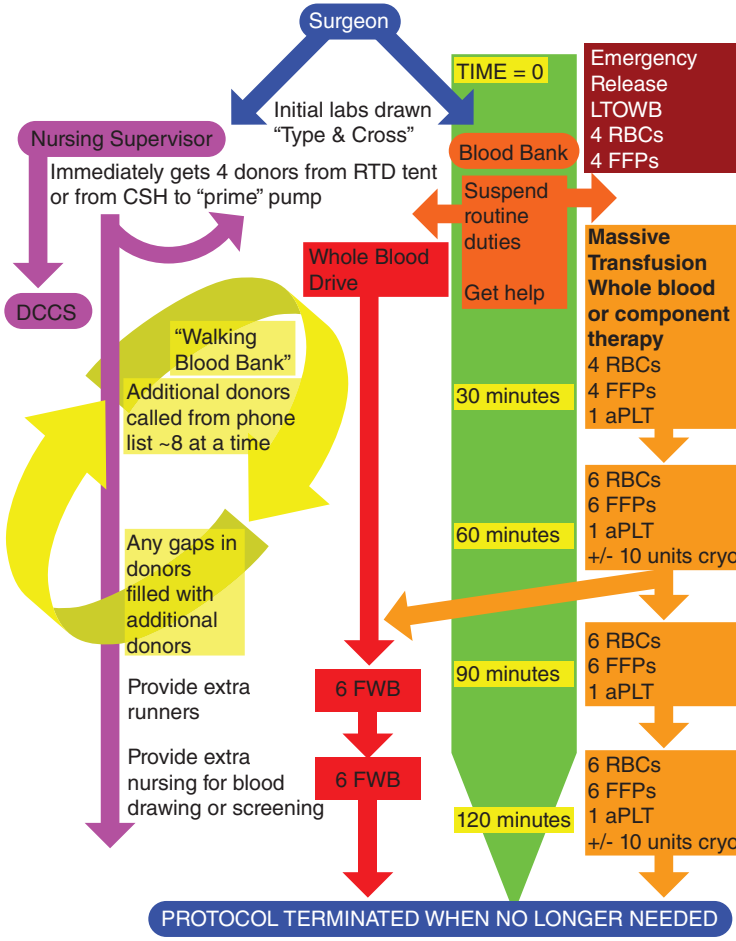

Fig. 33-1. Role 3 combat support hospital example of massive transfusion protocol. aPLT: apheresis platelet; cryo: cryoprecipitate; CSH: combat support hospital; DCCS: Deputy Commander for Clinical Services; FFP: fresh frozen plasma; FWB: fresh whole blood; LTOWB: low titer O whole blood; RBCs: red blood cells; RBCs: red blood cells; RTD: return to duty.

- If whole or component therapy including platelets and plasma are unavailable, fresh whole blood from a walking blood bank collecting LTOWB or **type-specific fresh whole blood** should be transfused.

- **Survival in massively transfused combat casualties is higher in patients who are transfused with whole blood or component therapy with increased ratios of plasma and platelets in relation to RBCs.**
- **Whole blood is the transfusion therapy of choice.**
- **Neither crystalloid nor colloid should be administered. The standard of care is resuscitation with blood, not crystalloid or colloid.**
- **Goal blood pressure is systolic blood pressure ~90–110 mm Hg (target 100).**
- **In patients with central nervous system injury, goal blood pressure should be 110 mm Hg.**
- **If whole blood is not available, blood components should be transfused with a goal ratio of 6 RBCs:6 FFPs:1 aPLT.**

Refer to Table 33-3 and Chapter 7, Shock, Damage Control Resuscitation, and Vascular Access, for further information on transfusion and resuscitation.

Table 33-3. Battlefield Transfusion and Damage Control Resuscitation Principles

Prehospital
Rapid recognition of life-threatening hemorrhagic shock
Point of care measurements: near infrared spectroscopy, INR, lactate level may be of value
Prevent hypothermia
Hemorrhage control with mechanical hemostatic adjuncts:
Tourniquet / junctional tourniquet
Pressure dressings / thrombin- and fibrin-impregnated gauze
REBOA
Intraabdominal foams (investigational)
Hemostatic resuscitation
Whole blood is optimal

(Table 33-3 *continues***)**

Table 33-3 *continued*

- Component therapy with plasma (dried, liquid, or thawed), RBCs, and platelets in 1:1:1 ratio
- Permissive hypotension for patients without traumatic brain injury*
- Avoid crystalloid resuscitation
- Consider TXA administration if less than 3 hours from time of injury†
- Consider source of fibrinogen (fibrinogen concentrate or cryoprecipitate)
- Avoid hypocalcemia
  - In prolonged evacuations, empiric calcium administration for every 4-6 units of RBCs or WB

Hospital

- Rapid surgical correction of bleeding
- Hemostatic resuscitation
  - Whole blood is optimal
  - Component therapy: plasma (dried, liquid, thawed, FFP/FP24), RBCs, platelets in 1:1:1 ratio
  - Shift from empiric whole blood based resuscitation to goal-directed resuscitation when feasible
- Permissive hypotension prior to surgical control of bleeding for patients without TBI*
- Intravenous hemostatic adjuncts:
  - Consider TXA administration indicated either empirically or guided by functional viscoelastic studies demonstrating LY30 > 3%†
  - Source of fibrinogen for reduced fibrinogen function
  - PCC for patients taking vitamin K antagonist
- Avoid crystalloid resuscitation
- Blood pressure goals after hemorrhage control
  - MAP ≥ 60; SBP >100 mm Hg and evidence of improved end organ perfusion
- Monitor CBC, electrolytes, and blood gas hourly
  - Calcium administration for every 4–6 units of RBC or WB; follow ionized calcium concentration
  - Treat hypomagnesaemia
  - Avoid/treat hyperkalemia

(Table 33-3 *continues***)**

Table 33-3 *continued*

CBC: complete blood count; FP24: frozen plasma, frozen within 24 h; FFP: fresh frozen plasma, frozen within 8 h; INR: international normalized ratio; LY30: percent of clot lysed after 30 minutes; MAP: mean arterial pressure; PCC: prothrombin complex concentrates; RBCs: red blood cells; REBOA: resuscitative endoscopic balloon occlusion of the aorta; SBP: systolic blood pressure; TBI: traumatic brain injury; TXA: tranexamic acid; WB: whole blood
*Conventional goal is systolic blood pressure >90 mm Hg. Recent concept indicates a higher goal of 90–110 mm Hg due to shift toward blood-based resuscitation and concern for prolonged hypoperfusion, especially for patients with long transport times.
†Military policy currently is to empirically administer 1 g of TXA for severe bleeding in both prehospital and in hospital settings.

Management of Complications During Massive Transfusion

- **Hypothermia** in trauma patients develops from conductive, convective, evaporative, and radiative losses due to environmental and surgical exposure.
  - Because whole blood, RBCs, and plasma are stored at 4°C, hypothermia can develop quickly during massive transfusion.
  - Hypothermia contributes to coagulopathy (impaired clotting factors and platelets) and increased risk of cardiac dysrhythmias.
  - Fluid warmers are absolutely essential for preventing or limiting hypothermia, along with other measures listed in Table 33-4.
  - Currently, the goal during resuscitation is normalization of body temperature, 37°C.
- **Acidosis** in massively transfused patients is largely due to hypoperfusion, but can be exacerbated by crystalloids and stored RBCs. (RBCs become progressively more acidic during storage due to cellular metabolism.)
  - Acidemia contributes to coagulopathy and can cause dysrhythmia, hypotension, and decreased responsiveness to catecholamines.
  - Reversal of acidosis is primarily accomplished through restoration of adequate tissue perfusion.
  - The best way to reverse acidosis is resuscitation; however, in extreme circumstances (eg, cardiac dysfunction),

bicarbonate or tromethamine (THAM) can be used as necessary to achieve an arterial blood gas pH >7.2.

- **Hyperkalemia** is a common complication due to extracellular potassium that increases over time in stored RBCs.
  - During massive transfusion, blood can be administered rapidly through central lines without sufficient time or mixture to prevent this extracellular potassium from reaching the right heart and result in ventricular arrhythmia and cardiac arrest.
  - Limit effects by transfusing blood from lines farther away from the right atrium.
  - Hyperkalemia can also be limited with the use of fresher blood (<14 days).
  - Vigilance for this complication is necessary (with labs and EKG monitoring).
  - Management of hyperkalemia is listed in Table 33-4.

Table 33-4. Management/Prevention of Complications of Massive Transfusion

Hypothermia
Prehospital active/resistive warming with hot packs/heating blankets
High-capacity fluid warmers
Warmed trauma suites/operating rooms
Forced-air warming blankets
Warmed/humidified oxygen
Limit surgical exposure (eg, damage control techniques)
Acidosis
Restoration of adequate tissue perfusion
Sodium bicarbonate
Hyperkalemia
Transfuse fresher blood (<14 days)
Transfuse blood from lines farther away from the right atrium
Calcium chloride (1 amp) or calcium gluconate (30 ml of 10% solution) to stabilize the myocardium
Correction of acidemia/alkalinizing solutions
Regular insulin 10 units with 1 amp (50 mL) 50% dextrose
Inhaled beta-agonists

(Table 33-4 *continues***)**

Table 33-4 *continued*

Hypocalcemia
Calcium chloride (1 amp) or calcium gluconate (30 mL of 10% solution) based on measurement of serum ionized calcium levels or with every 4 units of blood products
Coagulopathy/Microvascular Bleeding
Goal temperature > 37°C Goal pH > 7.25
Whole blood (LTOWB) or type-specific whole blood is the preferred therapy
Goal ratio of transfused blood components of **6 RBCs:6 FFPs:1 aPLT**.

aPLT: apheresis platelet; FFPs: fresh frozen plasmas; RBCs: red blood cells

- **Hypocalcemia** occurs in trauma patients even before transfusion, and is exacerbated by massive transfusion due to the citrate (anticoagulant) in blood products. Under normal physiological conditions, citrate is rapidly metabolized by the liver. Metabolism can be overwhelmed by rapid infusion of citrate-containing components (>100 mL/min). It is also dramatically impaired in hypoperfused patients or those with advanced liver disease.
  - Hypocalcemic/citrate toxicity manifests by decreased myocardial contractility and increased susceptibility to arrhythmia from coexisting hyperkalemia.
  - Monitor for/anticipate hypocalcemia based on the pace of plasma transfusion, electrocardiographic changes, or ionized calcium levels.
  - Treat with intravenous calcium chloride or calcium gluconate.
  - If labs are not immediately available, 1 amp of calcium chloride should be administered as soon as the decision to transfuse blood is taken and then with every 4 units of citrated blood products.
- **Coagulopathy (trauma-induced and dilutional).**
  - Trauma-induced coagulopathy is frequently present on admission in severely injured patients, and it is correlated with the need for massive transfusion, as well as increased mortality.

- Dilutional coagulopathy develops in massive transfusion as a consequence of the replacement of shed whole blood with factor and platelet-poor fluids like crystalloids, colloids, and stored RBCs.
- Dilutional coagulopathy may be inevitable in patients requiring a massive resuscitation with blood components due to the addition of preservative solutions to stored blood products following collection. Transfusion of RBCs, plasma, and platelets—even in a 1:1:1 ratio—results in a solution with a hematocrit of 30%, coagulation factor levels of about 60%, and platelets of 80×10^9/L. This is why whole blood is preferred over component therapy!
- Do not give crystalloids or colloids; they greatly intensify dilutional effects.
  - Primarily used only as a carrier for medications.
  - Additional administration of crystalloids to restore volume should be avoided in preference to whole blood or blood components.
- TXA should be given within 3 hours of injury to reduce fibrinolysis and stabilize clots. Use of TXA has been shown to reduce mortality in bleeding trauma patients.
- Refer to Chapter 36, Emergency Whole Blood Collection.

Transfusion Reactions in the Field

Transfusion reactions may be difficult to recognize in severely or multiply injured casualties. Regardless, clinicians should be aware of the potential complications of transfusion and their management in the deployed environment.

Treatment Plan for Transfusion Reaction

- STOP the transfusion.
- Disconnect tubing from infusion site; flush IV site with NS; send blood product to blood bank for testing.
- Keep IV line open with NS.
- Assess the patient: review vitals and auscultate lungs. If patient is conscious, ask about subjective complaints.
- If fever and unexplained hypotension, consider **ABO mismatch** and **bacterial contamination/sepsis**.

- ABO mismatch can cause disseminated intravascular coagulation (DIC) and diffuse bleeding, which may be the only intraoperative manifestation of ABO mismatch and hemolysis.
- If unexplained hypoxia, consider **volume overload** and **TRALI** (transfusion-related acute lung injury).
- If unexplained hypotension/shock without fever, consider severe allergic reaction/**anaphylaxis**.
- If bronchospasm or angioedema, consider **anaphylactoid reaction**.
- If only urticaria, likely **urticarial reaction**.
- If only fever in stable patient, consider **febrile reaction**, but still send unit to blood bank to rule out ABO mismatch or bacterial contamination.

Acute Hemolytic Transfusion Reaction (ABO Incompatibility)

- Generally develops rapidly (minutes to a few hours) after initiation of an ABO incompatible RBC transfusion.
- Mortality can be >15% and increases with the amount of incompatible blood that is infused.
- The most common cause of hemolytic transfusion reaction is clerical error that occurs outside of the blood bank, or mistyping the patient or donor information inside the blood bank.
- Fever is the most common early sign; thus, a hemolytic transfusion should be considered any time a febrile reaction follows a transfusion.
- In unconscious/sedated patients, the only signs may be:
  - **Fever.**
  - **Inappropriate hypotension.**
  - **Tachycardia.**
  - **Dark urine (reflecting hemoglobinuria).**
  - **Renal failure.**
  - **Development of generalized/coagulopathic bleeding due to associated diffuse intravascular coagulation (DIC).**
- Frequently, such patients are given additional units of incompatible blood before medical personnel realize that a hemolytic transfusion reaction is occurring.

- Conscious patients can also report **chills, severe low back pain (reflecting renal involvement), dyspnea, apprehension, chest pain, nausea, and vomiting.**
- To prevent renal failure, administer 0.9% normal saline and intravenous furosemide as needed to maintain urinary output (goal: 100 mL/h or 1–2 mL/kg/h for small patients) until resolution of hemoglobinuria.
- If a transfusion reaction occurs during resuscitation for ongoing bleeding, stop transfusion of offending product and switch to emergency release blood.
- The coagulation system and platelet count must be monitored for the development of DIC.
- FFP and platelet transfusions may be needed if coagulopathic bleeding develops.

Acute Hemolytic Transfusion Reaction Treatment

- Stop transfusion and clearly mark the suspected unit.
- If a transfusion reaction occurs during resuscitation for ongoing bleeding, stop transfusion of offending product and switch to emergency release blood.
- If not in active resuscitation, maintain blood pressure and urinary output with 0.9% saline ± intravenous furosemide as needed (goal urine output: 100 mL/h until resolution of hemoglobinuria).
- Observe for coagulopathic bleeding from diffuse intravascular coagulation and monitor coagulation tests/platelet counts. Treat as necessary with fresh frozen plasma and/or platelets.
- Recheck identification of patient and unit for clerical errors and retype to rule out mistyping errors.
- Annotate patient record with description of the suspected reaction and treatments.
- Send all transfused units at the bedside to the blood bank (or to the next echelon of care).

Bacteremia and Sepsis From Contaminated Blood Products

- Liquid stored blood products (aPLTs and RBCs) are a fertile culture media, and small amounts of contaminating bacteria may grow in blood products during their storage. These bacteria can

cause fevers and bacteremia during or soon after a transfusion. If the bacterial load is sufficiently high or gram- negative organisms are present, frank sepsis (hypotension/shock) can develop.

- Room temperature-stored platelets carry the highest risk for bacteremia/sepsis because they are stored for up to 7 days in theater. Cold-stored platelets present a much lower risk of bacterial contamination (similar to red blood cells).
- If fever and hypotension develop during or immediately following a transfusion of room temperature platelets, then broad-spectrum antibiotics should be administered.
- Because fever and hypotension are also signs of ABO mismatch, sepsis often cannot be immediately distinguished from an acute hemolytic transfusion reaction at bedside. The blood bank can clarify/rule out ABO incompatibility. Once ABO mismatch has been excluded by the blood bank, broad-spectrum antibiotics should be considered.

Febrile Nonhemolytic Transfusion Reaction

- Approximately 1% of all transfusions are accompanied by a temperature elevation (defined as an increase of 1°C above normal within 1 hour of transfusion), which can be with or without chills.
- Prevented by use of leuko-reduced blood products.
- There is no definitive test with which to make the diagnosis of a benign febrile reaction, which may also be the first sign of a hemolytic reaction or the infusion of a unit contaminated with bacteria. For this reason, if a fever occurs, management involves:
  - Immediate cessation of the transfusion.
  - Evaluation/consideration for ABO mismatch or bacteremia.

Transfusion-Related Acute Lung Injury

- Transfusion-related acute lung injury (TRALI) is manifested by rapid onset of "noncardiogenic" pulmonary edema with dyspnea, hypoxemia, and pulmonary infiltrates within 6 hours after transfusion.
- The estimated mortality rate for recognized TRALI is 5%–8%, although most patients recover completely with appropriate supportive care.
- Recognition.

- TRALI in trauma patients can be challenging to distinguish from concomitant pulmonary contusions, blood aspiration, fat embolization, and/or inhalational injury (particular mechanism of injury is an important consideration) and is a diagnosis of exclusion.
- Chest radiography is similar to acute respiratory distress syndrome, with bilateral patchy alveolar infiltrates, typically with a normal cardiac silhouette and without effusions.
- Patients who require intubation have elevated peak airway pressures and frothy pink airway secretions.
- TRALI is noncardiogenic pulmonary edema and must be differentiated from volume overload or heart failure.
  - At Role 2, evaluation is guided by clinical evaluation, exam, and transduced central venous pressure.
  - At Role 3, bedside ECHO may further assist in evaluation of volume status.

- Management of TRALI:
  - Supportive.
  - Milder cases may only require supplemental oxygen as required to maintain oxygen saturation.
  - Intubation with mechanical ventilation is often required.
  - Ventilation is preferably with "lung protective" modes (eg, low tidal volumes and plateau pressures).
  - Unlike adult respiratory distress syndrome, resolution occurs rapidly. Most patients can be extubated within 48 hours, and chest radiographs generally return to normal within 4–7 days.

Urticarial Transfusion Reactions

- Urticaria (hives/itching) is the only transfusion reaction in which the blood product can be continued.
- Thought to occur from an allergenic substance in the plasma of donated blood products.
- Does NOT have wheezing/bronchospasm or inappropriate hypotension (which are allergic reactions).
- Management of urticarial reactions:
  - Hold transfusion.

- Treat with diphenhydramine 25–50 mg IV or PO.
- If urticaria wanes and neither dyspnea nor hypotension are apparent, the transfusion may be resumed.

Anaphylactoid Transfusion Reactions

- Anaphylactoid reactions involve dyspnea, bronchospasm/wheezing, and/or abdominal pain (intestinal edema).
- More severe reactions can include rapid onset of stridor, angioedema, and respiratory failure.
- True anaphylactic reactions (marked by hypotension and shock) are rare.
- **Does not cause fevers.**
- Management of anaphylactoid reactions:
  - Immediate cessation of the transfusion.
  - If only bronchospasm (without stridor, angioedema, or hypotension) is evident:
    - Bronchodilators (albuterol).
    - Diphenhydramine 25–50 mg IV.
    - Consider giving ranitidine 50 mg IV.
    - Oxygen 6–8 L/min via face mask to maintain oxygen saturations >93%.
  - If stridor or angioedema is evident, include the measures above and also:
    - Intubation.
    - Epinephrine, 0.3 mL of a 1:1,000 solution intramuscularly (adult dose), repeated every 3–5 minutes as needed.
  - If inappropriate hypotension or shock are evident:
    - Fluid resuscitation and vasopressors (eg, dopamine) as needed to maintain blood pressure.
    - Consider giving methylprednisolone 125 mg IV.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 34

Compartment Syndrome

Introduction

- Compartment syndrome may occur with an injury to any fascial compartment. The fascial defect caused by the injury may not be adequate to fully decompress the compartment, and compartment syndrome may still occur.
- Mechanisms of injuries associated with compartment syndrome.
  - Open fractures.
  - Closed fractures.
  - Penetrating wounds.
  - Crush injuries.
  - Vascular injuries.
  - Injection injuries.
  - Infiltrated intravenous catheters.
  - Reperfusion following vascular repairs.
  - Burns/electrical shock.
- Early clinical diagnosis of compartment syndrome.
  - Pain out of proportion.
  - Pain with passive stretch.
  - Tense, swollen compartment.
- Late clinical diagnosis.
  - Paresthesia.
  - Pulselessness and pallor.
  - Paralysis.
- Measurement of compartment pressures: **If available, compartment pressure monitors (including improvised use of arterial line transducers) may provide additional information, especially in obtunded patients. Compartment syndrome, however, remains a clinical diagnosis, and prophylactic fasciotomies are indicated in high energy**

injuries, especially if prolonged transport times are anticipated.

- Diagnosis of compartment syndrome is made on clinical grounds, and the formal measurement of compartment pressures is generally not necessary.
- Compartment pressure measurement can be considered in obtunded patients with questionable exam findings. Measurement threshold of $\Delta P < 30$ mmHg (ΔP = DBP-absolute compartment pressure) is an indication for fasciotomy.

- Consider **prophylactic fasciotomy for**:
  - Vascular repair/shunt and/or ligation independent of ischemia time. (See Chapter 25, Vascular Injuries.)
  - **High index of suspicion injuries and limited capacity for serial examination.**
    - Intubated, comatose, sedated.
    - Traumatic brain injury.
    - Prolonged transport.

Fasciotomy Technique

- **Upper extremity.**
  - **Arm:** The arm has two compartments: the **anterior flexors** (biceps, brachialis) and the **posterior extensors** (triceps).
    - Lateral skin incision from the deltoid insertion to the lateral epicondyle.
    - Spare the larger cutaneous nerves.
    - At the fascial level, the intermuscular septum between the anterior and posterior compartments is identified, and the fascia overlying each compartment is released with longitudinal incisions.
    - Protect the radial nerve as it passes through the intermuscular septum from the posterior compartment to the anterior compartment just below the fascia.
    - Compartment syndrome in the hand is discussed in Chapter 24, Injuries to the Hands and Feet.
  - **Forearm:** The forearm has three compartments: the **mobile wad** proximally, the **volar** compartment, and the **dorsal** compartment (Fig. 34-1). Both the superficial and deep fascial layers of the volar compartment must be released.

- A palmar incision is made between the thenar and hypothenar musculature in the palm, releasing the carpal tunnel as needed.
- This incision is extended obliquely across the wrist flexion crease to the ulnar side of the wrist and then arched across the volar forearm proximally to the ulnar side at the elbow (Fig 34.1a).
- At the elbow, just radial to the medial epicondyle, the incision is curved obliquely across the elbow flexion crease. The deep fascia is then released.
- At the antecubital fossa, the fibrous band of the lacertus fibrosus overlying the brachial artery and median nerve is carefully released.

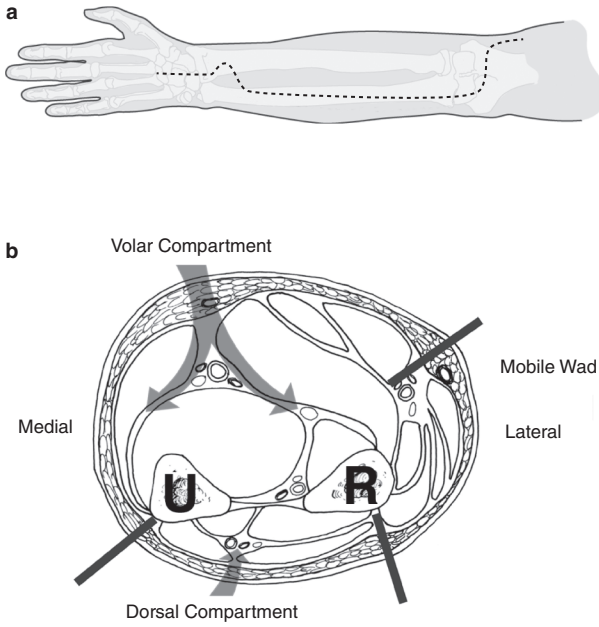

Fig. 34-1. (**a**) Fasciotomy incision for volar compartment. (**b**) Forearm compartments. R: radius; U: ulnar.

- This incision allows for soft-tissue coverage of the neurovascular structures at the wrist and elbows, and prevents soft-tissue contractures from developing at the flexion creases.
- A second straight dorsal incision can be made from the dorsal wrist to the lateral epicondyle to release the dorsal compartment, reaching proximally to release the mobile wad, if necessary.

- **Lower extremity.**
  - **Thigh:** The thigh has three compartments: the **anterior** compartment (quadriceps), the **medial** compartment (adductors), and the **posterior** compartment (hamstrings).
    - A lateral incision is made from the greater trochanter to the lateral condyle of the femur.
    - Then, the iliotibial band is incised, and the vastus lateralis is reflected off the intermuscular septum bluntly, releasing the anterior compartment.
    - The intermuscular septum is then incised the length of the incision, releasing the posterior compartment.
    - This release of the intermuscular septum should not be made close to the femur, because there are a series of perforating branches of the profunda femoris artery passing through the septum from posterior to anterior near the bone.
    - The medial adductor compartment is released, if necessary, through a separate anteromedial incision starting slightly distal to the adductor origin on the pubis and extending to the distal medial thigh.
  - **Lower leg:** The lower leg has four compartments: the **lateral** compartment, containing the peroneus longus and brevis; the **anterior** compartment, containing the extensor hallucis longus, the extensor digitorum communis, the tibialis anterior, and the peroneus tertius; the **superficial posterior** compartment, containing the gastrocnemius and soleus; and the **deep posterior** compartment, containing the flexor hallucis longus, the flexor digitorum longus, and the tibialis posterior (Fig. 34-2).
    - Two-incision technique. (**Caveat:** The one incision technique **IS NOT APPROPRIATE** for compartment syndrome decompression in combat theater.)

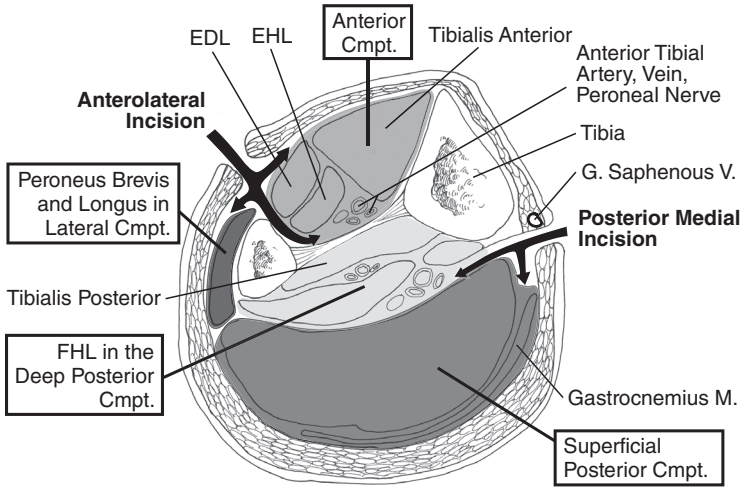

Fig. 34-2. Leg compartments.
Cmpt.: compartment; EDL: extensor digitorum longus; EHL: extensor hallucis longus; FHL: flexor hallucis longus; G.: greater; M.: muscle; V.: vein.

- ◊ Incisions must extend the entire length of the calf to release each compartment in its entirety (Fig. 34-3).
- ◊ A lateral incision is made centered between the fibula and anterior tibial crest.
- ◊ The lateral intermuscular septum and superficial peroneal nerve are identified, and the anterior compartment is released in line with the tibialis anterior muscle, proximally toward the tibial tubercle and distally toward the anterior ankle.
- ◊ The lateral compartment is then released through the same incision in line with the fibular shaft, proximally toward the fibular head, and distally toward the lateral malleolus.
- ◊ A second incision is made medially at least 2 cm posterior to the posteromedial and palpable edge of the tibia.
- ◊ A medial incision over or near the subcutaneous surface of the tibia is avoided, preventing exposure of the tibia when the tissues retract.

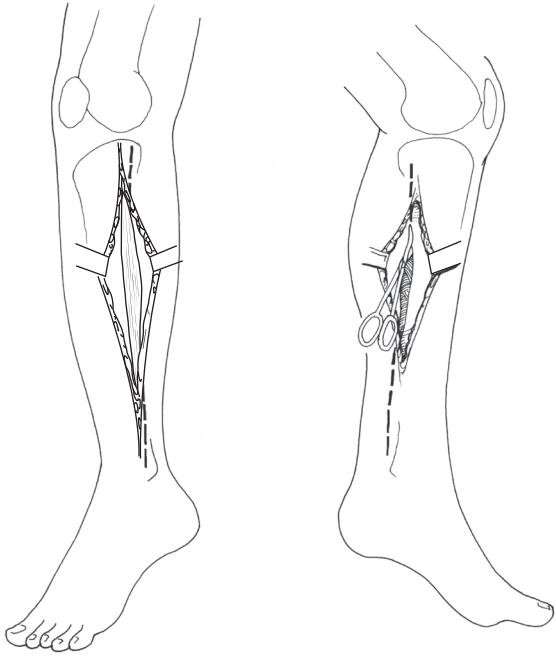

Fig. 34-3. Anteromedial incision of the calf.

- ◊ The saphenous vein and nerve are retracted anteriorly.
- ◊ The superficial compartment is released through its length, and then the deep posterior compartment is released by the gentle dissection of the septum off of the posterior aspect of the tibia.
- ◊ The direct visualization of the tendons and their associated muscle bellies can assist in ensuring the complete release of each respective compartment.

- **Foot.**
  - See Chapter 24, Injuries to the Hands and Feet.
  - Compartment release of the foot is rarely indicated and not routinely recommended in combat surgery.

- Fasciotomy wound management.

  - As with all war wounds, the fasciotomy is initially left open and covered with sterile dressings or NPWT.
  - Following fasciotomy, the wound should be treated with delayed primary surgical closure and standard wound management, removing debridement of all devitalized tissue.
- The vacuum wound closure system is an important adjunct to modern combat wound care and may be considered at higher echelons of care.
  - Sterile perforated IV bags.
    - For wounds of the **soft tissue and extremities**, layer laparotomy sponges with JP drains sandwiched between the sponges and covered with Ioban. Apply Benzoin to the skin edges to prevent leaks.
    - Attach the JP drains to the standard vacuum pump adjusted to 125 mm Hg suction. This dressing eliminates the need for skin traction in amputations.
    - For **skin grafts**, staple the graft to the edges of the wound. Apply nonadhering gauze and apply to field-expedient vacuum dressing. Do not remove for 3 days. Grafts can be dressed with Silvadene when the field-expedient vacuum dressing is removed.
    - For **open abdominal wounds**, place sterile perforated IV bags on the bowel and sew the IV bag to the fascia, or underlay the fascia with the IV bag. Place laparotomy sponges on the IV bags and layer with JP drains. Apply Benzoin to the skin edge and cover with Ioban. Attach the drains to suction. This dressing prevents leaking of abdominal fluids during transport.

Many surgeons consider the use of vacuum systems an important part of wound management because their use may improve and accelerate wound healing in a variety of conditions, including:

- pressure ulcers,
- partial thickness burns,
- orthopaedic wounds with large soft-tissue defects,
- open abdominal wounds, and
- skin graft viability.

Treatment of soft-tissue injury is the most common denominator in the management of war wounds.

Pitfalls

- Delay in diagnosis and treatment of suspected or impending compartment syndrome.
- Inadequate fascial incision length.
- Failure to open deep posterior and anterior compartments.
- Failure to locate lateral leg intermuscular septum and perform both lateral and anterior release.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 35

Battlefield Trauma Systems

Introduction

A trauma system is an organized, coordinated effort in a defined geographic area that delivers the full range of care to all injured patients and is integrated with the local public health system. The true value of a trauma system is the ability to provide the appropriate level of care to injured patients, integrating existing resources to achieve improved patient outcomes.

Military Trauma Systems

In the battlefield setting, the region is frequently represented as the Combatant Command (COCOM), which has principal responsibility for military operations, including medical support. Regions may be further subdivided into Theater of Operations (TO) and areas of responsibility (AOR), or more correctly described, area of focus (AOF). Military trauma systems can be functional as part of specific operations (eg, Operation Enduring Freedom [OEF] and Operation Iraqi Freedom [OIF]). For US forces injured outside the continental United States (OCONUS), the continuum of care includes all levels of care within the TO (Roles 1–3), care delivered outside the TO (Role 4), care delivered within the United States (CONUS) (Roles 4 and 4a), and all phases of patient movement (en route care) from point of injury to definitive care. The goal of a battlefield trauma system is to ensure that every casualty gets the right care, at the right time, in the right place, and that overall survival and chance for maximal function recovery are maintained throughout the continuum of care.

Battlefield Trauma System Model

The current model of the deployed military trauma system is the Joint Theater Trauma System (JTTS). Currently being codified in Services and Joint doctrine, the development, implementation,

and maturation of the JTTS are major factors in the low died of wounds (DOW) rate and in the improved functional recovery seen in battlefield casualties in OEF/OIF.

The COCOM JTTS team is assigned to and works directly within the TO and reports directly to the COCOM Surgeon General (SG). A dedicated triservice JTTS team undergoes specialized training in CONUS just prior to deployment to the TO. The team consists of: 1 Theater Medical Director or Trauma Medical Director (TMD) who is either a trauma-trained/critical care surgeon or a combat experienced general surgeon, 1 critical care nurse who is the Program Manager (PM), sufficient numbers of critical care nurses who function as Trauma Nurse Coordinators (TNCs) attached to Role 3 medical treatment facilities (MTFs) within theater, sufficient numbers of enlisted personnel to support the team and its taskings, and additional nurses and enlisted personnel to support special projects as directed by the Department of Defense (DoD) or the COCOM SG.

The TMD is the senior consultant to the COCOM SG on all matters related to the care of the trauma patient. The TMD works closely with all trauma care providers within the TO and within the bounds of the operational environment. Also, the TMD makes frequent site visits to fixed MTFs and evacuation platforms. The TMD is the primary advocate for the theater-wide performance improvement (PI) program. The principal duties of the TMD are to advise the COCOM SG on all matters related to trauma; conduct system-wide patient care conferences on a regular basis; update, revise, educate, and oversee compliance with theater Clinical Practice Guidelines (CPGs); and produce a monthly theater update report based on data from the DoD Trauma Registry (DoDTR).

The primary responsibilities of the PM are to support the TMD in all efforts and taskings, manage the entire team of nurses and enlisted personnel, ensure a robust theater-wide PI program with the TNCs, communicate with theater and the CONUS Joint Trauma System (JTS) team on a regular basis, and ensure quality data abstraction into the DoDTR by the TNCs.

TNCs are critical to the success of the JTTS. Their primary duty is to facilitate a robust PI program within their respective MTFs working directly with the Chief of Trauma. Additionally, they perform near real-time extraction of data from the casualty's medical record into the DoDTR to support ongoing PI initiatives.

Enlisted personnel provide critical administrative and technical support to the team, as well as functional expertise in their primary duty designation.

Purpose of the JTTS

The JTTS is a systematic and integrated approach to coordinate battlefield care to minimize morbidity and mortality, and optimize essential casualty care. The primary focus of JTTS is to improve battlefield trauma care to ensure that the right patient gets to the right place at the right time to receive the right care.

The JTTS was modeled after the civilian trauma system principles outlined in the American College of Surgeons–Committee on Trauma *Resources for Optimal Care of the Injured Patient, 2006*. This document identifies trauma care resources and practices for optimization of standards of care, policies, procedures, and protocols for both prehospital and hospital personnel. Additionally, it identifies and integrates processes and procedures to record trauma patient-related data at all levels of care for continual process improvement.

There is joint service participation in the JTTS and DoDTR. A JTTS trauma TMD and theater TNCs are rotated from each service and integrated into the TO to facilitate improvements in care. The DoDTR, the repository for all significant trauma-related data, is utilized to facilitate PI, utilization of resources, and provide command-level information to the battlefield commanders and DoD decision makers.

JTTS Goals

- Establish and maintain a trauma registry to capture data and provide information on the care and outcomes of military and civilian trauma patients.
  - Provide the services with full and complete access to data in the trauma registry.

  - Provide a database that can generate reports for authorized government agencies.
  - Provide a database that can be queried for Institutional Review Board-approved research studies.
  - Provide electronic collection and dissemination of trauma patient data available for all levels of care supporting a longitudinal health record.
  - Establish and maintain a trauma outcomes database to analyze and evaluate clinical decision-making and measure subsequent outcomes for improving treatment modalities.
- Provide the DoD and other authorized interests with timely and relevant information about care and outcomes.
- Create a research strategy that supports reduction of morbidity and mortality.
- Standardize trauma practices across the continuum of care with the development and implementation of evidence-based CPGs.
- Improve medical record documentation quality.
- Improve communication across the continuum of casualty care.

Joint Trauma System

The Joint Trauma System (JTS) has been written into the National Defense Authorization Act (NDAA) of 2017. The JTS is the CONUS-based enduring organization in the DoD that promotes improved trauma care to our wounded warriors and other DoD-eligible trauma victims. It also exists as the chief organization for consultation in the care of the injured for the services, COCOMs, and the entire DoD, to include its senior leadership. It is designed to meet the needs of the President, the Secretary of Defense, and COCOMs with regard to all aspects of trauma care within the DoD. To fulfill this mission, there is a core cadre of trained individuals led by a senior surgeon with prior deployment experience as the JTTS TMD and adequate resources and funding to sustain all the components of the trauma system. The ultimate size of the organization is dictated by events and contingencies—i.e., a larger, more robust organization during times of extreme conflict and a smaller but still fully capable organization during times of relative low operations tempo and kinetic operations. JTS works proactively with COCOMs to

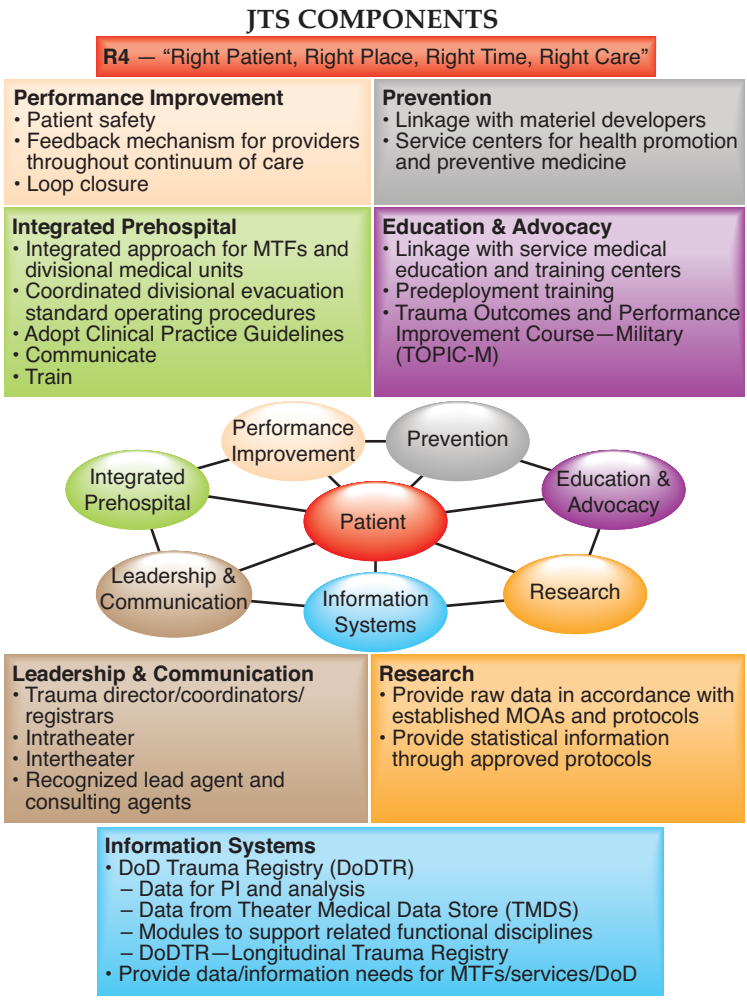

Fig. 35-1. JTS components across the continuum of care.
DoD: Department of Defense; JTS: Joint Trauma System; MTFs: medical treatment facilities; MOAs: memorandum of agreements; PI: performance improvement. Courtesy of Joint Trauma System, US Army Institute of Surgical Research.

facilitate the early implementation of JTTS in support of future kinetic operations or other contingencies. The JTS is the primary steward and maintainer of the DoDTR. Components of the JTS (Fig. 35-1) include:

- Prevention.
- Integrated prehospital, en route, and Roles 1–4 care.
- Education and advocacy.
- Leadership and communication.
- Continuous PI.
- Research.
- Information systems (eg, DoDTR Level II Database, Massive Transfusions Database, etc).

Summary

Implementation of the JTS and the JTTS has been a major advance in casualty care during OEF/OIF. Lessons learned have been codified in multiple ways to include doctrinal and policy changes, manning, CPGs, and patient treatment and management techniques. **Every** individual involved in casualty care is a member of the system, including providers, MEDEVAC personnel, medical logisticians, etc. A systems approach to casualty care contributed to decreased morbidity and mortality in OEF/OIF.

Reference

American College of Surgeons. *Resources for Optimal Care of the Injured Patient, 2006*. Chicago, IL: ACS; 2007.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 36

Emergency Whole Blood Collection

Introduction
This chapter describes the steps for emergency whole blood collection.

All blood support requests should be routed to the area or combatant command Joint Blood Program Office (JBPO). The JBPO can assist with training and resources for emergency whole blood collection.

MATERIALS AND EQUIPMENT

Miscellaneous
- Sharps containers
- Biohazard bags
- Trash bags
- Leak-resistant chucks
- Ammonia inhalants
- Cold packs
- Test tube racks
- Lancets
- Alcohol pads
- 2 x 2 gauze

Donor Screening
- Emergency Donor List
- Modified ASBP 572-EWB form
- Clipboards

Vitals
- Sphygmomanometer
- Stethoscope
- Temperature monitor

Logistical
- Emergency Whole Blood Collection Log
- ISBT (International Society of Blood Transfusion) labels or DIN labels; request from BSD
- Deferral lists

Phlebotomy and Supplies - Best Case Scenario (Role 3)
- Chinook kits
- Donor chair
- Blood bag scales
- HemoFlow
- Blood bag stand
- Terumo single blood bags
- Frepp/Sepp kit
- Gloves
- Surgical tape
- 4 x 4 gauze
- Hand stripper, sealer, cutter
- Hand sealer clips
- Scissors
- Hemostats
- VENOJECT Luer Adapter
- Luer Adapter hub
- Collection tubes
  - 3 EDTA plasma tubes (purple top)
  - 3 serum separator tubes (marble top)
- Coban self-adherent wrap
- Rapid Malaria Screening Test
- Rapid HCV Screening Test
- Rapid HIV Screening Test
- Rapid HBsAg Screening Test
- Rapid RPR Test for syphilis
- Antiserum for ABO/Rh testing

Phlebotomy and Supplies – Role 2 and below

- Whole blood kits
- System for prescreening → should be done prior to arrival at location or have a system to outsource prescreening

EDTA: ethylenediaminetetraacetic acid; HBsAg: hepatitis B surface antigen; HCV: hepatitis C virus; HIV: human immunodeficiency virus; RPR: Rapid Plasma Reagin; Sharps: refers to sharp objects (needles, scalpel blades, disposable scissors, stylets, trocars, glass, etc).
The rapid HBsAg is not FDA approved and these "rapid" tests take at least 20 mins if all done simultaneously. The RPR (syphilis) test requires a centrifuge because the test requires serum not whole blood.

Activation/Donor Screening

- An order to activate the walking blood bank must come from the Commander of the medical unit under the advisement of the Chief Medical Officer or senior surgeon caring for the intended recipient of fresh whole blood.
- The recipient/patient blood type must be obtained by laboratory or rapid kit testing.
- If a patient has already been massively transfused with universal donor blood products, if may be difficult to determine their original blood type. In this situation, it is good to have low titer O donors pre-identified and the patient should continue to receive low titer O whole blood (LTOWB) or universal blood components (O red blood cells [RBCs]/A or AB plasma).
- Fresh whole blood (FWB) must be a type-specific match to the recipient/patient (ie, A to A, B to B, and O to O). If type O donors have been titer tested and found to be low titer (anti-A and anti-B <1:256), FWB from these donors may be given to any patient regardless of blood type. ABO/Rh of donor should be verified at time of donation. Titer testing will normally be completed prior to deployment and should be performed within 12 months of donation.
- Once the recipient ABO/Rh blood type is known, the walking blood bank is activated by calling in donors of the patient's blood type. Laboratory personnel, or other trained individuals, will then interview donors for suitability to donate and review the ASBP 572-EWB, and determine if the donor is a **GO** or **NO GO** for donating whole blood. Due to staffing limitations at

some deployed facilities, it is important to ensure non-medical staff have been trained to do the majority of these whole blood donor screening tasks.

Ensure donor reads and signs the consent statement at the bottom of the ASBP 572-EWB. If donor refuses to sign the statement, then the individual is deferred from donation.

- Donors of the required ABO type who have been pre-screened are preferred over donors with no history of pre-screening.
- If the donor is accepted, record donor temperature, heart rate, and blood pressure on the ASBP 572-EWB to ensure adequacy for donation: temperature <99.6°F, heart rate <100 beats per minute, and blood pressure £180/100 mm Hg.
  - Each donor gets one sheet of ISBT labels. One label will go on the ASBP 572-EWB and the rest can be placed on the back of the donation bag.
  - If ISBT labels are not available, label the ASBP 572-EWB, donation bag, and sample tubes with a unique donor identifier such as service number.
  - Properly fill out the Emergency Blood Bank Donor Log. Annotate bag lot number, manufacturer, expiration date, and bag tubing segment number on the donor's ASBP 572-EWB.

Performing Phlebotomy

- Confirm with donor his/her full name, the last 4 digits of the Social Security Number (SSN), date of birth, and check against the ASBP 572-EWB.
- Confirm that the donor identification number on the ASBP 572-EWB and whole blood bag match.
- Place blood pressure cuff on the donor's arm. Pump cuff up to 40–60 mm/Hg and inspect arm for appropriate vein. Palpate vein. Release pressure.
  Note: You may use a rubber tourniquet.
- Ask the donor if he/she has an allergy to iodine, Betadine, shellfish, or latex. If no allergies exist, use the ChloraPrep Swabstick to prepare the donor arm for phlebotomy.
  - It is imperative to properly sterilize the site so that skin contaminates are not introduced into the unit of blood.

  - **If an allergy to iodine, Betadine, or shellfish exists, an alcohol alternative or chlorhexidine product may be used.**
- **A loose knot should be made in the tubing between the needle and the bag so that it can be tightened before the needle is removed from the arm.**
- Label all six blood collection tubes (3 red/marble top tubes and 3 lavender top tubes) with one of the bar coded labels from the back of the donor bag. If bar coded labels are not available, then be sure they are labeled with:
  - Full name.
  - SSN or other unique service number.
  - Date/time of collection.
- Properly label the blood collection bag.
  - Ensure that the **date of collection** is written on the unit in the space provided and document the **time the phlebotomy was initiated** underneath the collection date.
  - Document the expiration date and time in the space identified on the right-hand side of the blood collection bag. **Expiration date is 24 hours after the date and time of collection. However, if extenuating supply concerns exist, may coordinate with JBPO for extended storage of the product for 21 or 35 days.**
  - Do not write the donor's blood type until the blood has been typed and tested.
  - After all labeling of the blood collection bag has been accomplished, apply hemostats approximately 6 inches above the needle.
- Donor blood unit and sample tube collection.
  - Pump blood pressure cuff up between 40–60 mm Hg. A rubber constricting band or tourniquet may be used instead of a blood pressure cuff.
  - Verify vein again, **but do not repalpate**. Advise the donor to make a fist and squeeze several times. Then squeeze and hold.
  - Twist off the needle cover and inspect the needle for barbs or other defects.
  - Pull the skin taut below the venipuncture site. This helps prevent sudden movement of the arm and anchors the vein.

- With the bevel up, hold the needle at the hub. At approximately a 30°–45° angle, pierce the skin at the selected point of entry. When the bevel is completely under the skin, lower the angle of the needle to approximately 10° or less. With a steady push, advance the needle to penetrate the vein wall. Thread the needle approximately ½ inch inside the vein to maintain a secure position and to lessen the chance of a clot forming.
- Release the hemostat clamp on the collection bag tubing and observe the blood flow through the tubing and into the collection bag.
- If there is no blood flow, try adjusting the needle without hurting the donor, and seek assistance from another phlebotomist before discontinuing the procedure.
  Note: A second venipuncture may be performed if there was an unsuccessful collection (no blood entered the collection bag), if donor agrees to a second venipuncture, and an acceptable vein is available on the opposite arm**. The second collection requires a new blood bag to prevent contamination of the unit!**
- The donor bag must be below the level of the donor so that gravity can help to fill the bag more quickly.
- Instruct the donor to relax his/her grip and to squeeze rhythmically every 3–5 seconds.
- Secure the needle to the donor's arm with tape across the hub and/or on the tubing near the hub of the needle. The tape optimizes the positioning of the needle and prevents rotation of the needle while in the vein.
- Partially reduce the pressure by loosening the tourniquet or blood pressure cuff to approximately 20–40 mm Hg.
- Cover the phlebotomy site with a 4 × 4 gauze dressing, keeping the site clean and the needle out of view. Lift the gauze occasionally to monitor for evidence of a hematoma.
- Annotate on the ASBP 572-EWB the time phlebotomy was started in the "start" block and supply the initials of the laboratory technician performing the phlebotomy. Ensure that the start time is annotated beneath the collection date on the collection bag.

- Monitor the donor for signs of discomfort or the onset of a donor reaction, such as dizziness or fainting.
- Manually mix the blood and anticoagulant every 90 seconds to prevent clotting in the line and bag.
- **Sample tubes may be collected via the whole blood bag system if a sample port is included. If there is no sample port on the whole blood bag tubing, perform a second venipuncture on the other arm to fill the donor sample tubes.**
- A 10-inch piece of 550 cord may be used to determine when whole blood bag is full. As the bag fills, the piece of cord can be placed around the center of the bag and when the ends of the cord touch, the bag is full. There is a tendency to under-fill the bags because most people are used to seeing packed red blood cells which are roughly half the volume in the same size bag.
- Annotate the time the unit has reached the desired volume on the ASBP 572-EWB in stop time block. **Acceptable units should have a volume between 405 and 495 mL.**
- Place the hemostat 1 to 2 inches below the hub of the needle.
- Remove blood pressure cuff.
- The knot that was placed in the tubing must be tightened prior to smoothly and quickly withdrawing the needle.
- Apply firm pressure to the phlebotomy site with the gauze and instruct the donor to maintain pressure on the phlebotomy site and extend the arm vertically. Instruct the donor **NOT** to bend the arm at the elbow to reduce/prevent the chance of a hematoma.
- On completion of venipuncture, use a knife or scissors to cut the tubing between the knot and the needle. Discard the needle into a secure biohazard container.

Postdonor Care

- Apply pressure with fresh gauze on the collection site and tape it down, ensuring a stable clot has formed.
- When the donor is ready to stand, have him/her remain in the area under close supervision for at least 10 minutes. Observe for signs of a reaction and ask donor how he/she feels.

- Instruct the donor on fluid replacement and light postdonation activities. Provide extra rest time for donors who have experienced a donor reaction: either dizziness or fainting.
- Ensure the ability to rehydrate orally and walk with a steady gait without dizziness prior to leaving the area.

Performing Rapid Testing

- **ABO/Rh** blood typing of the donated unit must be performed and verified using lab testing or Eldon card, with appropriate results documented prior to the release of fresh whole blood from the laboratory. Rapid tests for HIV, HBV, and HCV should be performed prior to transfusion when time permits. (Other rapid disease test kits for malaria and syphilis maybe also be available). **Follow appropriate testing standard operating procedures for each rapid test performed: ABO/Rh, HIV, HCV, HBV (hepatitis B virus), malaria, and RPR (Rapid Plasma Reagin) for syphilis. If not performed prior to whole blood transfusion, rapid disease tests should be performed as soon as time permits and should not be skipped.**
- Document test results of ABO/Rh on the bag of whole blood and on the ASBP 572-EWB. Use standardized forms to document the results of all rapid infectious disease testing.
- The laboratory technician performing each test will place his/her initials on the donor's blood bag.
- Prior to releasing FWB for patient use, all testing of the donor and patient should be verified and documentation checked for accuracy. Ensure donor screening is appropriately documented and donor is not deferred. Ensure the correct ABO/Rh type of the patient and donor are recorded and are compatible.
- **Proper blood typing and infectious screening require time**. This is at times at odds with the deterioration of the recipient patient's clinical status. In such circumstances, if the **licensed clinical providers caring for the recipient patient** deem it necessary to obtain fresh whole blood at a faster rate, they **may authorize** the emergency release of fresh whole blood from the walking blood bank after only ABO/Rh typing without the completion of all infectious screening tests. This is to be

meticulously documented by personnel, and they must obtain written documentation of this directive from the licensed provider(s).

Note: Fresh whole blood may be kept stored at room temperature for up to 8 hours. However, it is highly recommended that units of fresh whole blood be stored immediately following collection at 1°–6°C for up to 24 hours.

Posttransfusion Verification

- After completion of the walking blood bank, all donor blood units—or donor unit blood bags posttransfusion—will be returned to a person who has Theater Medical Data System (TMDS) access to properly document the donations, destructions and the transfusions in the system.
  - If some of the fresh whole blood is sent with the patient in transport to another facility, ensure the TMDS administrator is informed and can "ship" these units in the system.

Specimen Processing

- During whole blood collection, draw the specified tubes of blood for further testing:
  - 3 pearl or purple top tubes.
  - 2 gold or red top tubes.
  - 1 purple top tube—used for blood typing/Eldon card.
- Tubes will be spun down to separate serum/plasma from red blood cells. If a centrifuge is not available, get the tubes to a Role 2 or 3 that has a centrifuge within 24 hours if at all possible.
- Specimens will be shipped to the Blood Support Detachment, Blood Support Unit, or other designated receiving unit for shipment for US Food and Drug Administration (FDA) licensed infectious disease testing.

Onsite Specimen Processing

- Spin down tubes for 5 minutes at 4,000 rpm's.
- Using a transfer pipette, transfer serum from the spun-down specimen into a transfer tube. Label the transfer tube with the the donor identification number or ISBT label. Secure the cap on the transfer tube.

- Ship all specimens in a shipping container with cold packs or 14 pounds of wet ice as soon as possible.

Blood Donor Criteria

- **Appropriate donor criteria.**
  - Donor weight: ≥110 lbs.
  - Blood pressure: <180/100 mm Hg.
  - Pulse: 50–100 beats per minute (may be <50 if donor is athletic).
  - Temperature: <99.6°F.
- **Medications.**
  - Do not collect from donors currently on antibiotics, to exclude antimalarial prophylaxis.
  - Reference drugs listed on the back of the ASBP 572-EWB to determine medications that can exclude donation.
  - **Be advised**: If the purpose of the whole blood drive is to derive a source of platelets and clotting factors for a recipient, then donors who have taken aspirin in the last 72 hours should be deferred.
- **Recent donation.**
  - A single unit of whole blood may be drawn from a single donor no more often than every 56 days.

References

American Association of Blood Banks. *AABB Standards*. 4th ed. Bethesda, MD: AABB; 2012.

American Association of Blood Banks. *Technical Manual*. 17th ed. Bethesda, MD: AABB; 2011.

National Committee for Clinical Laboratory Standards. *Clinical Laboratory Technical Procedures Manual: Approved Guideline, GP02-A5*. 5th ed. Wayne, PA: NCCLS; 2002.

For Clinical Practice Guidelines, go to http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

Chapter 37

Tactical Combat Casualty Care

Introduction

For US military men and women wounded on the battlefield, the most critical phase of care is the period from the time of injury until the time that they arrive at a medical treatment facility (MTF) capable of providing surgical care. If a casualty survives long enough to reach the care of a combat trauma surgeon, the likelihood is very high that he or she will survive. Almost 90% of US service men and women who die from combat wounds do so before they arrive at an MTF.[1] This fact highlights the importance of the battlefield trauma care provided by combat medics, corpsmen, and pararescuemen (PJs), as well as non-medical unit members, in improving the survival of the country's combat wounded.

Prehospital trauma care in the US military has undergone an unprecedented transformation in the last 2 decades with the advent of Tactical Combat Casualty Care (TCCC). TCCC is a set of evidence-based, best-practice prehospital trauma care guidelines customized for use on the battlefield. DoD Instruction 1322.24, Medical Readiness Training (MRT), effective 16 March 2018, provides added guidance.

The need for reconsideration of prehospital trauma care guidelines in the tactical setting has long been recognized, but had not been accomplished as of 1992, when a research project was undertaken as a combined effort of the US Special Operations Command and the Uniformed Services University of the Health Sciences. This effort resulted in the publication of the original TCCC Guidelines in 1996.[2]

After 10 years of intense combat operations in Iraq and Afghanistan by the Ranger Regiment, Kotwal and colleagues reported that the incidence of preventable deaths among 419

combat casualties sustained by the 75th Rangers was 3%,[3] and that the single death that was deemed preventable occurred in the hospital, not the prehospital, setting. This finding stands in stark contrast to the 15% to 28% reported in other studies of preventable deaths among US casualties in these conflicts.[1,4,5] Considering the prehospital phase only, the incidence of preventable deaths among fatalities in the 75th Rangers was zero, as compared to 24% in a study by Eastridge et al.[1] The remarkable disparity in the incidence of preventable deaths between early adopters of TCCC and the rest of the US military was not widely known until the Kotwal study was published in 2011,[3] followed by the Eastridge study in 2012.[1]

After 16 years of conflict in the Middle East, US military units that have trained their members in TCCC have documented the lowest incidence of preventable deaths among their casualties in the history of modern warfare. The accumulated published evidence and battlefield experience has resulted in all services in the US military, and many allied nations, using TCCC concepts to care for their combat wounded. TCCC-based prehospital trauma training is now widespread in the US civilian sector as well. Although observed differences in potentially preventable deaths may be due to differences in the methodology of determining which deaths are considered potentially preventable, in 2017 there is little disagreement that the interventions pioneered by TCCC do clearly reduce preventable deaths during the phase of care when they are most likely to occur.[6–8] As a result of the TCCC's success at saving lives on the battlefield, on 16 March 2018, the Department of Defense mandated TCCC training for everyone in the US military.[9]

References

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4. Holcomb JB, McMullen NR, Pearse L, et al. Causes of death in Special Operations forces in the global war on terrorism: 2001–2004. *Ann Surg*. 2007;245(6):986–991.

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The guidelines printed below were updated in August 2017. They are divided into three sections: care under fire, tactical field care, and tactical evacuation care.

TCCC Guidelines for Medical Personnel

28 August 2017

Basic Management Plan for Care Under Fire

1. Return fire and take cover.
2. Direct or expect casualty to remain engaged as a combatant if appropriate.
3. Direct casualty to move to cover and apply self-aid if able.
4. Try to keep the casualty from sustaining additional wounds.
5. Casualties should be extricated from burning vehicles or buildings and moved to places of relative safety. Do what is necessary to stop the burning process.
6. Stop life-threatening external hemorrhage if tactically feasible:
   a. Direct casualty to control hemorrhage by self-aid if able.
   b. Use a CoTCCC-recommended limb tourniquet for hemorrhage that is anatomically amenable to tourniquet use.
   c. Apply the limb tourniquet over the uniform clearly proximal to the bleeding site(s). If the site of the life-threatening bleeding is not readily apparent, place the tourniquet "high and tight" (as proximal as possible) on the injured limb and move the casualty to cover.
7. Airway management is generally best deferred until the Tactical Field Care phase.

Basic Management Plan for Tactical Field Care

1. Establish a security perimeter in accordance with unit tactical standard operating procedures and/or battle drills. Maintain tactical situational awareness.
2. Triage casualties as required. Casualties with an altered mental status should have weapons and communications equipment taken away immediately.
3. Massive Hemorrhage
   a. Assess for unrecognized hemorrhage and control all sources of bleeding. If not already done, use a CoTCCC-recommended limb tourniquet to control life-threatening external hemorrhage that is anatomically amenable to tourniquet use or for any traumatic amputation. Apply directly to the skin 2–3 inches above the bleeding site. If bleeding is not controlled with the first tourniquet, apply a second tourniquet side-by-side with the first.
   b. For compressible (external) hemorrhage not amenable to limb tourniquet use or as an adjunct to tourniquet removal, use Combat Gauze as the CoTCCC hemostatic dressing of choice.
      - Alternative hemostatic adjuncts:
        - Celox Gauze or
        - ChitoGauze or
        - XStat (Best for deep, narrow-tract junctional wounds)
      - Hemostatic dressings should be applied with at least 3 minutes of direct pressure (optional for XStat). Each dressing works differently, so if one fails to control bleeding, it may be removed and a fresh dressing of the same type or a different type applied. (Note: XStat is not to be removed in the field, but additional XStat, other hemostatic adjuncts, or trauma dressings may be applied over it.)
      - If the bleeding site is amenable to use of a junctional tourniquet, immediately apply a CoTCCC-recommended junctional tourniquet. Do not delay in the application of the junctional tourniquet once it is ready for use. Apply hemostatic dressings with direct pressure if a junctional tourniquet is not available or while the junctional tourniquet is being readied for use.

4. Airway Management
   a. Conscious casualty with no airway problem identified:
      - No airway intervention required
   b. Unconscious casualty without airway obstruction:
      - Place casualty in the recovery position
      - Chin lift or jaw thrust maneuver or
      - Nasopharyngeal airway or
      - Extraglottic airway
   c. Casualty with airway obstruction or impending airway obstruction:
      - Allow a conscious casualty to assume any position that best protects the airway, to include sitting up.
      - Use a chin lift or jaw thrust maneuver
      - Use suction if available and appropriate
      - Nasopharyngeal airway or
      - Extraglottic airway (if the casualty is unconscious)
      - Place an unconscious casualty in the recovery position.
   d. If the previous measures are unsuccessful, perform a surgical cricothyroidotomy using one of the following:
      - Cric-Key technique (preferred option)
      - Bougie-aided open surgical technique using a flanged and cuffed airway cannula of less than 10 mm outer diameter, 6–7 mm internal diameter, and 5–8 cm of intratracheal length
      - Standard open surgical technique using a flanged and cuffed airway cannula of less than 10 mm outer diameter, 6–7 mm internal diameter, and 5–8 cm of intra-tracheal length (least desirable option)
      - Use lidocaine if the casualty is conscious.
   e. Cervical spine stabilization is not necessary for casualties who have sustained only penetrating trauma.
   f. Monitor the hemoglobin oxygen saturation in casualties to help assess airway patency.
   g. Always remember that the casualty's airway status may change over time and requires frequent reassessment.

* The i-gel is the preferred extraglottic airway because its gel-filled cuff makes it simpler to use and avoids the need for cuff inflation and monitoring. If an extraglottic airway with an air-filled cuff is used, the cuff pressure must be monitored

to avoid overpressurization, especially during TACEVAC on an aircraft with the accompanying pressure changes.

* Extraglottic airways will not be tolerated by a casualty who is not deeply unconscious. If an unconscious casualty without direct airway trauma needs an airway intervention, but does not tolerate an extraglottic airway, consider the use of a nasopharyngeal airway.
* For casualties with trauma to the face and mouth, or facial burns with suspected inhalation injury, nasopharyngeal airways and extraglottic airways may not suffice and a surgical cricothyroidotomy may be required.
* Surgical cricothyroidotomies should not be performed on unconscious casualties who have no direct airway trauma unless use of a nasopharyngeal airway and/or an extraglottic airway have been unsuccessful in opening the airway.

5. Respiration/Breathing
   a. In a casualty with progressive respiratory distress and known or suspected torso trauma, consider a tension pneumothorax and decompress the chest on the side of the injury with a 14-gauge, 3.25 inch needle/catheter unit inserted in the second intercostal space at the midclavicular line. Ensure that the needle entry into the chest is not medial to the nipple line and is not directed towards the heart. An acceptable alternate site is the 4th or 5th intercostal space at the anterior axillary line (AAL).
   b. All open and/or sucking chest wounds should be treated by immediately applying a vented chest seal to cover the defect. If a vented chest seal is not available, use a non-vented chest seal. Monitor the casualty for the potential development of a subsequent tension pneumothorax. If the casualty develops increasing hypoxia, respiratory distress, or hypotension and a tension pneumothorax is suspected, treat by burping or removing the dressing or by needle decompression.
   c. Initiate pulse oximetry. All individuals with moderate/severe TBI should be monitored with pulse oximetry. Readings may be misleading in the settings of shock or marked hypothermia.

d. Casualties with moderate/severe TBI should be given supplemental oxygen when available to maintain an oxygen saturation > 90%.

6. Circulation
   a. Bleeding
      - A pelvic binder should be applied for cases of suspected pelvic fracture:
        - Severe blunt force or blast injury with one or more of the following indications:
          - Pelvic pain
          - Any major lower limb amputation or near amputation
          - Physical exam findings suggestive of a pelvic fracture
          - Unconsciousness
          - Shock
      - Reassess prior tourniquet application. Expose the wound and determine if a tourniquet is needed. If it is needed, replace any limb tourniquet placed over the uniform with one applied directly to the skin 2–3 inches above the bleeding site. Ensure that bleeding is stopped. If there is no traumatic amputation, a distal pulse should be checked. If bleeding persists or a distal pulse is still present, consider additional tightening of the tourniquet or the use of a second tourniquet side-by-side with the first to eliminate both bleeding and the distal pulse. If the reassessment determines that the prior tourniquet was not needed, then remove the tourniquet and note time of removal on the TCCC Casualty Card.
      - Limb tourniquets and junctional tourniquets should be converted to hemostatic or pressure dressings as soon as possible if three criteria are met: the casualty is not in shock; it is possible to monitor the wound closely for bleeding; and the tourniquet is not being used to control bleeding from an amputated extremity. Every effort should be made to convert tourniquets in less than 2 hours if bleeding can be controlled with other means. Do not remove a tourniquet that has been in place more than 6 hours unless close monitoring and lab capability are available.

- Expose and clearly mark all tourniquets with the time of tourniquet application. Note tourniquets applied and time of application; time of re-application; time of conversion; and time of removal on the TCCC Casualty Card. Use a permanent marker to mark on the tourniquet and the casualty card.

b. IV Access
   - Intravenous (IV) or intraosseous (IO) access is indicated if the casualty is in hemorrhagic shock or at significant risk of shock (and may therefore need fluid resuscitation), or if the casualty needs medications, but cannot take them by mouth.
     - An 18-gauge IV or saline lock is preferred.
     - If vascular access is needed but not quickly obtainable via the IV route, use the IO route.

c. Tranexamic Acid (TXA)
   - If a casualty is anticipated to need significant blood transfusion (for example: presents with hemorrhagic shock, one or more major amputations, penetrating torso trauma, or evidence of severe bleeding):
     - Administer 1 g of tranexamic acid in 100 mL Normal Saline or Lactated Ringer's as soon as possible but NOT later than 3 hours after injury. When given, TXA should be administered over 10 minutes by IV infusion.
     - Begin the second infusion of 1 g TXA after initial fluid resuscitation has been completed.

d. Fluid Resuscitation
   - Assess for hemorrhagic shock (altered mental status in the absence of brain injury and/or weak or absent radial pulse).
   - The resuscitation fluids of choice for casualties in hemorrhagic shock, listed from most to least preferred, are: whole blood*; plasma, red blood cells (RBCs) and platelets in a 1:1:1 ratio*; plasma and RBCs in a 1:1 ratio; plasma or RBCs alone; Hextend; and crystalloid (Lactated Ringer's or Plasma-Lyte A). (NOTE: Hypothermia prevention measures [Section 7] should be initiated while fluid resuscitation is being accomplished.)

- If not in shock:
  - No IV fluids are immediately necessary.
  - Fluids by mouth are permissible if the casualty is conscious and can swallow.
- If in shock and blood products are available under an approved command or theater blood product administration protocol:
  - Resuscitate with whole blood*, or, if not available
  - Plasma, RBCs and platelets in a 1:1:1 ratio*, or, if not available
  - Plasma and RBCs in a 1:1 ratio, or, if not available
  - Reconstituted dried plasma, liquid plasma or thawed plasma alone or RBCs alone
  - Reassess the casualty after each unit. Continue resuscitation until a palpable radial pulse, improved mental status or systolic BP of 80–90 is present.
- If in shock and blood products are not available under an approved command or theater blood product administration protocol due to tactical or logistical constraints:
  - Resuscitate with Hextend, or if not available
  - Lactated Ringer's or Plasma-Lyte A
  - Reassess the casualty after each 500 mL IV bolus.
  - Continue resuscitation until a palpable radial pulse, improved mental status, or systolic BP of 80–90 mmHg is present.
  - Discontinue fluid administration when one or more of the above end points has been achieved.

- If a casualty with an altered mental status due to suspected TBI has a weak or absent radial pulse, resuscitate as necessary to restore and maintain a normal radial pulse. If BP monitoring is available, maintain a target systolic BP of at least 90 mmHg.
- Reassess the casualty frequently to check for recurrence of shock. If shock recurs, re-check all external hemorrhage control measures to ensure that they are still effective and repeat the fluid resuscitation as outlined above.

* Currently, neither whole blood nor apheresis platelets collected in theater are FDA-compliant because of the way they are collected. Consequently, whole blood and 1:1:1 resuscitation using apheresis platelets should be used only if all of the FDA-compliant blood products needed to support 1:1:1 resuscitation are not available, or if 1:1:1 resuscitation is not producing the desired clinical effect.

7. Hypothermia Prevention
   a. Minimize casualty's exposure to the elements. Keep protective gear on or with the casualty if feasible.
   b. Replace wet clothing with dry if possible. Get the casualty onto an insulated surface as soon as possible.
   c. Apply the Ready-Heat Blanket from the Hypothermia Prevention and Management Kit (HPMK) to the casualty's torso (not directly on the skin) and cover the casualty with the Heat-Reflective Shell (HRS).
   d. If an HRS is not available, the previously recommended combination of the Blizzard Survival Blanket and the Ready Heat blanket may also be used.
   e. If the items mentioned above are not available, use dry blankets, poncho liners, sleeping bags, or anything that will retain heat and keep the casualty dry.
   f. Warm fluids are preferred if IV fluids are required.
8. Penetrating Eye Trauma
   a. If a penetrating eye injury is noted or suspected:
      - Perform a rapid field test of visual acuity and document findings.
      - Cover the eye with a rigid eye shield (NOT a pressure patch.)
      - Ensure that the 400 mg moxifloxacin tablet in the Combat Wound Medication Pack (CWMP) is taken if possible and that IV/IM antibiotics are given as outlined below if oral moxifloxacin cannot be taken.
9. Monitoring
   a. Initiate advanced electronic monitoring if indicated and if monitoring equipment is available.
10. Analgesia
   a. Analgesia on the battlefield should generally be achieved using one of three options:

- Option 1
  - Mild to Moderate Pain
    Casualty is still able to fight
    - TCCC Combat Wound Medication Pack (CWMP)
      * Tylenol - 650 mg bilayer caplet, 2 PO every 8 hours
      * Meloxicam - 15 mg PO once a day
- Option 2
  - Moderate to Severe Pain
    Casualty IS NOT in shock or respiratory distress AND
    Casualty IS NOT at significant risk of developing either condition
    - Oral transmucosal fentanyl citrate (OTFC) 800 μg
      * Place lozenge between the cheek and the gum
      * Do not chew the lozenge
- Option 3
  - Moderate to Severe Pain
    Casualty IS in hemorrhagic shock or respiratory distress OR
    Casualty IS at significant risk of developing either condition
    - Ketamine 50 mg IM or IV
      Or
    - Ketamine 20 mg slow IV or IO
      * Repeat doses q30min prn for IM or IN
      * Repeat doses q20min prn for IV or IO
      * End points: Control of pain or development of nystagmus (rhythmic back-and-forth movement of the eyes)

Analgesia notes:

a. Casualties may need to be disarmed after being given OTFC or ketamine.
b. Document a mental status exam using the AVPU method prior to administering opioids or ketamine.
c. For all casualties given opioids or ketamine – monitor airway, breathing, and circulation closely
d. Directions for administering OTFC:
   - Recommend taping lozenge-on-a-stick to casualty's finger as an added safety measure OR utilizing a safety

pin and rubber band to attach the lozenge (under tension) to the patient's uniform or plate carrier.
- Reassess in 15 minutes
- Add second lozenge, in other cheek, as necessary to control severe pain
- Monitor for respiratory depression

e. IV Morphine is an alternative to OTFC if IV access has been obtained
- 5 mg IV/IO
- Reassess in 10 minutes.
- Repeat dose every 10 minutes as necessary to control severe pain.
- Monitor for respiratory depression.

f. Naloxone (0.4 mg IV or IM) should be available when using opioid analgesics.

g. Both ketamine and OTFC have the potential to worsen severe TBI. The combat medic, corpsman, or PJ must consider this fact in his or her analgesic decision, but if the casualty is able to complain of pain, then the TBI is likely not severe enough to preclude the use of ketamine or OTFC.

h. Eye injury does not preclude the use of ketamine. The risk of additional damage to the eye from using ketamine is low and maximizing the casualty's chance for survival takes precedence if the casualty is in shock or respiratory distress or at significant risk for either.

i. Ketamine may be a useful adjunct to reduce the amount of opioids required to provide effective pain relief. It is safe to give ketamine to a casualty who has previously received morphine or OTFC. IV Ketamine should be given over 1 minute.

j. If respirations are noted to be reduced after using opioids or ketamine, provide ventilatory support with a bag-valve-mask or mouth-to-mask ventilations.

k. Ondansetron, 4 mg Orally Dissolving Tablet (ODT)/IV/IO/IM, every 8 hours as needed for nausea or vomiting. Each 8-hour dose can be repeated once at 15 minutes if nausea and vomiting are not improved. Do not give more than 8 mg in any 8-hour interval. Oral ondansetron is NOT an acceptable alternative to the ODT formulation.

l. Reassess – reassess – reassess!

11. Antibiotics: recommended for all open combat wounds
    a. If able to take PO meds:
       - Moxifloxacin (from the CWMP), 400 mg PO once a day
    b. If unable to take PO meds (shock, unconsciousness):
       - Ertapenem, 1 g IV/IM once a day
12. Inspect and dress known wounds.
13. Check for additional wounds.
14. Burns
    a. Facial burns, especially those that occur in closed spaces, may be associated with inhalation injury. Aggressively monitor airway status and oxygen saturation in such patients and consider early surgical airway for respiratory distress or oxygen desaturation.
    b. Estimate total body surface area (TBSA) burned to the nearest 10% using the Rule of Nines.
    c. Cover the burn area with dry, sterile dressings. For extensive burns (>20%), consider placing the casualty in the Heat-Reflective Shell or Blizzard Survival Blanket from the Hypothermia Prevention Kit in order to both cover the burned areas and prevent hypothermia.
    d. Fluid resuscitation (USAISR Rule of Ten)
       - If burns are greater than 20% of TBSA, fluid resuscitation should be initiated as soon as IV/IO access is established. Resuscitation should be initiated with Lactated Ringer's, normal saline, or Hextend. If Hextend is used, no more than 1000 mL should be given, followed by Lactated Ringer's or normal saline as needed.
       - Initial IV/IO fluid rate is calculated as %TBSA x 10 mL/hr for adults weighing 40–80 kg.
       - For every 10 kg ABOVE 80 kg, increase initial rate by 100 ml/hr.
       - If hemorrhagic shock is also present, resuscitation for hemorrhagic shock takes precedence over resuscitation for burn shock. Administer IV/IO fluids per the TCCC Guidelines in Section (6).
    e. Analgesia in accordance with the TCCC Guidelines in Section (10) may be administered to treat burn pain.
    f. Prehospital antibiotic therapy is not indicated solely for burns, but antibiotics should be given per the TCCC

guidelines in Section (11) if indicated to prevent infection in penetrating wounds.

g. All TCCC interventions can be performed on or through burned skin in a burn casualty.
h. Burn patients are particularly susceptible to hypothermia. Extra emphasis should be placed on barrier heat loss prevention methods.

15. Splint fractures and recheck pulses.
16. Communication
    a. Communicate with the casualty if possible. Encourage, reassure and explain care.
    b. Communicate with tactical leadership as soon as possible and throughout casualty treatment as needed. Provide leadership with casualty status and evacuation requirements to assist with coordination of evacuation assets.
    c. Communicate with the evacuation system (the Patient Evacuation Coordination Cell) to arrange for TACEVAC. Communicate with medical providers on the evacuation asset if possible and relay mechanism of injury, injuries sustained, signs/symptoms, and treatments rendered. Provide additional information as appropriate.
17. Cardiopulmonary Resuscitation (CPR)
    a. Resuscitation on the battlefield for victims of blast or penetrating trauma who have no pulse, no ventilations, and no other signs of life will not be successful and should not be attempted. However, casualties with torso trauma or polytrauma who have no pulse or respirations during TFC should have bilateral needle decompression performed to ensure they do not have a tension pneumothorax prior to discontinuation of care. The procedure is the same as described in section (5a) above.
18. Documentation of Care
    a. Document clinical assessments, treatments rendered, and changes in the casualty's status on a TCCC Card (DD Form 1380). Forward this information with the casualty to the next level of care.
19. Prepare for Evacuation.
    a. Complete and secure the TCCC Card (DD 1380) to the casualty.

b. Secure all loose ends of bandages and wraps.
c. Secure hypothermia prevention wraps/blankets/straps.
d. Secure litter straps as required. Consider additional padding for long evacuations.
e. Provide instructions to ambulatory patients as needed.
f. Stage casualties for evacuation in accordance with unit standard operating procedures.
g. Maintain security at the evacuation point in accordance with unit standard operating procedures.

Basic Management Plan for Tactical Evacuation Care

* The term "Tactical Evacuation" includes both Casualty Evacuation (CASEVAC) and Medical Evacuation (MEDEVAC) as defined in Joint Publication 4-02.

1. Transition of Care
   a. Tactical force personnel should establish evacuation point security and stage casualties for evacuation.
   b. Tactical force personnel or the medic should communicate patient information and status to TACEVAC personnel as clearly as possible. The minimum information communicated should include stable or unstable, injuries identified, and treatments rendered.
   c. TACEVAC personnel should stage casualties on evacuation platforms as required.
   d. Secure casualties in the evacuation platform in accordance with unit policies, platform configurations and safety requirements.
   e. TACEVAC medical personnel should re-assess casualties and re-evaluate all injuries and previous interventions.
2. Massive Hemorrhage
   a. Assess for unrecognized hemorrhage and control all sources of bleeding. If not already done, use a CoTCCC-recommended limb tourniquet to control life-threatening external hemorrhage that is anatomically amenable to tourniquet use or for any traumatic amputation. Apply directly to the skin 2–3 inches above the bleeding site. If bleeding is not controlled with the first tourniquet, apply a second tourniquet side-by-side with the first.
   b. For compressible (external) hemorrhage not amenable to limb tourniquet use or as an adjunct to tourniquet removal, use Combat Gauze as the CoTCCC hemostatic dressing of choice.
      - Alternative hemostatic adjuncts:
        - Celox Gauze or
        - ChitoGauze or
        - XStat (Best for deep, narrow-tract junctional wounds)

- Hemostatic dressings should be applied with at least 3 minutes of direct pressure (optional for XStat). Each dressing works differently, so if one fails to control bleeding, it may be removed and a fresh dressing of the same type or a different type applied. (Note: XStat is not to be removed in the field, but additional XStat, other hemostatic adjuncts, or trauma dressings may be applied over it.)
- If the bleeding site is amenable to use of a junctional tourniquet, immediately apply a CoTCCC-recommended junctional tourniquet. Do not delay in the application of the junctional tourniquet once it is ready for use. Apply hemostatic dressings with direct pressure if a junctional tourniquet is not available or while the junctional tourniquet is being readied for use.

3. Airway Management
   a. Conscious casualty with no airway problem identified:
      - No airway intervention required
   b. Unconscious casualty without airway obstruction:
      - Place casualty in the recovery position
      - Chin lift or jaw thrust maneuver or
      - Nasopharyngeal airway or
      - Extraglottic airway
   c. Casualty with airway obstruction or impending airway obstruction:
      - Allow a conscious casualty to assume any position that best protects the airway, to include sitting up.
      - Use a chin lift or jaw thrust maneuver
      - Use suction if available and appropriate
      - Nasopharyngeal airway or
      - Extraglottic airway (if the casualty is unconscious)
      - Place an unconscious casualty in the recovery position.
   d. If the previous measures are unsuccessful, assess the tactical and clinical situations, the equipment at hand, and the skills and experience of the person providing care, and then select one of the following airway interventions:
      - Endotracheal intubation or
      - Perform a surgical cricothyroidotomy using one of the following:

- Cric-Key technique (Preferred option)
- Bougie-aided open surgical technique using a flanged and cuffed airway cannula of less than 10 mm outer diameter, 6–7 mm internal diameter, and 5–8 cm of intra-tracheal length
- Standard open surgical technique using a flanged and cuffed airway cannula of less than 10 mm outer diameter, 6–7 mm internal diameter and 5–8 cm of intra-tracheal length (Least desirable option)

● Use lidocaine if the casualty is conscious.

e. Cervical spine stabilization is not necessary for casualties who have sustained only penetrating trauma.
f. Monitor the hemoglobin oxygen saturation in casualties to help assess airway patency. Use capnography monitoring in this phase of care if available.
g. Always remember that the casualty's airway status may change over time and requires frequent reassessment.

* The i-gel is the preferred extraglottic airway because its gel-filled cuff makes it simpler to use and avoids the need for cuff inflation and monitoring. If an extraglottic airway with an air-filled cuff is used, the cuff pressure must be monitored to avoid overpressurization, especially during TACEVAC on an aircraft with the accompanying pressure changes.
* Extraglottic airways will not be tolerated by a casualty who is not deeply unconscious. If an unconscious casualty without direct airway trauma needs an airway intervention, but does not tolerate an extraglottic airway, consider the use of a nasopharyngeal airway.
* For casualties with trauma to the face and mouth, or facial burns with suspected inhalation injury, nasopharyngeal airways and extraglottic airways may not suffice and a surgical cricothyroidotomy may be required.
* Surgical cricothyroidotomies should not be performed on unconscious casualties who have no direct airway trauma unless use of a nasopharyngeal airway and/or an extraglottic airway have been unsuccessful in opening the airway.

4. Respiration/Breathing
   a. In a casualty with progressive respiratory distress and known or suspected torso trauma, consider a tension

pneumothorax and decompress the chest on the side of the injury with a 14-gauge, 3.25 inch needle/catheter unit inserted in the second intercostal space at the midclavicular line. Ensure that the needle entry into the chest is not medial to the nipple line and is not directed towards the heart. An acceptable alternate site is the 4th or 5th intercostal space at the anterior axillary line (AAL).

b. Consider chest tube insertion if no improvement and/or long transport is anticipated.
c. Initiate pulse oximetry if not previously done. All individuals with moderate/severe TBI should be monitored with pulse oximetry. Readings may be misleading in the settings of shock or marked hypothermia.
d. Most combat casualties do not require supplemental oxygen, but administration of oxygen may be of benefit for the following types of casualties:
    - Low oxygen saturation by pulse oximetry
    - Injuries associated with impaired oxygenation
    - Unconscious casualty
    - Casualty with TBI (maintain oxygen saturation > 90%)
    - Casualty in shock
    - Casualty at altitude
    - Known or suspected smoke inhalation
e. All open and/or sucking chest wounds should be treated by immediately applying a vented chest seal to cover the defect. If a vented chest seal is not available, use a non-vented chest seal. Monitor the casualty for the potential development of a subsequent tension pneumothorax. If the casualty develops increasing hypoxia, respiratory distress, or hypotension and a tension pneumothorax is suspected, treat by burping or removing the dressing or by needle decompression.

5. Circulation
    a. Bleeding
        - A pelvic binder should be applied for cases of suspected pelvic fracture:
            - Severe blunt force or blast injury with one or more of the following indications:
                - Pelvic pain

    - Any major lower limb amputation or near amputation
    - Physical exam findings suggestive of a pelvic fracture
    - Unconsciousness
    - Shock
- Reassess prior tourniquet application. Expose the wound and determine if a tourniquet is needed. If it is needed, replace any limb tourniquet placed over the uniform with one applied directly to the skin 2–3 inches above the bleeding site. Ensure that bleeding is stopped. If there is no traumatic amputation, a distal pulse should be checked. If bleeding persists or a distal pulse is still present, consider additional tightening of the tourniquet or the use of a second tourniquet side-by-side with the first to eliminate both bleeding and the distal pulse. If the reassessment determines that the prior tourniquet was not needed, then remove the tourniquet and note time of removal on the TCCC Casualty Card.
- Limb tourniquets and junctional tourniquets should be converted to hemostatic or pressure dressings as soon as possible if three criteria are met: the casualty is not in shock; it is possible to monitor the wound closely for bleeding; and the tourniquet is not being used to control bleeding from an amputated extremity. Every effort should be made to convert tourniquets in less than 2 hours if bleeding can be controlled with other means. Do not remove a tourniquet that has been in place more than 6 hours unless close monitoring and lab capability are available.
- Expose and clearly mark all tourniquets with the time of tourniquet application. Note tourniquets applied and time of application; time of re-application; time of conversion; and time of removal on the TCCC Casualty Card. Use a permanent marker to mark on the tourniquet and the casualty card.

b. IV Access
- Reassess need for IV access.
- IV or IO access is indicated if the casualty is in

hemorrhagic shock or at significant risk of shock (and may therefore need fluid resuscitation), or if the casualty needs medications, but cannot take them by mouth.
- An 18-gauge IV or saline lock is preferred.
- If vascular access is needed but not quickly obtainable via the IV route, use the IO route.

c. Tranexamic Acid (TXA)
- If a casualty is anticipated to need significant blood transfusion (for example: presents with hemorrhagic shock, one or more major amputations, penetrating torso trauma, or evidence of severe bleeding):
  - Administer 1 g of tranexamic acid in 100 mL Normal Saline or Lactated Ringers as soon as possible but NOT later than 3 hours after injury. When given, TXA should be administered over 10 minutes by IV infusion.
  - Begin second infusion of 1 g TXA after initial fluid resuscitation has been completed.

d. Fluid Resuscitation
- Assess for hemorrhagic shock (altered mental status in the absence of brain injury and/or weak or absent radial pulse).
- The resuscitation fluids of choice for casualties in hemorrhagic shock, listed from most to least preferred, are: whole blood*; plasma, RBCs and platelets in a 1:1:1 ratio*; plasma and RBCs in a 1:1 ratio; plasma or RBCs alone; Hextend; and crystalloid (Lactated Ringer's or Plasma-Lyte A). (NOTE: Hypothermia prevention measures [Section 7] should be initiated while fluid resuscitation is being accomplished.)
  - If not in shock:
    - No IV fluids are immediately necessary.
    - Fluids by mouth are permissible if the casualty is conscious and can swallow.
  - If in shock and blood products are available under an approved command or theater blood product administration protocol:
    - Resuscitate with whole blood*, or, if not available

    - Plasma, RBCs and platelets in a 1:1:1 ratio*, or, if not available
    - Plasma and RBCs in a 1:1 ratio, or, if not available
    - Reconstituted dried plasma, liquid plasma or thawed plasma alone or RBCs alone
    - Reassess the casualty after each unit. Continue resuscitation until a palpable radial pulse, improved mental status or systolic BP of 80–90 is present.
  - If in shock and blood products are not available under an approved command or theater blood product administration protocol due to tactical or logistical constraints:
    - Resuscitate with Hextend, or if not available
    - Lactated Ringer's or Plasma-Lyte A
    - Reassess the casualty after each 500 mL IV bolus.
    - Continue resuscitation until a palpable radial pulse, improved mental status, or systolic BP of 80–90 mmHg is present.
    - Discontinue fluid administration when one or more of the above end points has been achieved.
- If a casualty with an altered mental status due to suspected TBI has a weak or absent radial pulse, resuscitate as necessary to restore and maintain a normal radial pulse. If BP monitoring is available, maintain a target systolic BP of at least 90 mmHg.
- Reassess the casualty frequently to check for recurrence of shock. If shock recurs, recheck all external hemorrhage control measures to ensure that they are still effective and repeat the fluid resuscitation as outlined above.

* Currently, neither whole blood nor apheresis platelets collected in theater are FDA-compliant because of the way they are collected. Consequently, whole blood and 1:1:1 resuscitation using apheresis platelets should be used only if all the FDA-compliant blood products needed to support 1:1:1 resuscitation are not available, or if 1:1:1 resuscitation is not producing the desired clinical effect.

6. Traumatic Brain Injury
   a. Casualties with moderate/severe TBI should be monitored for:
      - Decreases in level of consciousness
      - Pupillary dilation
      - SBP should be >90 mmHg
      - O_2 sat > 90
      - Hypothermia
      - Pco_2 (If capnography is available, maintain between 35–40 mmHg)
      - Penetrating head trauma (if present, administer antibiotics)
      - Assume a spinal (neck) injury until cleared.
   b. Unilateral pupillary dilation accompanied by a decreased level of consciousness may signify impending cerebral herniation; if these signs occur, take the following actions to decrease intracranial pressure:
      - Administer 250 mL of 3% or 5% hypertonic saline bolus.
      - Elevate the casualty's head 30 degrees.
      - Hyperventilate the casualty.
        - Respiratory rate 20
        - Capnography should be used to maintain the end-tidal CO_2 between 30–35 mmHg
        - The highest oxygen concentration (FIO_2) possible should be used for hyperventilation.

* Notes:
Do not hyperventilate the casualty unless signs of impending herniation are present.
Casualties may be hyperventilated with oxygen using the bag-valve-mask technique.

7. Hypothermia Prevention
   a. Minimize casualty's exposure to the elements. Keep protective gear on or with the casualty if feasible.
   b. Replace wet clothing with dry if possible. Get the casualty onto an insulated surface as soon as possible.
   c. Apply the Ready-Heat Blanket from the Hypothermia Prevention and Management Kit (HPMK) to the casualty's torso (not directly on the skin) and cover the casualty with the Heat-Reflective Shell (HRS).

d. If an HRS is not available, the previously recommended combination of the Blizzard Survival Blanket and the Ready Heat blanket may also be used.
e. If the items mentioned above are not available, use poncho liners, sleeping bags, or anything that will retain heat and keep the casualty dry.
f. Use a portable fluid warmer capable of warming all IV fluids including blood products.
g. Protect the casualty from wind if doors must be kept open.

8. Penetrating Eye Trauma
   a. If a penetrating eye injury is noted or suspected:
      - Perform a rapid field test of visual acuity and document findings.
      - Cover the eye with a rigid eye shield (NOT a pressure patch.)
      - Ensure that the 400 mg moxifloxacin tablet in the Combat Wound Medication Pack (CWMP) is taken if possible and that IV/IM antibiotics are given as outlined below if oral moxifloxacin cannot be taken.
9. Monitoring
   a. Initiate advanced electronic monitoring if indicated and if monitoring equipment is available.
10. Analgesia
    a. Analgesia on the battlefield should generally be achieved using one of three options:
       - Option 1
         - Mild to Moderate Pain
           Casualty is still able to fight
           - TCCC CWMP
             * Tylenol – 650 mg bilayer caplet, 2 PO every 8 hours
             * Meloxicam – 15 mg PO once a day
       - Option 2
         - Moderate to Severe Pain
           Casualty IS NOT in shock or respiratory distress AND Casualty IS NOT at significant risk of developing either condition
           - Oral transmucosal fentanyl citrate (OTFC) 800 μg
             * Place lozenge between the cheek and the gum
             * Do not chew the lozenge

- Option 3
  - Moderate to Severe Pain
    Casualty IS in hemorrhagic shock or respiratory distress OR
    Casualty IS at significant risk of developing either condition
    - Ketamine 50 mg IM or IN
      Or
    - Ketamine 20 mg slow IV or IO
      * Repeat doses q30min prn for IM or IN
      * Repeat doses q20min prn for IV or IO
      * End points: Control of pain or development of nystagmus (rhythmic back-and-forth movement of the eyes)

Analgesia notes:

a. Casualties may need to be disarmed after being given OTFC or ketamine.
b. Document a mental status exam using the AVPU method prior to administering opioids or ketamine.
c. For all casualties given opioids or ketamine – monitor airway, breathing, and circulation closely
d. Directions for administering OTFC:
   - Recommend taping lozenge-on-a-stick to casualty's finger as an added safety measure OR utilizing a safety pin and rubber band to attach the lozenge (under tension) to the patient's uniform or plate carrier.
   - Reassess in 15 minutes
   - Add second lozenge, in other cheek, as necessary to control severe pain
   - Monitor for respiratory depression
e. IV Morphine is an alternative to OTFC if IV access has been obtained
   - 5 mg IV/IO
   - Reassess in 10 minutes.
   - Repeat dose every 10 minutes as necessary to control severe pain.
   - Monitor for respiratory depression.
f. Naloxone (0.4 mg IV or IM) should be available when using opioid analgesics.

g. Both ketamine and OTFC have the potential to worsen severe TBI. The combat medic, corpsman, or PJ must consider this fact in his or her analgesic decision, but if the casualty can complain of pain, then the TBI is likely not severe enough to preclude the use of ketamine or OTFC.
h. Eye injury does not preclude the use of ketamine. The risk of additional damage to the eye from using ketamine is low and maximizing the casualty's chance for survival takes precedence if the casualty is in shock or respiratory distress or at significant risk for either.
i. Ketamine may be a useful adjunct to reduce the amount of opioids required to provide effective pain relief. It is safe to give ketamine to a casualty who has previously received morphine or OTFC. IV Ketamine should be given over 1 minute.
j. If respirations are noted to be reduced after using opioids or ketamine, provide ventilatory support with a bag-valve-mask or mouth-to-mask ventilations.
k. Ondansetron, 4 mg ODT/IV/IO/IM, every 8 hours as needed for nausea or vomiting. Each 8-hour dose can be repeated once at 15 minutes if nausea and vomiting are not improved. Do not give more than 8 mg in any 8-hour interval. Oral ondansetron is NOT an acceptable alternative to the ODT formulation.
l. Reassess – reassess – reassess!

11. Antibiotics: recommended for all open combat wounds
    a. If able to take PO meds:
        - Moxifloxacin (from CWMP), 400 mg PO once a day
    b. If unable to take PO meds (shock, unconsciousness):
        - Ertapenem, 1 g IV/IM once a day
12. Inspect and dress known wounds.
13. Check for additional wounds.
14. Burns
    a. Facial burns, especially those that occur in closed spaces, may be associated with inhalation injury. Aggressively monitor airway status and oxygen saturation in such patients and consider early surgical airway for respiratory distress or oxygen desaturation.

b. Estimate total body surface area (TBSA) burned to the nearest 10% using the Rule of Nines.
c. Cover the burn area with dry, sterile dressings. For extensive burns (>20%), consider placing the casualty in the Heat-Reflective Shell or Blizzard Survival Blanket from the Hypothermia Prevention Kit to both cover the burned areas and prevent hypothermia.
d. Fluid resuscitation (USAISR Rule of Ten)
   - If burns are greater than 20% of TBSA, fluid resuscitation should be initiated as soon as IV/IO access is established. Resuscitation should be initiated with Lactated Ringer's, normal saline, or Hextend. If Hextend is used, no more than 1000 mL should be given, followed by Lactated Ringer's or normal saline as needed.
   - Initial IV/IO fluid rate is calculated as %TBSA x 10 mL/hr for adults weighing 40–80 kg.
   - For every 10 kg ABOVE 80 kg, increase initial rate by 100 mL/hr.
   - If hemorrhagic shock is also present, resuscitation for hemorrhagic shock takes precedence over resuscitation for burn shock. Administer IV/IO fluids per the TCCC Guidelines in Section (6).
e. Analgesia in accordance with the TCCC Guidelines in Section (10) may be administered to treat burn pain.
f. Prehospital antibiotic therapy is not indicated solely for burns, but antibiotics should be given per the TCCC guidelines in Section (11) if indicated to prevent infection in penetrating wounds.
g. All TCCC interventions can be performed on or through burned skin in a burn casualty.
h. Burn patients are particularly susceptible to hypothermia. Extra emphasis should be placed on barrier heat loss prevention methods and IV fluid warming in this phase.

15. Reassess fractures and recheck pulses.
16. Communication
    a. Communicate with the casualty if possible. Encourage, reassure and explain care.

b. Communicate with medical providers at the next level of care as feasible and relay mechanism of injury, injuries sustained, signs/symptoms, and treatments rendered. Provide additional information as appropriate.

17. CPR in TACEVAC Care
    a. Casualties with torso trauma or polytrauma who have no pulse or respirations during TACEVAC should have bilateral needle decompression performed to ensure they do not have a tension pneumothorax. The procedure is the same as described in Section (4a) above.
    b. CPR may be attempted during this phase of care if the casualty does not have obviously fatal wounds and will be arriving at a facility with a surgical capability within a short period of time. CPR should not be done at the expense of compromising the mission or denying lifesaving care to other casualties.
18. Documentation of Care
    a. Document clinical assessments, treatments rendered, and changes in the casualty's status on a TCCC Card (DD Form 1380). Forward this information with the casualty to the next level of care.

I remember preparing to go to Afghanistan a couple of months post 9/11. Part of my preparation was packing a chest with reference materials and books (just in case we were without power). One of those books was the Emergency War Surgery *handbook (EWS). As I grabbed the book, I took the time to look at its contents because this was the first time I was going to war and I wanted to be able to take care of my people if I got dislocated from higher medical care. The Special Operations Combat Medic Course taught me advanced interventions and it was nice to refresh on things I had not looked at recently.*

This new edition of EWS includes for the first time Tactical Combat Casualty Care (TCCC), which is the basis for military prehospital medical providers at all levels. The lives of many have been saved by applying TCCC. Morbidity rates have declined over the last decades of combat. As the beginning of the medical process, a well-informed and trained medic on the frontline is key to patient survival. This update to the EWS will enhance our capability to address many diverse and challenging situations not encountered in garrison environments.

Christopher R. Marshall, NRP, SO-ATP
Sergeant Major, US Army

Envoi

I would say that two contrary laws seem to be wrestling with each other nowadays: The one, a law of blood and death, ever imagining new means of destruction and forcing nations to be constantly ready for the battlefield—the other a law of peace, work, and health ever evolving new means of delivering man from the scourges which beset him. Which of these two laws will ultimately prevail God alone knows.

—***Louis Pasteur***

Appendix 1

Principles of Medical Ethics

Relevant to the Role of Health Personnel, Particularly Physicians, in the Protection of Prisoners and Detainees Against Torture and Other Cruel, Inhuman, or Degrading Treatment or Punishment

Adopted by the United Nations General Assembly, Resolution 37/194, December 18, 1982

Principle 1
Health personnel, particularly physicians, charged with the medical care of prisoners and detainees have a duty to provide them with protection of their physical and mental health and treatment of disease of the same quality and standard as is afforded to those who are not imprisoned or detained.

Principle 2
It is a gross contravention of medical ethics, as well as an offence under applicable international instruments, for health personnel, particularly physicians, to engage, actively or passively, in acts which constitute participation in, complicity in, incitement to, or attempts to commit torture or other cruel, inhuman, or degrading treatment or punishment.

Principle 3
It is a contravention of medical ethics for health personnel, particularly physicians, to be involved in any professional relationship with prisoners or detainees, the purpose of which is not solely to evaluate, protect, or improve their physical and mental health.

Principle 4
It is a contravention of medical ethics for health personnel, particularly physicians:
(a) to apply their knowledge and skills in order to assist in the interrogation of prisoners and detainees in a manner that may adversely affect the physical or mental health or condition of such prisoners or detainees and which is not in accordance with the relevant international instruments; and
(b) to certify, or to participate in the certification of, the fitness of prisoners or detainees for any form of treatment or punishment that may adversely affect their physical or mental health and which is not in accordance with the relevant international instruments, or to participate in any way in the infliction of any such treatment or punishment that is not in accordance with the relevant international instruments.

Principle 5
It is a contravention of medical ethics for health personnel, particularly physicians, to participate in any procedure for restraining a prisoner or detainee unless such a procedure is determined in accordance with purely medical criteria as being necessary for the protection of the physical or mental health or the safety of the prisoner or detainee himself, of his fellow prisoners or detainees, or of his guardians, and presents no hazard to the physical or mental health of the prisoner/detainee.

Principle 6
There may be no derogation from the foregoing principles on any ground whatsoever, including public emergency.

Declaration on the Protection of All Persons From Being Subjected to Torture and Other Cruel, Inhuman, or Degrading Treatment or Punishment follows on page 549.

Declaration on the Protection of All Persons From Being Subjected to Torture and Other Cruel, Inhuman, or Degrading Treatment or Punishment

Adopted by the United Nations General Assembly, Resolution 3452 (XXX), December 9, 1975

Article 1
(a) For the purpose of this Declaration, torture means any act by which severe pain or suffering, whether physical or mental, is intentionally inflicted by or at the instigation of a public official on a person for such purposes as obtaining from him or a third person information or confession, punishing him for an act he has committed or is suspected of having committed, or intimidating him or other persons. It does not include pain or suffering arising only from, inherent in or incidental to, lawful sanctions to the extent consistent with the Standard Minimum Rules for the Treatment of Prisoners.
(b) Torture constitutes an aggravated and deliberate form of cruel, inhuman, or degrading treatment or punishment.

Article 7
Each State shall ensure that all acts of torture as defined in Article 1 are offences under its criminal law. The same shall apply in regard to acts which constitute participation in, complicity in, incitement to, or an attempt to commit torture.

The information contained herein is adapted from the Office of the United Nations High Commissioner for Human Rights (Geneva, Switzerland).

Appendix 2

Glasgow Coma Scale

EYE OPENING	Spontaneous To sound To pressure None	
VERBAL RESPONSE	Oriented Confused Words Sounds None	
MOTOR RESPONSE	Obey commands Localizing Normal flexion Abnormal flexion Extension None	

Serial findings should be documented on a coma scale chart. The observations can then be clearly communicated and the trends rapidly appreciated so that any improvement or deterioration in a patient's condition can be seen. Deterioration in a patient's condition should precipitate urgent medical review in order to identify any remediable factors that have contributed to this change. This assessment may include performing cranial imaging (usually computed tomography (CT)) to identify problems such as hematomas, contusions, or brain swelling.

In addition to plotting trends on a coma scale chart, a patient's ratings can be documented numerically as a shorthand aid to quickly record findings (eg, E2V4M6). However, when describing the patient, always use the full criteria alongside the numbers to ensure that the assessment is accurately understood.

The shorthand numbers can also be added together to give a total Coma Score (eg, E2V4M6 = 12). This provides an overview summary of the severity of the patient's condition, but this score does not communicate the more informative detailed description of each response, which should always be used in addition to the score in clinical care of an

individual patient. It is important to note, for example, that a total score of 8 could be E2V2M4 or E1V1M6, with very different implications for the severity of the patient's condition.

Appendix 3

Department of Defense Trauma Registry

General

Evidence-based medicine allows for identification of best practices and the timely formulation of clinical practice guidelines. Unfortunately, because of the realities of combat trauma, timely and accurate data collection and interpretation of results are difficult. Quality information on casualties for combatant commanders is essential because it facilitates optimal placement, utilization, and resupply of scarce medical resources, and rapid identification of new trends in wounding, prevention, and treatment. Timely, accurate, aggregated theater information is necessary to shorten quality improvement cycles and improve outcomes.

Furthermore, aggregation, evaluation, and reporting of these data provide rapid feedback for providers across the entire chain of care and evacuation in the Joint Trauma System (JTS). Application of these principles to the battlefield, using a set of jointly approved data elements as a means to drive concurrent performance improvement within the JTS, has been a major advancement of the recent conflicts in Afghanistan and Iraq. This effort has led to the adaption of technology and the training of specialists to serve the mission of timely and accurate collection of combat injury data. The trauma documentation tool that facilitates this process should be used as the trauma medical record (for both battle and nonbattle injuries) and should accompany the casualty throughout the chain of care and evacuation.

Situational Awareness

The revolution in warfighting that has digitized the battlefield to display friendly positions, intelligence, and engagements electronically has not been equally applied to the casualty care side of the equation. This places demands on medical organizations to provide online and continuously updated status and location information on killed, wounded, ill, and psychologically impaired combatants and noncombatants, including both the casualty loss to the unit and the return-to-duty patient. This need will only escalate as medical situational awareness plays an increasing role in the tactical risk assessment process. At a minimum, commanders should be able to assess the case fatality rate (CFR; fraction of an exposed group—all those wounded in action [WIA] who die—a measure of the lethality of the battlefield; the calculation includes those WIA individuals who are returned to duty [RTD]), percentage killed in action (KIA; died before reaching medical care/force wounded), and percentage died of wounds (DOW; died after reaching medical care/force wounded) in order to measure risk associated with operations and the capability of the medical force to control mortality.

$$\text{CFR} = \frac{(\text{KIA} + \text{DOW})}{(\text{KIA} + \text{WIA})} \times 100$$

$$\%\text{KIA} = \frac{(\text{Deaths before MTF})}{\text{KIA} + (\text{WIA} - \text{RTD})} \times 100$$

$$\%\text{DOW} = \frac{(\text{Deaths after MTF})}{(\text{WIA} - \text{RTD})} \times 100,$$

where MTF is defined as medical treatment facility or any fixed facility with a medical provider.

Categorization of casualties by type and distribution of injury within the major body regions (ie, face, head and neck, chest, abdomen and pelvis, upper and lower extremities, and skin) enables analysis of injury patterns and assessment of injury severity that can be utilized to design prevention applications

and care interventions, thus decreasing the burden of injury, morbidity, and mortality.

Other Uses

Data on types of wounds, their causes, and appropriate procedures have potential value in constructing predictive models for medical force development and placement, logistical delivery systems, and research on improved medical and surgical interventions and prevention. The history of improvements in medicine and surgery is grounded on the battlefield, and dissemination should not be limited to the isolated innovator with a personal spreadsheet for documentation. Individual providers at individual medical treatment facilities have long recorded clinical data and observations. This Department of Defense Trauma Registry (DoDTR) is an organized and coordinated effort to facilitate documentation of information that is aggregated into the registry that provides the means to better understand the effectiveness of prevention measures and casualty care, as well as the burden of injury, morbidity, and mortality in a population.

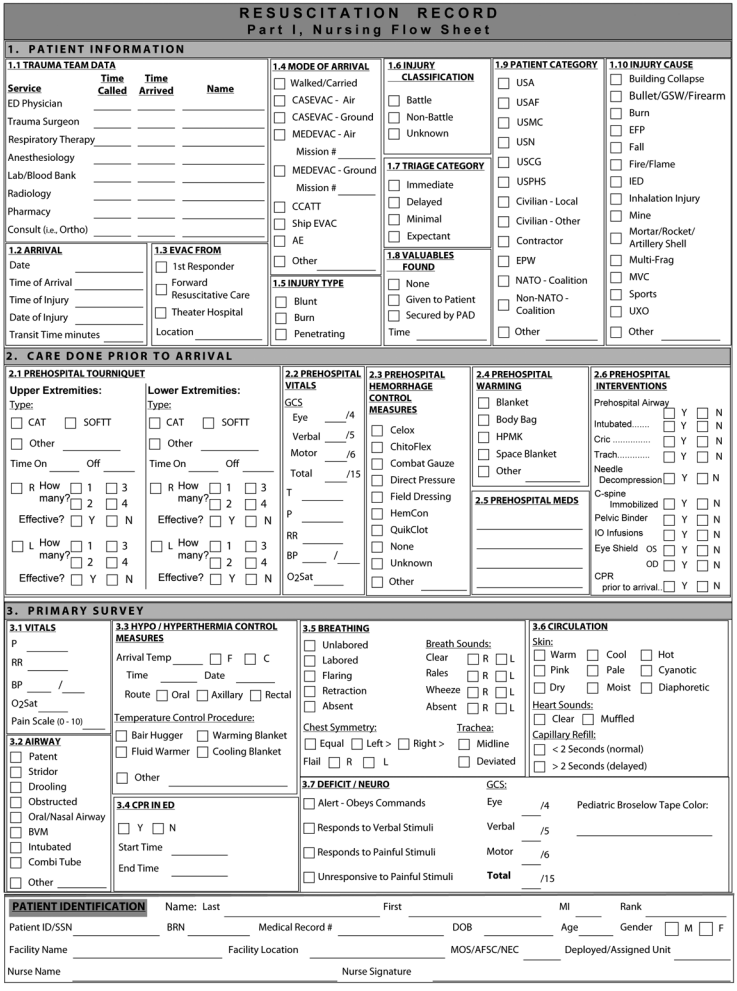
Minimum Essential Data

In addition to recording the standard contents of the postprocedure note (ie, who did what, on whom, why, and a plan), the standard data components of a trauma registry are especially helpful (eg, demographics, circumstance and mechanism of injury, injury severity, prehospital monitoring and care, hospital monitoring and care, outcome, participants, direct assessment against standards). Figure A3-1 is a sample of the form that serves as both the trauma medical record and as a source for data capture. The minimum essential elements present on this form have been agreed upon by the US Army, the US Air Force, and the US Navy; official Department of Defense (DoD) forms are pending. Data are collated into the registry, evaluated, and reported by the JTS.

Recommended Methods and Technology

The process to document emergency trauma care can be used on either the immature or mature battlefield. This would entail utilizing paper or computer-assisted electronic technology, respectively. In the ideal environment, this would be a single-step

process. Reality is much different. It is important to recognize that documentation should occur across the chain of care and evacuation, whereas aggregation of data should occur at the first level of care that can support such activity. At a minimum, paper



RESUSCITATION RECORD
Part I, Nursing Flow Sheet

1. PATIENT INFORMATION

1.1 TRAUMA TEAM DATA

Service	Time Called	Time Arrived	Name
ED Physician			
Trauma Surgeon			
Respiratory Therapy			
Anesthesiology			
Lab/Blood Bank			
Radiology			
Pharmacy			
Consult (i.e., Ortho)			

1.2 ARRIVAL
Date
Time of Arrival
Time of Injury
Date of Injury
Transit Time minutes

1.3 EVAC FROM
☐ 1st Responder
☐ Forward Resuscitative Care
☐ Theater Hospital
Location

1.4 MODE OF ARRIVAL
☐ Walked/Carried
☐ CASEVAC - Air
☐ CASEVAC - Ground
☐ MEDEVAC - Air
Mission #
☐ MEDEVAC - Ground
Mission #
☐ CCATT
☐ Ship EVAC
☐ AE
☐ Other

1.5 INJURY TYPE
☐ Blunt
☐ Burn
☐ Penetrating

1.6 INJURY CLASSIFICATION
☐ Battle
☐ Non-Battle
☐ Unknown

1.7 TRIAGE CATEGORY
☐ Immediate
☐ Delayed
☐ Minimal
☐ Expectant

1.8 VALUABLES FOUND
☐ None
☐ Given to Patient
☐ Secured by PAD
Time

1.9 PATIENT CATEGORY
☐ USA
☐ USAF
☐ USMC
☐ USN
☐ USCG
☐ USPHS
☐ Civilian - Local
☐ Civilian - Other
☐ Contractor
☐ EPW
☐ NATO - Coalition
☐ Non-NATO - Coalition
☐ Other

1.10 INJURY CAUSE
☐ Building Collapse
☐ Bullet/GSW/Firearm
☐ Burn
☐ EFP
☐ Fall
☐ Fire/Flame
☐ IED
☐ Inhalation Injury
☐ Mine
☐ Mortar/Rocket/Artillery Shell
☐ Multi-Frag
☐ MVC
☐ Sports
☐ UXO
☐ Other

2. CARE DONE PRIOR TO ARRIVAL

2.1 PREHOSPITAL TOURNIQUET

Upper Extremities:
Type:
☐ CAT ☐ SOFTT
☐ Other
Time On ____ Off ____
☐ R How many? ☐ 1 ☐ 2 ☐ 3 ☐ 4
Effective? ☐ Y ☐ N
☐ L How many? ☐ 1 ☐ 2 ☐ 3 ☐ 4
Effective? ☐ Y ☐ N

Lower Extremities:
Type:
☐ CAT ☐ SOFTT
☐ Other
Time On ____ Off ____
☐ R How many? ☐ 1 ☐ 2 ☐ 3 ☐ 4
Effective? ☐ Y ☐ N
☐ L How many? ☐ 1 ☐ 2 ☐ 3 ☐ 4
Effective? ☐ Y ☐ N

2.2 PREHOSPITAL VITALS
GCS
Eye ___/4
Verbal ___/5
Motor ___/6
Total ___/15
T
P
RR
BP ___/___
O2Sat

2.3 PREHOSPITAL HEMORRHAGE CONTROL MEASURES
☐ Celox
☐ ChitoFlex
☐ Combat Gauze
☐ Direct Pressure
☐ Field Dressing
☐ HemCon
☐ QuikClot
☐ None
☐ Unknown
☐ Other

2.4 PREHOSPITAL WARMING
☐ Blanket
☐ Body Bag
☐ HPMK
☐ Space Blanket
☐ Other

2.5 PREHOSPITAL MEDS

2.6 PREHOSPITAL INTERVENTIONS
Prehospital Airway ☐ Y ☐ N
Intubated ☐ Y ☐ N
Cric ☐ Y ☐ N
Trach ☐ Y ☐ N
Needle Decompression ☐ Y ☐ N
C-spine Immobilized ☐ Y ☐ N
Pelvic Binder ☐ Y ☐ N
IO Infusions ☐ Y ☐ N
Eye Shield OS ☐ Y ☐ N
OD ☐ Y ☐ N
CPR prior to arrival ☐ Y ☐ N

3. PRIMARY SURVEY

3.1 VITALS
P
RR
BP ___/___
O2Sat
Pain Scale (0 - 10)

3.2 AIRWAY
☐ Patent
☐ Stridor
☐ Drooling
☐ Obstructed
☐ Oral/Nasal Airway
☐ BVM
☐ Intubated
☐ Combi Tube
☐ Other

3.3 HYPO / HYPERTHERMIA CONTROL MEASURES
Arrival Temp ___ ☐ F ☐ C
Time ___ Date ___
Route ☐ Oral ☐ Axillary ☐ Rectal
Temperature Control Procedure:
☐ Bair Hugger ☐ Warming Blanket
☐ Fluid Warmer ☐ Cooling Blanket
☐ Other

3.4 CPR IN ED
☐ Y ☐ N
Start Time
End Time

3.5 BREATHING
☐ Unlabored
☐ Labored
☐ Flaring
☐ Retraction
☐ Absent
Breath Sounds:
Clear ☐ R ☐ L
Rales ☐ R ☐ L
Wheeze ☐ R ☐ L
Absent ☐ R ☐ L
Chest Symmetry:
☐ Equal ☐ Left > ☐ Right >
Flail ☐ R ☐ L
Trachea:
☐ Midline
☐ Deviated

3.6 CIRCULATION
Skin:
☐ Warm ☐ Cool ☐ Hot
☐ Pink ☐ Pale ☐ Cyanotic
☐ Dry ☐ Moist ☐ Diaphoretic
Heart Sounds:
☐ Clear ☐ Muffled
Capillary Refill:
☐ < 2 Seconds (normal)
☐ > 2 Seconds (delayed)

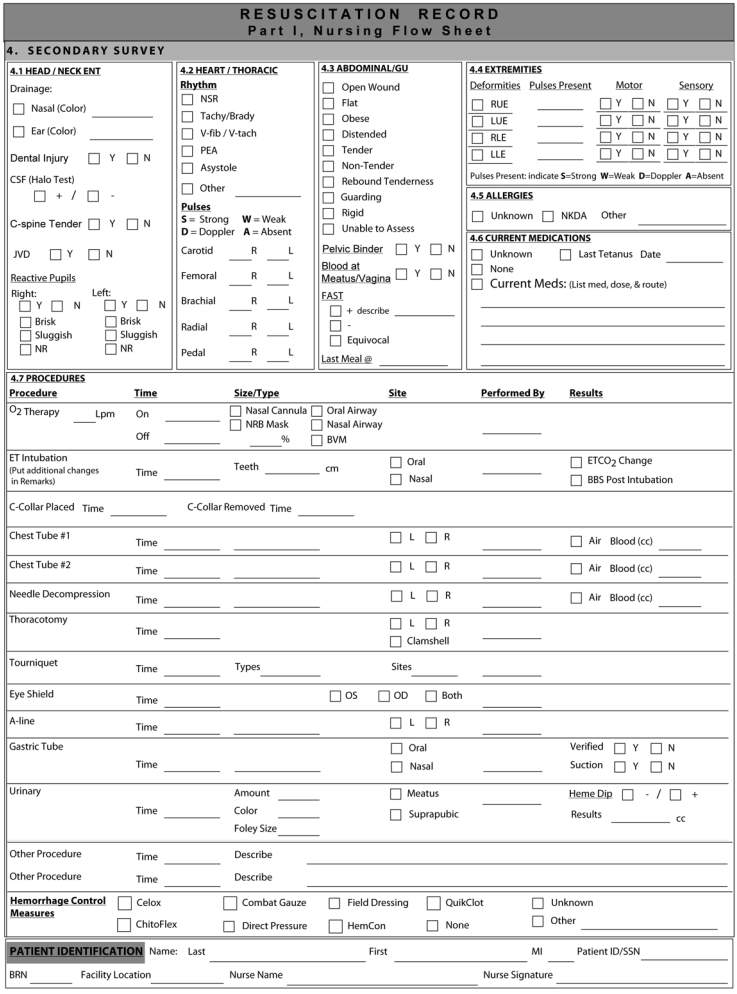
3.7 DEFICIT / NEURO
☐ Alert - Obeys Commands
☐ Responds to Verbal Stimuli
☐ Responds to Painful Stimuli
☐ Unresponsive to Painful Stimuli
GCS:
Eye ___/4
Verbal ___/5
Motor ___/6
Total ___/15
Pediatric Broselow Tape Color:

PATIENT IDENTIFICATION
Name: Last First MI Rank
Patient ID/SSN BRN Medical Record # DOB Age Gender ☐ M ☐ F
Facility Name Facility Location MOS/AFSC/NEC Deployed/Assigned Unit
Nurse Name Nurse Signature

Resuscitation Record *continues*

Fig. A3-1. Sample resuscitation record.

documentation should be used for each casualty, and the chart should accompany the patient to the rear as evacuation occurs. When effective electronic records are available, this process will be expedited and simplified.Bis doleceped ex et qui am untiati blab inis untior rest arum exerspi catquat eossi que volor mintis



RESUSCITATION RECORD
Part I, Nursing Flow Sheet

4. SECONDARY SURVEY

4.1 HEAD / NECK ENT

Drainage:
☐ Nasal (Color) _____
☐ Ear (Color) _____

Dental Injury ☐ Y ☐ N

CSF (Halo Test)
☐ + / ☐ -

C-spine Tender ☐ Y ☐ N

JVD ☐ Y ☐ N

Reactive Pupils

Right:	Left:
☐ Y ☐ N	☐ Y ☐ N
☐ Brisk	☐ Brisk
☐ Sluggish	☐ Sluggish
☐ NR	☐ NR

4.2 HEART / THORACIC

Rhythm
☐ NSR
☐ Tachy/Brady
☐ V-fib / V-tach
☐ PEA
☐ Asystole
☐ Other _____

Pulses
S = Strong **W** = Weak
D = Doppler **A** = Absent

Carotid	R	L
Femoral	R	L
Brachial	R	L
Radial	R	L
Pedal	R	L

4.3 ABDOMINAL/GU

☐ Open Wound
☐ Flat
☐ Obese
☐ Distended
☐ Tender
☐ Non-Tender
☐ Rebound Tenderness
☐ Guarding
☐ Rigid
☐ Unable to Assess

Pelvic Binder ☐ Y ☐ N

Blood at Meatus/Vagina ☐ Y ☐ N

FAST
☐ + describe _____
☐ -
☐ Equivocal

Last Meal @ _____

4.4 EXTREMITIES

Deformities	Pulses Present	Motor		Sensory	
☐ RUE	_____	☐ Y	☐ N	☐ Y	☐ N
☐ LUE	_____	☐ Y	☐ N	☐ Y	☐ N
☐ RLE	_____	☐ Y	☐ N	☐ Y	☐ N
☐ LLE	_____	☐ Y	☐ N	☐ Y	☐ N

Pulses Present: indicate **S**=Strong **W**=Weak **D**=Doppler **A**=Absent

4.5 ALLERGIES

☐ Unknown ☐ NKDA Other _____

4.6 CURRENT MEDICATIONS

☐ Unknown ☐ Last Tetanus Date _____
☐ None
☐ Current Meds: (List med, dose, & route)

4.7 PROCEDURES

Procedure	Time	Size/Type	Site	Performed By	Results
O_2 Therapy ___Lpm	On _____	☐ Nasal Cannula ☐ Oral Airway ☐ NRB Mask ☐ Nasal Airway ____% ☐ BVM		_____	
	Off _____				
ET Intubation (Put additional changes in Remarks)	Time _____	Teeth _____ cm	☐ Oral ☐ Nasal	_____	☐ $ETCO_2$ Change ☐ BBS Post Intubation
C-Collar Placed Time _____		C-Collar Removed Time _____			
Chest Tube #1	Time _____	_____	☐ L ☐ R	_____	☐ Air Blood (cc) _____
Chest Tube #2	Time _____	_____	☐ L ☐ R	_____	☐ Air Blood (cc) _____
Needle Decompression	Time _____	_____	☐ L ☐ R	_____	☐ Air Blood (cc) _____
Thoracotomy	Time _____		☐ L ☐ R ☐ Clamshell	_____	
Tourniquet	Time _____	Types _____	Sites _____	_____	
Eye Shield	Time _____		☐ OS ☐ OD ☐ Both	_____	
A-line	Time _____	_____	☐ L ☐ R	_____	
Gastric Tube	Time _____	_____	☐ Oral ☐ Nasal	_____	Verified ☐ Y ☐ N Suction ☐ Y ☐ N
Urinary	Time _____	Amount _____ Color _____ Foley Size _____	☐ Meatus ☐ Suprapubic	_____	Heme Dip ☐ - / ☐ + Results _____ cc
Other Procedure	Time _____	Describe _____			
Other Procedure	Time _____	Describe _____			

Hemorrhage Control Measures
☐ Celox ☐ Combat Gauze ☐ Field Dressing ☐ QuikClot ☐ Unknown
☐ ChitoFlex ☐ Direct Pressure ☐ HemCon ☐ None ☐ Other _____

PATIENT IDENTIFICATION Name: Last _____ First _____ MI ____ Patient ID/SSN _____

BRN _____ Facility Location _____ Nurse Name _____ Nurse Signature _____

Resuscitation Record *continues*

RESUSCITATION RECORD
Part I, Nursing Flow Sheet

4. SECONDARY SURVEY, continued

4.8 INTUBATION MECH/VENT

Time
MODE:
FiO_2:
RATE:
PEEP:
TV:

4.9 ABGs / VBGs

	Time	FiO_2	pH	pCO_2	pO_2	BE	HCO_3	SAT
☐ ABG or ☐ VBG								
☐ ABG or ☐ VBG								
☐ ABG or ☐ VBG								
☐ ABG or ☐ VBG								
☐ ABG or ☐ VBG								

4.10 INTRAVENOUS ACCESS AND FLUIDS

Time	Rate	Gauge	Site	IVF Type	Amount Up	Amount In	Stop

Total Amount Infused:

4.11 BLOOD PRODUCTS

Unit #	Type	Start	Stop	Volume	Initials

4.12 MEDICATIONS

Drug	Dose	Route	Time	Initials

4.13 VITAL SIGNS

Time	GCS	BP	P	RR	Temp	SaO_2	Pain Scale (0-10)	Other (ICP)

4.14 LABS

Time Test
_____ CBC
_____ ABG
_____ VBG
_____ Chemistry
_____ PT/PTT
_____ TEG
_____ H&H
_____ INR
_____ T&S
_____ T&C x ____
_____ UA
_____ HCG
_____ Other
Specify Other: _____

4.15 CT

Type Time
☐ Head
☐ C-Spine
☐ Chest
☐ Abd
☐ Pelvis
☐ Pan Scan*

* Select Pan Scan only if all of the above requested

4.16 X-RAY

Type Time
☐ C-Spine
☐ Chest
☐ Abd
☐ Pelvis
☐ Ext
☐ RUE ☐ LUE
☐ RLE ☐ LLE

4.17 DISPOSITION

Date:
Time:

Admit
☐ OR ☐ ICU ☐ ICW

RTD
☐ Full ☐ Quarters ☐ Profile
☐ RTD Unit:

RTD Mode of Transport:
☐ Ambulatory ☐ W/C

Evac to ☐ Host Nation ☐ Coalition ☐ CASF
Facility Name:

Evac Priority ☐ Routine ☐ Priority ☐ Urgent

Evac Transport Vehicle
MEDEVAC: ☐ Rotary Wing - ☐ MedTech ☐ Critical Care
☐ Fixed Wing - ☐ AE ☐ CCATT
Ground: ☐ Medical ☐ Non-Medical

Evac Mode of Transport ☐ Ambulatory ☐ W/C
☐ Litter ☐ Vacuum Spine Board

4.18 DEATH INFORMATION

Time of Death _____ Mortuary Affairs Notified? ☐ Y ☐ N Time to Morgue _____

Death Remarks _____

4.19 REMARKS

PATIENT IDENTIFICATION Name: Last _____ First _____ MI ____ Patient ID/SSN _____

BRN _____ Facility Location _____ Nurse Name _____ Nurse Signature _____

Resuscitation Record *continues*

RESUSCITATION RECORD
Part II, Physician H&P

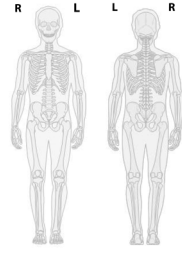
1. HISTORY & PHYSICAL - INJURY DESCRIPTION

1.1 ARRIVAL
Date _____
Time of Arrival _____

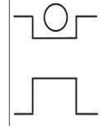
1.2 TRIAGE CATEGORY
☐ Immediate
☐ Delayed
☐ Minimal
☐ Expectant

1.3 CHIEF COMPLAINT, HISTORY AND PRESENTING ILLNESS

1.4 INJURY DESCRIPTION
(**AB**)rasion
(**AMP**)utation
(**AV**)ulsion
(**BL**)eeding
(**B**)urn %TBSA_____
(**C**)repitus
(**D**)eformity
(**DG**)Degloving
(**E**)cchymosis
(**FX**)Fracture
(**F**)oreign Body
(**GSW**)Gun Shot Wound
(**H**)ematoma
(**LAC**)eration
(**PW**)Puncture Wound
(**SS**)Seatbelt Sign
(**SW**)Stab Wound
(**P**)ain
(**PP**)Peppering



Pulses Present
S= Strong
W= Weak
D= Doppler
A=Absent



1.5 HISTORY AND PHYSICAL

Head & Neck :

Chest:

Abdomen/Back and Spine:

Pelvis: ☐ Stable ☐ Unstable ☐ Binder

Upper Extremities:

Lower Extremities:

Interventions Prior to Arrival:

1.6 PRE / INITIAL PROCEDURES / DIAGNOSTICS

Pre / Initial
☐ ☐ Cric
☐ ☐ ICP Monitor
☐ ☐ Ventric

Pre / Initial
☐ ☐ C-Collar/ Time Removed _____
☐ ☐ Cantholysis & Canthotomy ☐ R ☐ L
☐ ☐ Tympanic Membranes Rupture ☐ R ☐ L
Blood ☐ R ☐ L
☐ ☐ Eye Shield ☐ R ☐ L

Needle Decompression ☐ R ☐ L
Output ☐ Air Blood (cc) _____
Pericardial FAST ☐ - / ☐ + describe: _____
☐ Pericardiocentesis

DPL ☐ Gross Blood: ☐ - / ☐ + describe _____
Log Roll Time _____
Back Exam ☐ WNL ☐ ABNL describe _____
Rectal Exam ☐ WNL ☐ Weak/Absent Tone Gross Blood: ☐ - /☐ +

Prostate _____
Gyn _____

☐ Closed Reduction ☐ EXT Fixation ☐ Tourniquet ☐ R # _____ ☐ L # _____
☐ Wound Washout ☐ Splint

☐ Closed Reduction ☐ EXT Fixation ☐ Tourniquet ☐ R # _____ ☐ L # _____
☐ Wound Washout ☐ Splint

☐ Sedated ☐ 3% Saline ☐ Cntrl Line Loc _____ Site _____
☐ Chemical Paralyze ☐ Mannitol ☐ IO Loc _____ Site _____
☐ Seizure Protocol ☐ A-Line Loc _____ Site _____

1.7 PUPILS / VISION

Brisk	☐ R ☐ L	Hand Motion	☐ R ☐ L		
Sluggish	☐ R ☐ L	Light Perception	☐ R ☐ L		
NR	☐ R ☐ L	No Light Perception	☐ R ☐ L		

Size Right mm _____ Left mm _____

1.8 BURN
☐ 1st ☐ 2nd ☐ 3rd
%TBSA _____
>20% Use the Burn Flow Sheet
Cause _____

1.9 EXTREMITIES

	Motor	Sens	ROM
RUE	+ ____ / - ____	+ ____ / - ____	+ ____ / - ____
LUE	+ ____ / - ____	+ ____ / - ____	+ ____ / - ____
RLE	+ ____ / - ____	+ ____ / - ____	+ ____ / - ____
LLE	+ ____ / - ____	+ ____ / - ____	+ ____ / - ____

PATIENT IDENTIFICATION Name: Last _____ First _____ MI _____ Rank _____
Patient ID/SSN _____ BRN _____ Medical Record # _____ DOB _____ Age _____ Gender ☐ M ☐ F
Facility Name _____ Facility Location _____ Physician Signature _____

Resuscitation Record *continues*

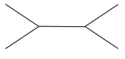
RESUSCITATION RECORD
Part II, Physician H&P

2. X-RAYS and CT

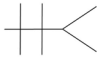
2.1 CT OBTAINED	2.2 X-RAYS OBTAINED	2.3 PENDING STUDIES	2.4 RESULTS (include TEG/Rotem results)	2.5 C-SPINE RESULTS
☐ Head ☐ C-Spine ☐ Chest ☐ Abd/Pelvis ☐ Pan Scan* * Select Pan Scan only if all of the above requested	☐ C-Spine ☐ Extremity ☐ Spine ☐ RUE ☐ Chest/Upright ☐ LUE ☐ Pelvis ☐ RLE ☐ LLE Other _____ Other _____			☐ CT Scan Normal ☐ CT Scan Abnormal C-Spine cleared based on: ☐ Normal exam, reliable Pt ☐ Normal CT scan, normal exam C-Spine not cleared based on: ☐ Neuro c/o, abnormal exam ☐ Abnormal imaging ☐ Unreliable Pt

3. LABORATORY RESULTS

3.1 CBC



3.2 CHEMISTRY 7



3.3 PT / INR / PTT _____ / _____ / _____

3.4 LFT

Amylase _____ Bili _____
Alk Phos _____ SGOT _____
LDH _____ SGPT _____
Other _____

3.5 URINALYSIS

SpGr _____ Chem _____
Micro _____ HCG _____
pH _____ Bact _____
WBC _____ RBC _____

4. IMPRESSION

5. DIAGNOSES

1	4
2	5
3	6

6. PLAN

6.1 PLAN

6.2 TRIAD INDICATORS UPON ARRIVAL IN ED

Temp < 96F/36C ☐ Yes ☐ No INR >1.4 ☐ Yes ☐ No Base Deficit >5 ☐ Yes ☐ No FWB Requested ☐ Yes ☐ No Damage Control ☐ Yes ☐ No

6.3 DISPOSITION ☐ OR ☐ ICU ☐ ICW ☐ Transfer Date: _____ Time: _____

7. DNBI / NBI CATEGORY

☐ Injury, Sports ☐ Injury, Work/Training ☐ Surgical ☐ _____
☐ Injury, MVC ☐ Injury, Other ☐ _____

8. CAUSE OF DEATH

8.1 ANATOMIC

☐ Airway ☐ Neck ☐ Abdomen ☐ Extremity ☐ U / ☐ L
☐ Head ☐ Chest ☐ Pelvis ☐ Other, Specify _____

8.2 PHYSIOLOGIC

☐ MOF ☐ Sepsis ☐ Total Body Disruption
☐ CNS ☐ Hemorrhage ☐ Breathing
☐ Other, Specify _____

PATIENT IDENTIFICATION Name: Last _____ First _____ MI ____ Patient ID/SSN _____

BRN _____ Facility Location _____ Physician Name _____ Physician Signature _____

Abbreviations and Acronyms

A

ABC: airway, breathing, circulation
ABCA: America, Britain, Canada, Australia
Abd: abdomen
ABD: autologous blood donation
ABG: arterial blood gas
A/C: assist/control
AC: hydrogen cyanide
ACE: angiotensin-converting enzyme
ACLS: Advanced Cardiac Life Support
ACS: abdominal compartment syndrome
ADH: antidiuretic hormone
ADMIN: administrative personnel
AE: aeromedical evacuation
AELT: Aeromedical Evacuation Liaison Team
AF: US Air Force
AFB: Air Force Base
AFI: Air Force Instruction
AFJI: Air Force Joint Instruction
AFP: Department of the Air Force pamphlet
AFRICOM: Africa Command
AIR EVAC: air evacuation
ALI: acute lung injury
amps: ampules
AMS: acute mountain sickness
AOR: area of responsibility
AP: anteroposterior
aPLTs: apheresis platelets
AR: Army Regulation
ARDS: acute respiratory distress syndrome
ARDSNet: Acute Respiratory Distress Syndrome Network
ARF: acute renal failure
ARG: Amphibious Ready Group
ASAP: as soon as possible
ASF: Aeromedical Staging Facility
ATLS: Advanced Trauma Life Support
ATN: acute tubular necrosis
ATNAA: Antidote Treatment Nerve Agent Autoinjector

B

BICEPS: Brief-Immediate-Central-Expectant-Proximal-Simple
bid/BID: twice a day
B.I.G.: Bone Injection Gun
BL: bladder
BP: blood pressure
bpm: beats per minute; breaths per minute
BSD: blood support detachment
BUN: blood urea nitrogen
BURP: Backward Upward Rightward Pressure
BW: biological warfare
BZ: benzodiazepine; 3-quinuclidinyl benzilate

C

Cal: caliber
CAR: cabin altitude restriction
CASEVAC: casualty evacuation
Cath: catheter
CBF: cerebral blood flow
CCATT: Critical Care Air Transportation (or Transport) Team
CENTCOM: US Central Command
CFR: case fatality rate
CG: phosgene
CHF: congestive heart failure
CK: creatinine phosphokinase; cyanogen chloride
CK_T: creatinine kinase
CNS: central nervous system
C.O.: cardiac output
CO_2: carbon dioxide
COCOM: Combatant Command
CONUS: continental United States
COPD: chronic obstructive pulmonary disease
CoTCCC: Committee on Tactical Combat Casualty Care
CPAP: continuous positive airway pressure
CPDA-1: citrate-phosphate-dextrose-adenine
CPG: Clinical Practice Guideline(s)
CPK: creatinine phosphokinase
CPP: cerebral perfusion pressure
CPR: cardiopulmonary resuscitation

CPS: Chief of Professional Services
CrCl: creatinine clearance
Cre/Cr: creatinine
CRNA: Certified Registered Nurse Anesthetist
CRTS: Casualty Receiving and Treatment Ship
CRVAP: combat-related ventilator-associated pneumonia
CSF: cerebrospinal fluid
CSH: Combat Support Hospital
C-spine: cervical spine
CSW: cerebral salt wasting
CT: computed tomography
CTA: computed tomography angiography/angiogram
CVA: cerebrovascular accident
CVN: this is a ship's hull classification symbol; C = aircraft carrier, V = fixed wing, N = nuclear powered
CX: phosgene oxide
CXR: chest X-ray

D
D5: 5% dextrose
D5NS: 5% dextrose in normal saline
D5W: 5% dextrose in water
D5½NS: 5% dextrose in ½ normal saline solution
DA: Department of the Army
DA PAM: Department of the Army pamphlet
Dbili: direct bilirubin
DBP: diastolic blood pressure
DCCS: Deputy Commander for Clinical Services
DCN: Deputy Commander of Nursing
DCS: damage control surgery
DD Form: Department of Defense Form
DD Form 572: Blood Donation Record
DDAVP: 1-deamino-8-D-arginine vasopressin (or Desmopressin)
Ddx: differential diagnosis
DECON: decontamination
DIC: diffuse/disseminated intravascular coagulation
DIN: donation identification number
DKA: diabetic ketoacidosis

DO_2: oxygen delivery
DOB: date of birth
DoD: Department of Defense
DoDTR: Department of Defense Trauma Registry
DOW: died of wounds
DP: diphosgene
DPA: diagnostic peritoneal aspiration
DSN: Defense Switched Network
DVA: Department of Veterans Affairs
DVT: deep venous thrombosis

E
EAC: Echelon Above Corps (or echelon of care)
EBL: estimated blood loss
ECFV: extracellular fluid volume
ECG: electroencephalogram
ECHO: echocardiogram
ED: Emergency Department
EDTA: ethylenediaminetetraacetic acid
EKG: electrocardiogram
ELISA: enzyme-linked immunosorbent assay
EMEDS: Expeditionary Medical Support
EMT: Emergency Medical Technician
ENT: ear-nose-throat
EOD: explosive ordnance disposal
ePTFE: expanded polytetrafluoroethylene
EPW: enemy prisoner of war
ER: emergency room
ERC: en route care
ERG: Expeditionary Ready Group
ET: endotracheal
ETT: endotracheal tube
EUCOM: European Command

F
FAST: Focused Abdominal Sonography for Trauma
FDA: Food and Drug Administration
FeNa: fractional excretion of sodium
FFP: fresh frozen plasma

FiO_2: fraction of inspired oxygen; inspired oxygen
FM: field manual
FMC: full metal case
Fr: French gauge
FS: Flight Surgeon
FST: Forward Surgical Team
FWB: fresh whole blood

G
GA: tabun
GB: sarin
GCS: Glasgow Coma Scale
GD: soman
GF: cyclosarinor cyclohexyl sarin
GI: gastrointestinal
GOS: Glasgow Outcomes Score
GPW: Geneva Convention Relative to the Treatment of Prisoners of War
gr: grains
GSW: gunshot wound
gtt: drops (from the Latin *guttae*)
GWS: Geneva Convention for the Amelioration of the Wounded and Sick in Armed Forces in the Field

H
H_2O: water
HACE: high-altitude cerebral edema
HAPE: high-altitude pulmonary edema
HBsAg: hepatitis B surface antigen
HBV: hepatitis B virus
HCV: hepatitis C virus
HD/H: sulfur mustard
HEAT: high explosive antitank
Hgb: hemoglobin
H/H: hematocrit/hemoglobin
HHS: hyperglycemic hyperosmolar syndrome
HIDA: hepatobiliary iminodiacetic acid
HIPAA: Health Insurance Portability and Accountability Act
HIT: heparin-induced thrombocytopenia

HIV: human immunodeficiency virus
HN: nitrogen mustard
HR: heart rate
HTS: hypertonic saline
HUB: Hospital Unit–Base
HUS: Hospital Unit–Surgical

I
iCa: hypocalcemia
ICFV: intracellular fluid volume
ICP: intracranial pressure
ICU: intensive care unit
ICW: intermediate care ward
I:E: inspiration:expiration
IED: improvised explosive device
IM: intramuscular
IMA: inferior maxillary artery
IMV: intermittent mandatory ventilation
INR: International Normalized Ratio
IO: intraosseous
I&O: intake and output
ISBT: International Society of Blood Transfusion
IV: intravenous
IVC: inferior vena cava
IVV: intravascular volume

J
JP: Jackson-Pratt
JTS: Joint Trauma System
JTTR: Joint Theater Trauma Registry
JTTS: Joint Theater Trauma System

K
K: clot time; potassium
KCl: potassium chloride
KIA: killed in action
KUB: kidneys, ureters, bladder (a frontal supine radiograph)
K-wires: Kirschner wires

L
L: Lewisite
LA: left atrium
LAT: lateral
LD: lethal dose
LHA: label for a Tarawa class ship
LHD: landing helicopter deck
LMA: laryngeal mask airway
LR: lactated Ringer's
LUQ: left upper quadrant
LV: left ventricle
LZ: landing zone

M
MA: maximal amplitude
MAC: minimal alveolar concentration
MAP: mean arterial pressure
MCO: Marine Corps Order
meds: medicine
MEDEVAC: medical evacuation
MEF: Marine Expeditionary Force
MESS: Mangled Extremity Severity Score
MF2K: Medical Force 2000
MFST: Mobile Field Surgical Team
MH: medium half
MMF: maxillary-mandibular fixation
MOPP: Mission-Oriented Protective Posture
MRI: magnetic resonance imaging
MRSA: methicillin-resistant *Staphylococcus aureus*
MTF: medical treatment facility
MVA: motor vehicle accident
MvO_2: mixed venous oxygen delivery

N
N_2O: nitrous oxide
N/A: not applicable
Na: sodium
NaCl: sodium chloride
$NaHCO_3$: sodium bicarbonate

NATO: North Atlantic Treaty Organization
NAVMED P: Department of the Navy publication
NBC: nuclear, biological, and chemical
NCO: noncommissioned officer
NG: nasogastric
NHLBI: National Heart, Lung, and Blood Institute
NIH: National Institutes of Health
NIPR: Nonsecure Internet Protocol Router
NOE: naso-orbital-ethmoid
NP: neuropsychiatric
NPO: nothing by mouth
NPWT: negative pressure wound therapy
NS: normal saline
NSAIDs: nonsteroidal antiinflammatory drugs
NSTEMI: non-ST elevation myocardial infarction

O

O_2: oxygen
OB/GYN: obstetrics/gynecology
OCONUS: outside the contiguous United States
ODD: once daily dosing
OEF: Operation Enduring Freedom
OET: oxygen economizer tube
OIF: Operation Iraqi Freedom
OPNAVINST: Office of the Chief of Naval Operations Instruction
OR: operating room

P

PA: Physician's Assistant; pulmonary artery; posteroanterior
$PaCO_2$: partial arterial gas pressure (tension) of carbon dioxide
PACOM: Pacific Command
2-PAMC: pralidoxime chloride
PaO_2: partial pressure of oxygen in the blood or in arterial blood
PBW: predicted body weight
PCWP: pulmonary capillary wedge pressure
pCXR: portable chest X-ray
PE: pulmonary embolism

PEEP: positive end-expiratory pressure
PHTLS: Pre-Hospital Trauma Life Support
PI: performance improvement
PM: preventive medicine; Program Manager
PMMA: poly(methyl methacrylate)
PMRC: Patient Movement Requirements Center
PNT: penetrating neck trauma
po/PO: per os (by mouth)
post-op: postoperative
Pplat: plateau pressure
PR interval: measured from the beginning of the P wave to the beginning of the QRS complex
PRBCs: packed red blood cells
PRN: as needed
PS: pressure support; chloropicrin
PSI: pounds per square inch
PvO_2: mixed venous oxygen tension

Q

q4h: every 4 hours
q6h: every 6 hours
q8h: every 8 hours
q12h: every 12 hours
qd: every day
qhs: at bedtime
qid/QID: 4 times a day
QRS complex: combination of three graphical deflections on an electrocardiogram; represents ventricular depolarization
QT interval: measure of time between start of Q wave and end of T wave

R

R: reaction time; radius/radial
R4: right patient, right place, right time, right care
RA: regional anesthesia; right atrium
RBC: red blood cell
RDD: radiological dispersal device
REBOA: resuscitative endovascular balloon occlusion of the aorta
Resus: resuscitation

rFVIIa: recombinant factor VIIa
RN: Registered Nurse
RPG: rocket-propelled grenade
rpm: revolutions per minute
RPR: Rapid Plasma Reagin
RR: respiratory rate
RSDL: Reactive Skin Decontamination Lotion
RSI: Rapid Sequence Intubation
RTD: return to duty
RUQ: right upper quadrant
RV: right ventricle

S

SaO_2: percentage of oxygen saturation of hemoglobin
SBP: systolic blood pressure
SCH: subconjunctival hemorrhage
SCre: serum creatinine
$ScvO_2$: central venous oxygen saturation
SEAL: SEa, Air, Land
SG: Surgeon General
SH: small half
Sharps: refers to sharp objects, such as needles, scalpel blades, disposable scissors, stylets, trocars, broken test tubes, glass, etc.
SIMV: synchronized intermittent mandatory ventilation
SNa: serum sodium
SOD: Surgeon of the Day
SOP: standard operating procedure
SPEARR: Small Portable Expeditionary Aeromedical Rapid Response (team)
SpO_2: noninvasive pulse oximetry
spp.: species
SSN: Social Security Number
STANAG: Standardization Agreement
STEMI: ST elevation myocardial infarction
STRATEVAC: strategic evacuation
ST segment: connects the QRS complex and the T wave
SV: stroke volume
SvO_2: mixed venous oxygen saturation of hemoglobin

T
TA: thoracoabdominal (stapler)
TBI: traumatic brain injury
Tbili: total bilirubin
TBSA: total body surface area
TCCC: Tactical Combat Casualty Care
TEG: thromboelastogram
TFC: tactical field care
THAM: tromethamine
tid/TID: three times a day
TMD: Theater Medical Director or Trauma Medical Director
TMDS: Theater Medical Data Store
TNC: Trauma Nurse Coordinator
TO: Theater of Operations
TOW: tube-launched, optically tracked, wire-guided (missile)
trach collar: tracheostomy collar
TRALI: transfusion-related acute lung injury
TTP: thrombotic thrombocytopenic purpura

U
U: ulnar/units
UCre: urine creatinine
UNa: urine sodium
UOP: urine output
UPAC: Universal Portable Anesthesia Complete
US: United States; ultrasound
USAF: US Air Force
USAISR: US Army Institute of Surgical Research
USMC: US Marine Corps
USNS: US Navy ship
USTRANSCOM: US Transportation Command
UV: ultraviolet
UXO: unexploded ordnance

V
VAC: Vacuum-Assisted Closure
VAP: ventilator-associated pneumonia
VCO_2: carbon dioxide production
Vd: deadspace volume

Ve: minute volume
VEE: Venezuelan equine encephalitis
Vel: velocity
VHF: viral hemorrhagic fever
VO_2: oxygen uptake
VRE: vancomycin-resistant enterococci
V_T: tidal volume
VX: methylphosphonothioic acid

W
WDMET: Wound Data and Munitions Effectiveness Team
WIA: wounded in action
Wt: weight

Product Manufacturers

Alcon Laboratories, Inc, Fort Worth, TX—Mydriacyl, Cyclogyl

Allergan, Inc, Irvine, CA—Ocuflox

Ambu, Cambridgeshire, UK — Ambu E-valve, Ambu bag

Ambu, Inc, Glen Burnie, MD — Ambu bag

Applied Science, Inc, Grass Valley, CA — HemoFlow

Arizant Healthcare, Inc, Eden Prairie, MN — Bair Hugger

Baxter Healthcare, Deerfield, IL – Plasma-Lyte A

Bayer HealthCare LLC, Morristown, NJ — Neo-Synephrine

Blizzard Protection Systems Ltd, Bethesda, Gwynedd, UK — Blizzard Survival Blanket

Block Scientific, Inc, Bohemia, NY — i-STAT Blood Gas Analyzer

Bovie Medical Corporation, Clearwater, FL — Bovie cauterizer

Bristol-Myers Squibb, New York, NY – Plavix

Cardinal Health, Dublin, OH — Frepp/Sepp Antiseptic Applicator Kit, Jamshidi disposable sternal/iliac aspiration needle, Esmark bandages

CareFusion, Leawood, KS — Iodine Sepp

Centocor, Malvern, PA – Reteplase

CERTEC, Sourcieux-les-Mines, France—CERTEC SA bag

Codman, Raynham, MA — ICP Monitoring System, ICP Express

Cook Critical Care, Bloomington, IN — Cook IO needle, Sur-Fast needle

Cook Medical, Bloomington, IN — Bakri balloon

Covidien, Mansfield, MA — Dexon, KERLIX, Hi-Lo Tracheal Tube

Draeger Medical, Inc, Telford, PA — Fabius Tiro M

DRE, Inc, Louisville, KY — Drager Narkomed anesthesia machine

E. I. duPont de Nemours and Company, Wilmington, DE — Kevlar

Electra House, Crewe, UK — Celox

Ethicon, Inc, Somerville, NJ — Surgicel, PDS sutures, Monocryl, Prolene, Vicryl

GE Healthcare, Laurel, MD — Ohmeda Universal Portable Anesthesia Complete

Glaxo Wellcome, Greenford, UK – Zofran

Healthcare Services, Mineral Wells, TX; Waismed Ltd/PerSys Medical, Houston, TX — Bone Injection Gun

Hospira, Inc, Lake Forest, IL — Hextend (hetastarch)

Impact Instrumentation, Inc, West Caldwell, NJ — Impact 754 Eagle Uni-Vent Ventilator

Intersurgical, Wokingham, Berkshire, UK – i-gel

Invista, Wichita, KS — Dacron

JHP Pharmaceuticals, Rochester, MI – Pitocin

Johnson & Johnson, New Brunswick, NJ — Tylenol, Polysporin

Kinetic Concepts, Inc/KCI Licensing, Inc, San Antonio, TX — Wound VAC Therapy System

LMA North America, Inc, San Diego, CA — Fastrach Laryngeal Mask

McNeil Healthcare, Inc, Waterford, CT — Kittner sponge

Medline, Northfield, IL – Chitogauze

Med TechSweden, Inc, Geneseo, IL — Vacuum Spine Board

MedTrade Products, Crewe, UK – Celox Gauze

Mölnlycke Health Care US, LLC, Norcross, GA — Hibiclens

Novartis Pharma, Stein, Switzerland – Lopressor

Ortho-Clinical Diagnostics, Inc, Rochester, NY — RhoGAM

Pall Corporation, Port Washington, NY — Pall Heat and Moisture Exchange Filter

Pfizer, New York, NY– Diamox, Cytotec, Gelfoam, Prostin, Zosyn

PMC, Sunnyvale, CA — Adaptec

Portable Hyperbarics, Inc, Ilion, NY — Garnow bag

Purdue Pharma, Stamford, CT —Betadine surgical scrub

PyngMedical, Richmond, British Columbia, Canada — FAST1

Reichert, Buffalo, NY – Tono-pen

Sanofi-Aventis, Laval, Quebec, Canada – Kayexalate, Lasix, Lovenox

Smith & Nephew, Andover, MA – OpSite

SmithKline Beecham, Brentford, UK –Ancef

SonoSite, Inc, Bothell, WA — SonoSite duplex ultrasound device

TECHStyles, Addison, TX — TECHStyles Thermo-Lite Hypothermia Prevention System

TechTrade LLC, New York, NY — Ready-Heat self-warming medical blanket

Terumo Medical Products, Somerset, NJ — VENOJECT Luer Adapter, Luer Adapter Hub, Terumo single blood bag

Thermogear, Inc, Lake Oswego, OR; Microtek Medical, Columbus, MS — ChillBuster

3M Company, St Paul, MN — Ioban, ACE wrap, Coban self-adherent wrap, Tegaderm

TraumaCure, Inc, Bethesda, MD — WoundStat

Verathon, Inc, Bothell, WA — GlideScope Ranger

Vida-Care, San Antonio, TX — EZ-IO device

West-Ward Pharmaceuticals, Eatontown, NJ — Robinul

W. L. Gore & Associates, Inc, Elkton, MD — PTFE, GORE-TEX

Z-Medica Corporation, Wallingford, CT — QuikClot Combat Gauze

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