Chapter 1

Weapons Effects
and Parachute Injuries

Just as with any medical topic, surgeons must understand the pathophysiology of war wounds in order to best care for the patient.

Treat the wound, not the weapon.

Epidemiology of Injuries

- Weapons of conventional war can be divided into explosive munitions and small arms.
  - Explosive munitions: artillery, grenades, mortars, bombs, and hand grenades.
  - Small arms: pistols, rifles, and machine guns.
- Two major prospective epidemiological studies were conducted during the 20th century looking at the cause of injury as well as outcome.
  - During the Bougainville campaign of World War II, a medical team was sent prospectively 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 collected by the Wound Data and Munitions Effectiveness Team (WDMET) in Vietnam.

US Casualties, Bougainville Campaign (WW II) and Vietnam

<table>
<thead>
<tr>
<th>Weapon</th>
<th>Bougainville %</th>
<th>Vietnam %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bullet</td>
<td>33.3</td>
<td>30</td>
</tr>
<tr>
<td>Mortar</td>
<td>38.8</td>
<td>19</td>
</tr>
<tr>
<td>Artillery</td>
<td>10.9</td>
<td>3</td>
</tr>
<tr>
<td>Grenade</td>
<td>12.5</td>
<td>11</td>
</tr>
<tr>
<td>Land mine/booby trap</td>
<td>1.9</td>
<td>17</td>
</tr>
<tr>
<td>RPG (rocket propelled grenade)</td>
<td>—</td>
<td>12</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>2.6</td>
<td>—</td>
</tr>
</tbody>
</table>
The most common pattern of injury seen on a conventional battlefield is the patient with multiple small fragment wounds of the extremity.

**Anatomical Distribution of Penetrating Wounds (%)**

<table>
<thead>
<tr>
<th>Conflict</th>
<th>Head and Neck</th>
<th>Thorax</th>
<th>Abdomen</th>
<th>Limbs</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>World War I</td>
<td>17</td>
<td>4</td>
<td>2</td>
<td>70</td>
<td>7</td>
</tr>
<tr>
<td>World War II</td>
<td>4</td>
<td>8</td>
<td>4</td>
<td>75</td>
<td>9</td>
</tr>
<tr>
<td>Korean War</td>
<td>17</td>
<td>7</td>
<td>7</td>
<td>67</td>
<td>2</td>
</tr>
<tr>
<td>Vietnam War</td>
<td>14</td>
<td>7</td>
<td>5</td>
<td>74</td>
<td>—</td>
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<tr>
<td>Northern Ireland</td>
<td>20</td>
<td>15</td>
<td>15</td>
<td>50</td>
<td>—</td>
</tr>
<tr>
<td>Falkland Islands</td>
<td>16</td>
<td>15</td>
<td>10</td>
<td>59</td>
<td>—</td>
</tr>
<tr>
<td>Gulf War (UK) **</td>
<td>6</td>
<td>12</td>
<td>11</td>
<td>71</td>
<td>(32)*</td>
</tr>
<tr>
<td>Gulf War (US)</td>
<td>11</td>
<td>8</td>
<td>7</td>
<td>56</td>
<td>18+</td>
</tr>
<tr>
<td>Afghanistan (US)</td>
<td>16</td>
<td>12</td>
<td>11</td>
<td>61</td>
<td>—</td>
</tr>
<tr>
<td>Chechnya (Russia)</td>
<td>24</td>
<td>9</td>
<td>4</td>
<td>63</td>
<td>—</td>
</tr>
<tr>
<td>Somalia</td>
<td>20</td>
<td>8</td>
<td>5</td>
<td>65</td>
<td>2</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>15</strong></td>
<td><strong>9.5</strong></td>
<td><strong>7.4</strong></td>
<td><strong>64.6</strong></td>
<td><strong>3.5</strong></td>
</tr>
</tbody>
</table>

* Buttock and back wounds and multiple fragment injuries, not included
+ Multiple wounds
** 80% caused by fragments; range of hits 1–45, mean of 9

**Mechanism of Injury**
- For missile injuries, there are two areas of projectile-tissue interaction, permanent cavity and temporary cavity (Fig. 1-1).

![Fig. 1-1](image.png)

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

1.2
- 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, such as skeletal muscle, blood vessels and skin, may be pushed aside after passage of the projectile, but then rebound. Inelastic tissue, such as bone or liver, may fracture in this area.

- The shock (or sonic) wave (commonly mistaken for the temporary cavity), though measurable, has **not** been shown to cause damage in tissue.

Explosive munitions have three mechanisms of injury (Fig. 1-2):

![Fig. 1-2. The probability of sustaining a given trauma is related to the distance from the epicenter of the detonation.](image)

- Ballistic.
  - Fragments from explosive munitions cause ballistic injuries.
  - Fragments are most commonly produced by mortars, artillery, and grenades.
  - Fragments produced by these weapons vary in size, shape, composition, and initial velocity. They may vary from a few milligrams to several grams in weight.
  - Modern explosive devices are designed to spread more uniform fragments in a regular pattern over a given area.
Emergency War Surgery

- Fragments from exploding munitions are smaller and irregularly shaped when compared to bullets from small arms.
- Although initial fragment velocities of 5,900 ft/s (1,800 m/s) have been reported for some of these devices, the wounds observed in survivors indicate that striking velocities were less than 1,900 ft/s (600 m/s). Unlike small arms, explosive munitions cause multiple wounds.

- Blast (see Fig. 1-2).
  - The blast effects take place relatively close to the exploding munition relative to the ballistic injury.
  - Blast overpressure waves, or sonic shock waves, are clinically important when a patient is close to the exploding munition, such as a land mine.
  - The ears are most often affected by the overpressure, followed by lungs and the gastrointestinal (GI) tract hollow organs. GI injuries may present 24 hours later.
  - Injury from blast overpressure is a pressure and time dependent function. By increasing the pressure or its duration, the severity of injury will also increase.
  - Thermobaric devices work by increasing the duration of a blast wave to maximize this mechanism of injury. 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 such as a bunker.
  - Air displaced on the site after the explosion creates a blast wind that can throw victims against solid objects, causing blunt trauma.

- Thermal.
  - Thermal effects occur as the product of combustion when the device explodes. Patients wounded near exploding munitions may have burns in addition to open wounds, which may complicate the management of soft tissue injuries.
<table>
<thead>
<tr>
<th>Misconception</th>
<th>Reality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased velocity causes increased tissue damage.</td>
<td>Velocity is one factor in wounding. An increase in velocity does not per se increase the amount of tissue damage. The amount of tissue damage in the first 12 cm of a M-16A1 bullet wound profile has relatively little soft tissue disruption, similar to that of a .22 long rifle bullet, which has less than half the velocity.</td>
</tr>
<tr>
<td>Projectiles yaw in flight, which can create irregular wounds.</td>
<td>Unless a projectile hits an intermediate target, the amount of yaw in flight is insignificant. This is untrue and has no bearing on surgical care.</td>
</tr>
<tr>
<td>Exit wounds are always greater than entrance wounds.</td>
<td>The M-193 bullet of the M-16A1 rifle reliably fragments at the level of the cannulure after traversing about 12 cm of tissue in soft tissue only.</td>
</tr>
<tr>
<td>Full metal-jacketed bullets do not fragment, except in unusual circumstances.</td>
<td>Elastic soft tissue (skeletal muscle, blood vessels, and nerves) generally heals uneventfully and does not require excision, provided the blood supply remains intact. Temporary cavity effects are analogous to blunt trauma.</td>
</tr>
<tr>
<td>All projectile tracts must be fully explored, due to the effects of the temporary cavity.</td>
<td></td>
</tr>
</tbody>
</table>
Antipersonnel Landmines

- There are three types of conventional antipersonnel landmines available 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 two major areas of injury (Fig. 1-3).
  - **Bounding** mines propel a small explosive device to about 1–2 m of height and then explode, causing multiple small fragment wounds to those standing nearby. These landmine casualties have the highest reported mortality.

Fig. 1-3. Mechanisms of injuries caused by antipersonnel land mines.

- Partial or complete traumatic amputation, most commonly at the midfoot or distal tibia.
- More proximally, debris and other tissue is driven up along fascial planes with tissue stripped from the bone.
- Factors influencing the degree of injury include size and shape of the limb, point of contact with the foot, amount of debris overlying the mine, and the type of footwear.
- **Horizontal spray** mines propel fragments in one direction. This land mine can be command-detonated or detonated by tripwire. The US Claymore mine fires about 700 steel spheres of \( \frac{3}{4} \) g each over a 60° arc. Horizontal spray mines produce multiple small-fragment wounds to those nearby.

- An unconventional weapon (improvised explosive device, or IED) is a fourth type of antipersonnel landmine. Either another piece of ordnance is used, such as a grenade or a mortar shell, or the device is completely fabricated out of locally available materials.

### 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.
- Below are some examples of the characteristics of commonly encountered firearms seen throughout the world. The illustrations are of the entire path of missiles fired consistently at 5–10 m in range into ordnance gelatin tissue-simulant blocks. Variations of range, intermediate targets such as body armor, and body tissue will alter the wound seen.

- The AK-47 rifle is one of the most common weapons seen throughout the world. For this particular bullet (full metal jacketed or ball) there is a 25 cm path of relatively minimal tissue disruption before the projectile begins to yaw. This explains why relatively minimal tissue disruption may be seen with some wounds (Fig. 1-4).

![Fig. 1-4. Idealized path of tissue disruption caused by an AK-47 projectile, (10% gelatin as a simulation).](image-url)
The AK-74 rifle was an attempt to create a smaller caliber 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-16A1 rifle fires a 55-grain full metal-jacketed bullet (M-193) 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 cannalure (a groove placed around the mid section of the bullet). The slightly heavier M-855 bullet used with the M-16A2 rifle, shows a similar pattern to the M-193 bullet (Fig. 1-5).

The 7.62 mm NATO 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. 1-6).
Armored Vehicle Crew Casualties

- Since the first large scale use of tanks during WWI, injuries to those associated with armored vehicles in battle have been a distinct subset of combat casualties.
- Tanks, infantry fighting vehicles, armored personnel carriers, armored support vehicles, and “light armored vehicles.”
  - Light armored vehicles tend to use wheels rather than tracks for moving and have lighter armor. The main advantage for these vehicles is to allow for greater mobility.

Compared to infantry, injuries to those inside or around armored vehicles are characterized by:
- Decreased overall frequency.
- Increased severity of injury and mortality (up to 50%).
- Increased incidence of burns and traumatic amputations.

- There are three main types of antiarmor weapons on the battlefield today.
  - **Shaped charge** (Fig. 1-7a).
    - 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 RPG.
Fig. 1-7. (a) Disruptive mechanisms of the shaped-charge warhead, (b) diagram taken from photograph of an actual detonation of shaped-charged warhead against armor plate caused by antitank land mines.

♦ Shaped charges range in diameter from the 85 mm RPG-7 to the 6-in diameter tube launched, optically tracked, wire guided (TOW) missile.

♦ If the armor is defeated by the shaped charge, there are two areas of behind-armor debris.
  ◊ First, there is the jet of the shaped charge itself. This may cause catastrophic wounds to soldiers who are hit, or it may ignite fuel, ammunition, or hydraulic fluid.
  ◊ There is a second type of debris, 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 of the compartment (Fig. 1-7b).

♦ Kinetic energy round.
  ◇ The kinetic energy (KE) round contains an aerodynamically shaped piece of hard metal (such as 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 should. There is a hypothetical risk, over years, that casualties with retained depleted uranium fragments may develop heavy metal poisoning. This concern by itself does not justify extensive operations to remove such fragments during initial wound surgery.
Injuries to those inside a vehicle are due 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.**
  - Blast mines are those with a large explosive filler of 4–5 kg. Injuries are often from blunt trauma due to crewmembers being thrown around inside the vehicle after it detonates the mine.
  - Closed fractures of the upper and lower extremities and spine are common (Fig. 1-8).
  - A modification of the shaped charge is the Mizonay-Schardin antitank mine that creates a projectile or large metal slug to cause damage to the vehicle. This is less likely than a conventionally shaped charge to be broken up by intermediate targets.

![Fig. 1-8. Distribution of fracture sites sustained within an armored vehicle that had detonated a land mine (Soviet data from Afghanistan, early 1980s).]
**Mechanisms of Injury** (Fig. 1-9)

- **Ballistic** injuries take place as the result of defeated armor as described above.

![Fig. 1-9. Injuries sustained as a result of defeated armor, (a) translational blast injury, (b) toxic gases, (c) blast overpressure, (d) penetrating missile wounds.](image)

- **Thermal.** Burns occur because of ignited fuel, ammunition, hydraulic fluid, or as the direct result of the antiarmor device.
  - Two large studies, one from British WWII tank crewmen and one from Israeli casualties in Lebanon, showed that about $\frac{1}{3}$ of living wounded casualties have burns.
The severity of burns range from a mild 1st degree burn to full thickness burns requiring skin coverage. Most burns are superficial burns to exposed skin, most often of the face, neck, forearms, and hands. These are often combined with multiple fragment wounds.

- **Blast overpressure** occurs from the explosion occurring inside a confined space. One study from WWII showed 31% of armored crewmen casualties had ear injury due to blast overpressure, including ruptured tympanic membranes.

- **Toxic Fumes** are secondary to phosgene-like combustion byproducts in Teflon coated interiors of armored vehicles (antispall liners).
  - HCL is produced at the mucous membrane.
  - Treatment is supportive and may require IV steroids (1,000 mg methylprednisolone, single dose).
  - Surgical triage considerations. Emergent if pulmonary edema, expectant if hypotensive and cyanotic. Reevaluate nonemergent patients q 2 h.

- **Blunt Trauma** is due to acceleration mechanisms.

### Unexploded Ordnance (UXO)

- UXOs are embedded in the casualty without exploding.
  - Rockets, grenades, mortar rounds.
  - Some UXO must travel a distance (50–70 m) in order to arm.
  - Fuses are triggered by different stimuli (impact, electromagnetic, laser).

- **Notify explosive ordnance disposal immediately!**
- 31/31 victims lived after removal (from recent review).
- The casualty should be triaged as nonemergent, placed far from others, and operated on last.
- Preplan for how to handle both transport and operation.
  - Transport.
    - If by helicopter, ground the casualty to the aircraft (there is a large electrostatic charge from rotors).
  - Move into safe area.
    - Revetment, parking lot, or back of building.
  - Operate in safe area, not in main OR area.

- Operative management.
  - Precautions for surgeon and staff.
Emergency War Surgery

- Sandbag operative area, use flak vests and eye protection.
  - Avoid triggering stimuli.
  - Electromagnetic (no defibrillator, monitors, Bovie cauteterizer, blood warmers, or ultrasound or CT machines).
  - Metal to metal.
  - Plain radiography is safe. It helps identify the type of ammunition.
- Anesthesia.
  - Regional/spinal/local preferred.
  - Keep oxygen out of OR.
  - 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 to explosive ordnance disposal (EOD) personnel for disposal.

**Parachute Injuries**

- Dependent on several factors: **Weather** (wind), **day/night**, drop zone hazards/terrain, low **drop altitude**, and **level of opposition** (enemy resistance) at the drop zone.
- Caused by improper aircraft exit, parachute malfunction, hazards (including enemy) on descent or in the landing zone, entanglements, or an improper parachute landing fall (PLF).
- Peacetime rate of injuries is 0.8%.
- Combat injury **rate** is historically higher (subject to above listed factors).
  - As high as 30% overall.
  - Majority of injuries are minor.
  - 8% to 10% of total jumpers are rendered either combat ineffective or significantly limited.
### Weapons Effects and Parachute Injuries

<table>
<thead>
<tr>
<th>Injury Site/Type</th>
<th>%</th>
<th>Injury Site/Type</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle</td>
<td>20</td>
<td>Sprain/Strains</td>
<td>37.7</td>
</tr>
<tr>
<td>Back</td>
<td>11.1</td>
<td>Contusions</td>
<td>30.1</td>
</tr>
<tr>
<td>Knee</td>
<td>10.7</td>
<td>Lacerations</td>
<td>14.7</td>
</tr>
<tr>
<td>Head/Neck</td>
<td>8.7</td>
<td>Closed Fractures</td>
<td>11.1</td>
</tr>
<tr>
<td>Leg</td>
<td>8.3</td>
<td>Concussions</td>
<td>2.0</td>
</tr>
<tr>
<td>Open Fractures</td>
<td>2.0</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

- Fractures result in a higher percentage of removal from combat.

Fractures of the calcaneus are associated with fractures of the axial skeleton (10%). Patients should be placed on spinal precautions until such injuries are ruled out.
1.16 Emergency War Surgery
Military doctrine supports an integrated health services support system to triage, treat, evacuate, and return soldiers to duty in the most time efficient manner. It begins with the soldier on the battlefield and ends in hospitals located within the continental United States (CONUS). Care begins with first aid (self-aid/buddy aid, and combat lifesaver), rapidly progresses through emergency medical care (EMT) and advanced trauma management (ATM) to stabilizing surgery, and is followed by critical care transport to a level where more sophisticated treatment can be rendered.

There are five levels of care (also known as “roles”), previously referred to as echelons by NATO and ABCA (USA, Britain, Canada, Australia) countries. Levels should not to be confused with American College of Surgeons use of the term in US trauma centers. Different levels denote differences in capability, rather than the quality of care. Each level has the capability of the level forward of it and expands on that capability. Soldiers with minor injuries can be returned to duty after simple treatments at forward locations, all others are prepared for evacuation with medical care while en route to a higher level.

Level I
- Immediate first aid delivered at the scene.
  - First aid and immediate life-saving measures provided by self-aid, buddy aid, or a combat lifesaver (nonmedical team/squad member trained in enhanced first aid).
  - Care by the trauma specialist (91W) (combat medic), assigned to the medical platoon, trained as an Emergency Medical Technician-Basic (EMT-B). Some other primary
care providers, with various levels of training, include the Special Forces Medical Sergeant 18D, Special Operations Combat Medic 91W, SEAL Independent Duty Corpsman, Special Boat Corpsman, Pararescueman, and Special Operations Medical Technician.

- Initial treatment of nuclear, biological, and chemical casualties, treatment of toxic industrial material casualties, primary disease prevention, combat stress control measures, and nonbattle injury prevention.

- Level I medical treatment facility (MTF) (commonly referred to as the Battalion Aid Station [BAS]).
  - Provides triage, treatment, and evacuation.
  - Physician, Physician Assistant (PA), and medics.
  - Return to duty, or stabilize and evacuate to the next level.
  - Can be chem/bio protected.
  - No surgical or patient holding capability.

  - Small forward unit supports the Marine Expeditionary Force (MEF).
  - Stabilization and collecting/clearing companies.
  - 2 physicians.
  - No surgical capability.
  - Patient holding time limited to 3 hours.

Level II

- Increased medical capability and limited inpatient bed space.
- Includes basic primary care, optometry, combat operational stress control and mental health, dental, laboratory, surgical (when augmented) and X-ray capability.

- 100% mobile.
- Each service has a slightly different unit at this level.

- Army.
  - Level II MTFs operated by the treatment platoon of divisional/nondivisional medical companies/troops.
    - Basic/emergency treatment is continued.
    - Packed RBCs (Type 0, Rh positive and negative), limited X-ray, laboratory, and dental.
    - 20–40 cots with 72-hour holding.
- Can be chem/bio protected.
- No surgical capability.

**Forward Surgical Team (FST).**
- Continuous operations for up to 72 hours.
- Life-saving resuscitative surgery, including general, orthopedic, and limited neurosurgical procedures.
- 20-person team with 1 orthopedic and 3 general surgeons, 2 nurse anesthetists, critical care nurses and technicians.
- The supporting medical company must provide logistical support and security. (Doctrinally, the FST is collocated with a Medical Company.)
- ~1,000 sq ft surgical area.
- Can be chem/bio protected.
- Operational within 1 hour of arrival at the supported company.
- May be transported by ground, fixed wing, or helicopter; some fleet surgical teams (FSTs) are airborne deployable.
- 2 operating tables for a maximum of 10 cases per day and for a total of 30 operations within 72 hours.
- Post-op intensive care for up to 8 patients for up to 6 hours.
- X-ray, laboratory, and patient administrative support provided by the supporting medical company.
- Requires additional electricity, water, and fuel from the supporting medical company.
- The FST is not designed, staffed, or equipped for stand alone operations or conducting sick-call operations. Augmentation requirements are discussed in FM 4-02.25.

**Air Force.**

- **Mobile Field Surgical Team (MFST).**
  - 5-person team (general surgeon, orthopedist, anesthetist, emergency medicine physician, and OR nurse/tech).
  - 10 life/limb saving procedures in 24–48 hours from five backpacks (350 lb total gear).
  - Designed to augment an aid station or flight line clinic.
  - Not stand alone, requires water, shelter of opportunity, communications, among other things.
Emergency War Surgery

- Integral to remainder of Air Force (AF) Theater Hospital System.
  - **Small Portable Expeditionary Aeromedical Rapid Response (SPEARR) team.**
    - 10-person team: 5-person MFST, 3-person CCATT (see Chapter 4, Aeromedical Evacuation) and a 2-person preventive medicine (PM) team (flight surgeon, public health officer).
    - Stand alone capable for 7 days, 600 sq ft tent.
    - 10 life/limb saving procedures in 24–48 hours.
    - Designed to provide surgical support, basic primary care, post-op critical care, and PM for early phase of deployment.
    - Highly mobile unit, with all equipment fitting in a one-pallet–sized trailer.
  - **Expeditionary Medical Support (EMEDS) Basic.**
    - Medical and surgical support for an airbase, providing 24-hour sick call capability, resuscitative surgery, dental care, limited laboratory and X-ray capability.
    - 25 member staff includes SPEARR team.
    - 4 holding beds, 1 OR table, 3 climate controlled tents, and 3 pallets.
    - 10 life/limb saving procedures in 24–48 hours.
    - ~2,000 sq ft.
  - **EMEDS + 10.**
    - Adds 6 beds to EMEDS Basic, for total of 10.
    - No additional surgical capability.
    - 56-person staff.
    - 6 tents, 14 pallets.
    - Can be chemically hardened.

- Navy.
  - **Casualty Receiving & Treatment Ships (CRTS).** CRTSs are part of an Amphibious Ready Group (ARG) and usually comprise one landing helicopter assault or amphibious (LHA) Tarawa-class or landing helicopter deck (LHD) Wasp-class ship, which are Marine amphibious
assault helicopter carriers that function as casualty receiving platforms. An ARG includes up to 6 ships with surgical capability only on the CRTS.

- 47-48 beds, 4-6 ORs, 17 ICU beds.
- 300 additional medical care beds may be available once Marines disembark.
- Fleet Surgical Teams (FSTs): 3-4 physicians, 1 surgeon, 1 CRNA or anesthesiologist and support staff.
- Usually 2 general surgeons and 2 orthopedic surgeons. OMFS (oral maxillofacial surgery) support available through the dental department. Can be substantially augmented.
- Laboratory, X-ray.
- Excellent casualty flow capability (large helicopter flight deck and landing craft units [LCU] well deck).
- Mass casualty (MASCAL) capability with triage area for 50 casualties.
- Doctrinally, holding capability is limited to 3 days.

- **Aircraft Carrier (CVN) Battle Group.**
  - 1 OR, 40–60 beds, 3 ICU beds.
  - 1 surgeon, 5 other medical officers.
  - Up to 9 ships, but usually only the CVN has physicians. Medical assets aboard aircraft carriers are intended for use by the aircraft carrier and its task force. Aircraft carriers are NOT casualty receiving ships and are not figured into medical assets for support to ground forces.

- **USMC.**
  - **Surgical Company.**
    - Provides surgical care for a MEF (Marine Expeditionary Force). Basis of allocation is 1 per infantry regiment.
    - 3 ORs, 60-bed capability.
    - Patient holding time up to 72 hours.
    - Stabilizing surgical procedures.
  - **Forward Resuscitative Surgical System (FRSS).**
    - Embedded organically as part of the TO&E of the surgical company, if employed reduces the capability of its parent surgical company.
Emergency War Surgery

♦ Rapid assembly, highly mobile.
♦ Resuscitative surgery for 18 patients within 48 hours without resupply.
♦ 1 OR, 2 surgeons.
♦ No holding capability.
♦ No intrinsic evacuation capability.
♦ Chem/bio protected.
♦ Stand alone capable.

Level III
Represents the highest level of medical care available within the combat zone with the bulk of inpatient beds. Most deployable hospitals are modular, allowing the commander to tailor the medical response to expected or actual demand.

• Army.
  ♦ Two different Corps-level Combat Support Hospital (CSH) designs.
    ♦ Medical Force 2000 (MF2K) CSH.
    ♦ Medical Reengineering Initiative (MRI) CSH will replace the MF2K.
  ♦ Combat Support Hospital.
    ♦ MF2K CSH.
      ◊ Resuscitation, initial surgery, post-op care, and either return to duty or stabilize for further evacuation.
      ◊ Up to 296 patients, typically divided into 8 ICUs (96 ICU beds), and 7 Intermediate Care Wards (ICWs) (140 beds), 1 neuropsychiatric (NP) ward (20 beds), and 2 minimal care wards (40 beds).
      ◊ 175 officers, 429 enlisted; specialty attachments may increase numbers.
      ◊ Up to 8 OR tables for a maximum of 144 operating hours per day.
      ◊ General, orthopedic, urologic, neurosurgical, dental and oromaxillofacial surgery.
      ◊ Blood bank, laboratory, X-ray / computer tomography (CT); nutrition, physical therapy and NP capabilities.
      ◊ Dependent on a number of Corps support elements for personnel, finance, mortuary, legal, laundry,
security, and enemy prisoners of war (EPW) management, support.
◊ Transportation support required for both incoming and outgoing patient evacuation, and to transport the hospital.
◊ Transferred via semitrailer, railcar, air cargo, or ship.
◊ Fully deployed CSH (including motor pool, billeting, heliport, and other life support activities) covers 30.3 acres.
◊ Divided into modules, deployed as a single unit or separately as the mission dictates. The main modules are the Hospital Unit-Base (HUB) and the Hospital Unit-Surgical (HUS).

-**HUB** is the infrastructure of the CSH.
  - Up to 236 patients, divided into 36 ICU, 140 intermediate, 40 minimal, and 20 NP beds.
  - Two operating modules with specialty surgical care capability.
  - HQ, administrative, personnel, chaplain, laboratory, pharmacy, X-ray, and blood bank services.
  - Part of the HUB can be chem/bio protected (FM 4-02.7).

-**HUS** capabilities.
  - 60 ICU patients, 2 OR modules, X-ray.
  - Dependent on the HUB for all logistical support.
  - Can be deployed forward, separate from the HUB, for brief periods as the mission dictates.

-**MRI CSH (Corps).**
  - Provides hospitalization and outpatient services for all classes of patients in the theater, either returned to duty or stabilized for further evacuation.
  - Headquarters/headquarters detachment: 15 officers and 44 enlisted.
  - Up to 248 patients, typically divided into an 84-bed hospital company and a 164-bed hospital company, with split base operations capability.
Emergency War Surgery

♦ 84-bed hospital company.
  ◦ 24 ICU beds.
  ◦ Up to 2 OR tables, maximum of 36 operating hours per day.
  ◦ 3 ICWs (total 60 beds, including NP patients).
  ◦ 56 officers and 112 enlisted personnel.
    - Some patient care areas can be chem/bio protected.

♦ 164-bed hospital company.
  ◦ 24 ICU beds.
  ◦ Up to 4 OR tables, maximum of 60 operating hours per day.
  ◦ 7 ICWs (total 140 beds, including NP patients).
  ◦ 84 officers and 169 enlisted personnel.
    - Some patient care areas can be chem/bio protected.

♦ Applicable to 84-, 164-, and 248-bed (see CSH [Echelon of Care, EAC] below) hospital companies.
  ◦ General, orthopedic, urologic, thoracic, OB/GYN, neurosurgical, dental and oromaxillofacial surgery.
  ◦ Blood bank, laboratory, X-ray, nutrition, and physical therapy.
  ◦ Dependent on EAC support elements for personnel, finance, mortuary, legal, laundry services, security and EPW support.
  ◦ Parts can be chem/bio protected.
  ◦ Transportation support required for both incoming and outgoing patient evacuation, and to transport the hospital.
  ◦ Transported by semi-trailer, railcar, air cargo, or ship.
  ◦ Fully deployed, covers 5.7 acres.
  ◦ Minimal care wards are provided by an attached minimum care detachment.

• Air Force.
  o EMEDS +25.
    ♦ 25-bed version of EMEDS Basic.
    ♦ 84 personnel, 2 OR tables, 9 x 600 sq ft tents, and 20 pallets.
    ♦ 20 operations in 48 hours.
    ♦ Can be chemically hardened.
♦ Additional specialty modules can be added, including vascular/cardiothoracic, neurosurgery, OB/GYN, ear, nose and throat (ENT), ophthalmology teams; each comes with own personnel and equipment.

● Navy.
  o **Fleet Hospital.**
    ♦ 500-bed hospitals, 80 ICU beds, and 6 ORs.
    ♦ 1,000 personnel.
    ♦ Stand alone; full ancillary services.
    ♦ 8–10 days to be operational.
    ♦ Large footprint — 28 acres, 450 isolation (ISO) shelters.
    ♦ No limit on holding capability.
  o **Hospital Ships (TAH) — USNS Mercy and USNS Comfort.**
    ♦ 1,000 beds, 100-bed ICU capability, and 12 ORs.
    ♦ 1,000 staff, over 50 physicians.
    ♦ Extensive laboratory and X-ray capabilities.
    ♦ Patient holding is doctrinally limited to 5 days.

**Level IV**
● Definitive medical and surgical care outside the combat zone, yet within the communication zone/EAC of the theater of operations (TO).
● Patients requiring more intensive rehabilitation or special needs.
● Traditionally includes the MF2K Field Hospital (FH) and General Hospital (GH).
● In some situations, the MF2K CSH or a fixed hospital may act as a Level IV facility (eg, Landstuhl Army Regional Medical Center, Germany).
  o **Field Hospital.**
    ♦ Semipermanent hospital that provides primarily convalescent care.
    ♦ At least 2 OR tables for 24 OR hours per day.
    ♦ General, orthopedics, OB/GYN, urologic, oral surgery, and dental services.
    ♦ Up to 504 patients, with 2 ICUs (24 patients), 7 ICWs (140 patients), 1 NP ward (20 patients), 2 minimum care wards (40 patients), and 7 patient support sections (280 patients).
Emergency War Surgery

- **General Hospital.**
  - ♦ Usually a permanent or semipermanent facility.
  - ♦ At least 8 OR tables for 144 OR hours per day.
  - ♦ General, orthopedic, gynecologic, urologic, and oral surgery.
  - ♦ Dental and optometry services.
  - ♦ Outpatient specialty and primary care services.
  - ♦ Up to 476 patients, with 8 ICUs (96 patients), 16 ICWs (320 patients), 1 NP ward (20 patients), and 2 minimum care wards (40 patients).

The MRI CSH Echelon Above Corps (EAC) will replace the FH and GH.

- **CSH (EAC).**
  - o Headquarters/headquarters detachment: 17 officers and 33 enlisted.
  - o Cannot operate in a split-based mode like the CSH (Corps).
  - o 248-bed hospital company.
    - ♦ 4 ICUs (total 48 ICU beds), and 10 ICWs (total 200 beds, including NP patients). A specialty clinic section that can treat NP patients. Minimal care wards are provided by attached minimum care detachments.
    - ♦ 140 officers, 244 enlisted personnel.
    - ♦ Up to 6 OR tables for 96 operating hours per day.
    - ♦ Fully deployed (including motor pool, troop billeting, heliport, and other life support activities), covers 9.3 acres.
    - ♦ See other general characteristics under MRI CSH (Corps).

**Level V**

This level of care is provided in the CONUS. Hospitals in the CONUS sustaining base will provide the ultimate treatment capability for patients generated within the theater. Department of Defense (DoD) hospitals (military hospitals for the tri-service) and Department of Veterans Affairs (DVA) hospitals will be specifically designated to provide the soldier with maximum return to function through a combination of medical, surgical, rehabilitative, and convalescent care. Under the
Levels of Medical Care

National Disaster Medical System, patients overflowing DoD and DVA hospitals will be cared for in designated civilian hospitals.
2.12 Emergency War Surgery
Chapter 3

Triage

Introduction
Modern combat casualty evacuation has become so immediate and efficient that it can result in a mass casualty situation at military treatment facilities (MTFs) within the military medical care system. Consequently, a method of dealing with the conflicting factors of severity of injury, the tactical situation, the mission, and the resources available for treatment and evacuation is essential. Triage is an attempt to impose order during chaos and make an initially overwhelming situation manageable.

Triage is the dynamic process of sorting casualties to identify the priority of treatment and evacuation of the wounded, given the limitations of the current situation, the mission, and available resources (time, equipment, supplies, personnel, and evacuation capabilities).

Triage occurs at every level of care, starting with buddy and medic care, extending through the OR, the ICU, and the evacuation system.

The ultimate goals of combat medicine are the return of the greatest possible number of soldiers to combat and the preservation of life, limb, and eyesight in those who must be evacuated.

The decision to withhold care from a wounded soldier who in another less overwhelming situation might be salvaged, is difficult for any surgeon or medic. Decisions of this nature are infrequent, even in mass casualty situations. Nonetheless, this is the essence of military triage.
Triage Categories
It is anticipated that triage will be performed at many levels, ranging from the battlefield to the battalion aid station to the field hospital. Traditional categories of triage are Immediate, Delayed, Minimal, and Expectant. This classification scheme is useful for mass casualties involving both surgical and medical patients. An additional category of Urgent has been used to describe surgical patients who need an operation but can wait a few hours.

- **Immediate**: This group includes those soldiers requiring life-saving surgery. The surgical procedures in this category should not be time consuming and should concern only those patients with high chances of survival (e.g., respiratory obstruction, unstable casualties with chest or abdominal injuries, or emergency amputation).

- **Delayed**: This group includes those wounded who are badly in need of time-consuming surgery, but whose general condition permits delay in surgical treatment without unduly endangering life. Sustaining treatment will be required (e.g., stabilizing IV fluids, splinting, administration of antibiotics, catheterization, gastric decompression, and relief of pain). The types of injuries include large muscle wounds, fractures of major bones, intra-abdominal and/or thoracic wounds, and burns less than 50% of total body surface area (TBSA).

- **Minimal**: These casualties have relatively minor injuries (e.g., minor lacerations, abrasions, fractures of small bones, and minor burns) and can effectively care for themselves or can be helped by nonmedical personnel.

- **Expectant**: Casualties in this category have wounds that are so extensive that even if they were the sole casualty and had the benefit of optimal medical resource application, their survival would be unlikely. The expectant casualty should not be abandoned, but should be separated from the view of other casualties. Expectant casualties are unresponsive patients with penetrating head wounds, high spinal cord injuries, mutilating explosive wounds involving multiple anatomical sites and organs, second and third degree burns in excess of 60% TBSA, profound shock with multiple injuries, and agonal respiration. Using a minimal but competent staff, provide comfort measures for these casualties.
Alternative Triage Categories

In practice, however, the division of patients into these four categories is not useful for a surgical unit. The casualties should be divided into emergent, nonemergent, and expectant. These divisions are useful in dividing casualties into those requiring further surgical triage (emergent), and those that are less injured, still require care, but have little chance of dying (nonemergent). It is anticipated that 10%–20% of casualties presenting to a surgical unit will be in the emergent category, requiring urgent surgery. The vast majority of wounded will not require intensive decision-making, intervention, and care.

- **Emergent**: Although this category has been historically subdivided into **Immediate** (unstable and requiring attention within 15 minutes) and **Urgent** (temporarily stable but requiring care within a few hours), except in the most overwhelming circumstances, such division is rarely of practical significance. This group of wounded will require attention within minutes to several hours of arriving at the point of care to avoid death or major disability.
  - Types of wounds include:
    - Airway obstruction/compromise (actual or potential).
    - Uncontrolled bleeding.
    - Shock.
      - Systolic BP < 90 mm Hg.
      - Decreased mental status without head injury.
    - Unstable penetrating or blunt injuries of the trunk, neck, head, and pelvis.
    - Threatened loss of limb or eyesight.
    - Multiple long-bone fractures.

- **Nonemergent**: This category was historically divided between **Delayed** (would require intervention, however, could stand significant delay) and **Minimal**. This is the group of patients that, although injured and may require surgery, does not require the attention of the emergent group and lacks significant potential for loss of life, limb, or eyesight. Examples include:
  - Walking wounded.
  - Single long-bone fractures.
  - Closed fractures.
  - Soft tissue injuries without significant bleeding.
  - Facial fractures without airway compromise.
Emergency War Surgery

- **Expectant**: This group of wounded, *given the situation and resource constraints*, would be considered unsalvageable. Examples may include:
  - Any casualty arriving without vital signs or signs of life, regardless of mechanism of injury.
  - Transcranial gunshot wound (GSW).
  - Open pelvic injuries with uncontrolled bleeding; in shock, with decreased mental status.
  - Massive burns.

- **Special categories**: Patients who do not easily fit into the above categories and casualties who pose a risk to other casualties, the medics, and the treatment facility, may require special consideration:
  - **Wounded contaminated in a biological and/or a chemical battlefield environment**: The threat posed by these patients mandates decontamination prior to entering the treatment facility. Appropriately protected medical personnel may treat emergent casualties prior to decontamination.
  - **Retained, unexploded ordnance**: These patients should be segregated immediately. See Chapter 1, Weapons Effects and Parachute Injuries, which describes the special handling of these wounded.
  - **Enemy Prisoners of War (EPWs)/Internees**: Although treated the same as friendly casualties, it is essential that the threat of “suicide bombers” and “human booby traps” be prevented by carefully screening all EPWs prior to moving into patient areas, including the triage area. See Chapter 34, Care of Enemy Prisoners of War/Internees.

- **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 as 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 BICEPS mnemonic where resources/tactical situations allow.**

◊ **Brief:** Keep interventions to 3 days or less of rest, food, 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.

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**If battlefield casualties do not have physical injuries, DO NOT send them out of the battle area, as this will worsen stress reactions, and possibly start evacuation syndromes!**

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**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 procedure (“on-the-table triage”).**

---

**Resource Constraints**

Including all of the factors that influence triage decision making would be encyclopedic and of little benefit. Rather, a
framework for thinking about this process in a logical fashion is presented here.

**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 this time interval, expect the complexity of triage decisions to increase, especially sorting the worst emergent patients from the expectant. Longer intervals will result in the opposite, with “autotriage” of the sicker patients from the emergent to the expectant/dead on the battlefield category.
  - **Time spent with the individual casualty.** In a mass casualty situation, time itself is a resource that must be carefully triaged/husbanded. All patients receive an evaluation, but only some receive operative intervention. Time on the OR table is usually the choke point. Apply the concepts of damage control to minimize the time casualties spend in surgery. On-table triage to expectant may be necessary due to deteriorating casualty physiologic response and/or the pattern of injury (aorta-vena cava GSW, dual
exsanguination sites, extensive pancreatic-duodenal injury, and so forth).

♦ **Evacuation out.** Casualties must move expeditiously to the next echelon of care (EOC), otherwise valuable local resources will be consumed in maintaining patients, thereby preventing additional patients from receiving care.

♦ **Internal factors.** These issues are known to the surgeon/nurse/medic and should be factored into triage decisions.
  
  o **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.

  o **Space/Capability.** This category includes the number of OR tables and ICU beds: the holding capacity and ward capacity; and the available diagnostic equipment—ultrasound (US), X-ray, computed tomography (CT)—and laboratory tests. For example, if your MTF has the only CT scanner in theater, plan for an increased number of head-injured patients.

  o **Personnel.** This includes knowing the professional capability (type and experience of individual physician/nurse/medic), and the emotional stability, sleep status, and so forth, of your hospital 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.

  o **Stress.** Soldiers, including medical personnel, are affected by the consequences of war; individual and unit capability is 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. At the front line, the medic must make a decision about whether or not to evacuate patients from the battlefield and how fast. The following decision tree is an example of a triage tool that may be used in the field as an initial decision-making aid.

In the emergent treatment area, the surgeon 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, difficulty breathing (e.g., a casualty with normal mentation...
Triage

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

- The following data from the Vietnam War indicate the numerical distribution of diagnoses that were seen in the low-intensity light-infantry combat that characterized that war. Casualties from armored combat can be expected to have a higher prevalence of burns and multiple injuries. Of 100 injured in combat:
  - 30%—**Minor or superficial wounds** (minor burns, abrasions, intraocular foreign body, ruptured tympanic membrane/deafness).
  - 16%—**Open comminuted fractures of a long bone.** Several patients with multiple fractures and injuries to named nerves and blood vessels.
  - 10%—**Major soft tissue injury or burn** requiring general anesthesia for treatment. Several had an injury to major nerves.
  - 10%—**Had laparotomies,** two of which were negative, and several involved extensive, complicated procedures.
  - 6%—**Open comminuted fractures of hand, fingers, and feet.**
  - 5%—Required closed thoracostomy and had soft tissue wounds.
  - 4%—**Major multiple trauma.**
  - 3%—**Major amputations** (above the knee [AK], below the knee [BK], below the elbow [BE], above the elbow [AE]). In three out of four cases, the surgical procedure simply required completion of the amputation.
Emergency War Surgery

- 3%—Craniotomies. Two were for fragments and one for a depressed skull fracture.
- 3%—Vascular repair (one was to repair a femoral artery, and another involved named nerves or fractures).
- 3%—Major eye injuries, one involving enucleation.
- 2%—Minor amputations (toes, fingers, hand, foot).
- 2%—Maxillofacial reconstructions (one half were mandibular injuries, and most of the rest were maxillary).
- 1%—Formal thoracotomy.
- 1%—Neck exploration.
- 1%—“Miscellaneous.”

Data from more recent American combat operations in Iraq (OIF) and Afghanistan (OEF), 2003–2004, indicating the spectrum of injury type (Table 3-1), mechanism (Table 3-2), and anatomical location (Table 3-3) are found below.

### Table 3-1. Type of Injury.*

<table>
<thead>
<tr>
<th>Type of Injury</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetrating</td>
<td>645</td>
<td>35.7%</td>
</tr>
<tr>
<td>Blast</td>
<td>425</td>
<td>23.5%</td>
</tr>
<tr>
<td>Blunt</td>
<td>410</td>
<td>22.7%</td>
</tr>
<tr>
<td>Unknown</td>
<td>84</td>
<td>4.6%</td>
</tr>
<tr>
<td>Crush</td>
<td>63</td>
<td>3.5%</td>
</tr>
<tr>
<td>Mechanical</td>
<td>49</td>
<td>2.7%</td>
</tr>
<tr>
<td>Thermal</td>
<td>48</td>
<td>2.7%</td>
</tr>
<tr>
<td>Undetermined</td>
<td>21</td>
<td>1.2%</td>
</tr>
<tr>
<td>Other</td>
<td>16</td>
<td>0.9%</td>
</tr>
<tr>
<td>Chemical agent</td>
<td>10</td>
<td>0.6%</td>
</tr>
<tr>
<td>Bites/Stings</td>
<td>8</td>
<td>0.4%</td>
</tr>
<tr>
<td>Degloving</td>
<td>8</td>
<td>0.4%</td>
</tr>
<tr>
<td>Electrical</td>
<td>7</td>
<td>0.4%</td>
</tr>
<tr>
<td>Heat Injury</td>
<td>7</td>
<td>0.4%</td>
</tr>
<tr>
<td>Inhalation</td>
<td>3</td>
<td>0.2%</td>
</tr>
<tr>
<td>Multiple Penetration System</td>
<td>3</td>
<td>0.2%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1807</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

* A casualty may have more than one type of injury. These numbers are based on 1530 Level III casualties.
Triage

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, ensuring optimal pain control. The dead should

Table 3-2. Mechanism of Injury.

<table>
<thead>
<tr>
<th>Mechanism of Injury</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>IED</td>
<td>310</td>
<td>18.4%</td>
</tr>
<tr>
<td>MVA</td>
<td>207</td>
<td>12.3%</td>
</tr>
<tr>
<td>Gun Shot Wound (GSW)</td>
<td>188</td>
<td>11.1%</td>
</tr>
<tr>
<td>Grenade (includes RPG)</td>
<td>170</td>
<td>10.1%</td>
</tr>
<tr>
<td>Shrapnel/Fragment</td>
<td>141</td>
<td>8.3%</td>
</tr>
<tr>
<td>Unknown</td>
<td>119</td>
<td>7.0%</td>
</tr>
<tr>
<td>Machinery or Equipment</td>
<td>95</td>
<td>5.6%</td>
</tr>
<tr>
<td>Fall or Jump from height</td>
<td>90</td>
<td>5.3%</td>
</tr>
<tr>
<td>Mortar</td>
<td>84</td>
<td>5.0%</td>
</tr>
<tr>
<td>Burn</td>
<td>53</td>
<td>3.1%</td>
</tr>
<tr>
<td>Aggravated Range of Motion</td>
<td>31</td>
<td>1.8%</td>
</tr>
<tr>
<td>Landmine</td>
<td>29</td>
<td>1.7%</td>
</tr>
<tr>
<td>Other</td>
<td>27</td>
<td>1.6%</td>
</tr>
<tr>
<td>Knife or other sharp object</td>
<td>21</td>
<td>1.2%</td>
</tr>
<tr>
<td>Helicopter Crash</td>
<td>19</td>
<td>1.1%</td>
</tr>
<tr>
<td>Blunt object (eg, rock or bottle)</td>
<td>17</td>
<td>1.0%</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>16</td>
<td>0.9%</td>
</tr>
<tr>
<td>Free Falling Objects</td>
<td>14</td>
<td>0.8%</td>
</tr>
<tr>
<td>Bomb</td>
<td>12</td>
<td>0.7%</td>
</tr>
<tr>
<td>None</td>
<td>12</td>
<td>0.7%</td>
</tr>
<tr>
<td>UXO</td>
<td>10</td>
<td>0.6%</td>
</tr>
<tr>
<td>Environmental</td>
<td>9</td>
<td>0.5%</td>
</tr>
<tr>
<td>Exertion/overexertion</td>
<td>5</td>
<td>0.3%</td>
</tr>
<tr>
<td>Flying debris</td>
<td>5</td>
<td>0.3%</td>
</tr>
<tr>
<td>Building Collapse</td>
<td>2</td>
<td>0.1%</td>
</tr>
<tr>
<td>Hot Object/Substance</td>
<td>2</td>
<td>0.1%</td>
</tr>
<tr>
<td>Altercation, fight</td>
<td>1</td>
<td>0.1%</td>
</tr>
<tr>
<td>Total</td>
<td>1689</td>
<td>100%</td>
</tr>
</tbody>
</table>

* A casualty may have more than one mechanism of injury. These numbers are based on 1530 Level III casualties.
Emergency War Surgery

Table 3-3. Anatomical Location of Injury.*

<table>
<thead>
<tr>
<th>Anatomical Location</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple Sites</td>
<td>761</td>
<td>49.7%</td>
</tr>
<tr>
<td>Lower Extremity</td>
<td>248</td>
<td>16.2%</td>
</tr>
<tr>
<td>Upper Extremity</td>
<td>223</td>
<td>14.6%</td>
</tr>
<tr>
<td>Head/Face</td>
<td>174</td>
<td>11.4%</td>
</tr>
<tr>
<td>Thorax/Back</td>
<td>48</td>
<td>3.1%</td>
</tr>
<tr>
<td>Neck</td>
<td>20</td>
<td>1.3%</td>
</tr>
<tr>
<td>None</td>
<td>20</td>
<td>1.3%</td>
</tr>
<tr>
<td>Abdomen</td>
<td>16</td>
<td>1.0%</td>
</tr>
<tr>
<td>Unknown</td>
<td>9</td>
<td>0.6%</td>
</tr>
<tr>
<td>Buttock</td>
<td>6</td>
<td>0.4%</td>
</tr>
<tr>
<td>N/A</td>
<td>3</td>
<td>0.2%</td>
</tr>
<tr>
<td>Genitalia</td>
<td>1</td>
<td>0.1%</td>
</tr>
<tr>
<td>Soft Tissue</td>
<td>1</td>
<td>0.1%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1530</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

* Casualties with more than one injury location are included in ‘Multiple Sites’. These numbers are based on 1530 Level III casualties.

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.

- Qualities of an ideal initial triage area should include
  - **Proximity** to the receiving area for casualties—LZ, ground evacuation, 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.
  - **Well-lit, 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, 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 office.
  - Ideally, a surgeon experienced in dealing with combat trauma should be used in this capacity. Unfortunately, using a surgeon outside of the OR is a luxury that most small forward surgical units cannot afford.
  - It is essential that another person with clinical experience be trained to assume this function. Using mass casualty exercises or limited mass casualty situations is one way to train/identify the right person to fill this role in the absence of a surgeon.

- 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 3-person team to work.
      - Easy access in and out of bay.
      - Availability of equipment needed for ATLS style resuscitation (Fig. 3-1 a,b).

- Staffing.
  - Team leader: a surgeon serves as the surgical triage officer.
    - Responsible for determining priority for operative interventions.
    - Needs to identify patients that require early evacuation.
    - If a surgeon is unavailable, may be a physician who maintains close communication with the operating surgeons.
  - Administrative person. Responsible for recording flow of patients through unit.
Fig. 3-1a. Triage.
♦ Resuscitation team. A physician, nurse, and medical technician, ideally.
◊ Each individual treatment team will coordinate movement of its patient via the team leader.
ο Operation.
♦ Manpower team delivers patient.
Emergency War Surgery

- Team Leader retriages patient and assigns resuscitation team to patient.
- Resuscitation team treats patient and determines required disposition (surgery, ICU, ward, air evacuation).
- Resuscitation team communicates to Team Leader the recommended disposition.
- Team Leader 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 and several nurses and medical technicians can form the nucleus of the treatment team. Lacerations can be sutured, closed fractures splinted, IVs placed, and radiographs taken. The team leader should be alert to changing vital signs, mental status changes, and any failure to respond to appropriate treatment measures. 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. 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. These options (sister service, local national assistance, or local NATO assets) should be established prior to the mass casualty event.
- 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, and a new rotation must be established to sustain a modified but continuous effort. Once the press is over, personnel must be encouraged to rest rather than to socialize. Rest must be enforced because the entire scenario may recur at any time.

- Prior to an actual mass casualty situation, all deployable units should exercise a variety of triage scenarios to ensure smooth patient flow and identification. "Driving" litters without running into things can be difficult unless practiced! These scenarios should evaluate personnel, supplies, and equipment.

**Conclusion**

Small, highly mobile units, either Special Operations or conventional forces, are currently performing military operations around the globe. These units are usually supported by highly mobile, small footprint surgical elements that have limited diagnostic, operative, holding, and resupply capability. Evacuation may entail an extremely long transport from point of wounding to the forward surgery team, then another long transport directly to a Level IV/V. Air superiority may be in question, especially the use of helicopters for initial patient evacuation. In these situations the tactical, logistic, and physiologic integration of triage concepts becomes of paramount importance and needs to be considered and extensively discussed prior to arrival of the first casualty.
Emergency War Surgery
Chapter 4

Aeromedical Evacuation

Introduction
Evacuation of injured personnel using aircraft, fixed or rotary wing, 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. While 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): The movement of a casualty from the point of injury to medical treatment by nonmedical personnel. Casualties transported under these circumstances do not receive en route medical care; if the casualty’s medical condition deteriorates during transport, an adverse impact on the casualty’s prognosis and long-term disability may result. Traditionally, this situation involves a helicopter mission returning from the battlefield.

- Medical evacuation (MEDEVAC): 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 a ship to shore.

- Aeromedical evacuation (AE): Providing USAF fixed-wing intra-theater (Tactical Evacuation [TACEVAC]: from the combat zone to points outside the combat zone, and between points within the communications zone) and inter-theater (Strategic Evacuation [STRATEVAC]: from out of the theater
Emergency War Surgery

of operations to a main support area) movement of sick or injured personnel, with enroute care provided by AE crewmembers and critical care air transport teams (CCATTs), to locations offering appropriate levels of medical care.

- Enroute care: 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

<table>
<thead>
<tr>
<th>Medical Considerations/Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Medical evacuation request includes requirement for surgical equipment and/or providers.</td>
</tr>
<tr>
<td>• Patient is sufficiently stabilized for the anticipated mode and duration of travel.</td>
</tr>
<tr>
<td>• Patient’s airway and breathing is adequate for movement.</td>
</tr>
<tr>
<td>• Patient’s IV lines, drainage devices, and tubes are fully secured and patent.</td>
</tr>
<tr>
<td>• Patient at high risk for barotrauma should be considered for prophylactic chest tube placement before prolonged aeromedical evacuation.</td>
</tr>
<tr>
<td>• Heimlich valves on chest tubes are functioning.</td>
</tr>
<tr>
<td>• Foley catheters and nasogastric (NG) tubes are placed and allowed to drain.</td>
</tr>
<tr>
<td>• Patient is securely covered with both a woolen and aluminized blanket for air transport, cold environment, or postoperative hypothermia.</td>
</tr>
<tr>
<td>• 3 litter straps are used to secure the patient to the litter.</td>
</tr>
<tr>
<td>• Personal effects and all medical records accompany the patient.</td>
</tr>
</tbody>
</table>

- The evacuation of a patient is initiated by the surgeon according to established procedures. The support 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 (such
as flying in the pressurized cabin of an aircraft), patients entering the USAF AE system must also be validated for evacuation by the supporting flight surgeon.

- For patients evacuated from Level II MTFs or forward surgical teams (FST), the brigade surgeon (or designee) determines the evacuation precedence for all patients requiring evacuation from that facility. This is done in consultation with the forward surgical team’s chief surgeon and/or senior nurse. When a patient is readied for evacuation from the forward surgical team by USAF assets, the supporting patient movement requirements center (PMRC) should be established at the earliest possible time. This allows the PMRC sufficient time to coordinate airlift and patient movement items requirements.

Implications of Aviation Environment

- General Considerations Prior to Transport.
  - Due to altitude effects, limited mobility, decreased staffing enroute, and unpredictable evacuation times, the referring physician should tailor vital signs (VS) monitoring requirements, and frequency of wound and neurovascular checks.
  - Some therapies that might not be used in a fixed MTF are appropriate for AE.
    - For example, patients with significant medical or surgical conditions should have Foley catheters, NG tubes, provisions for IV pain medications, extended duration IV antibiotics.
  - Consider liberal use of fasciotomies/escharotomies.
  - Consider securing airway with prophylactic endotracheal (ETT) tube.
  - Wounds dressed for delayed primary closure. Unless directed otherwise, AE crew should not routinely re-dress wounds. If a patient develops fever or sepsis enroute, wounds must be inspected.
  - Casts must be bivalved. If the cast is over a surgical wound site, “window” the cast to allow for tissue expansion and emergency access. Document neurovascular checks prior to and frequently during flight.
Emergency War Surgery

- Decreased Barometric Pressure.
  - The diameter of a gas bubble in liquid doubles at 5,000 ft above sea level, doubles again at 8,000 ft, and doubles again at 18,000 ft. 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, with increased flight time and fuel.

- Consider a 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 required, even for small, asymptomatic lesions. A Heimlich valve or collection system must be in place prior to patient transfer to the flight line.

- Air Splints: Should not be used if alternate devices are available. Because air expands at altitude, air splints require close observation and adjustments during flight.

- 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 ft, 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.

- Gravitational 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 rearward 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.

• Noise: Exposure to noise can produce problems with communication and patient evaluation (auscultation is impossible — use noninvasive blood pressure [NIBP] and an arterial line). Provide hearing protection. Audible medical equipment alarms are useless.

  o 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.

  o Nuclear and chemical casualties must be externally decontaminated, and time allowed for off-gassing of residual chemical agent.

  o 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.

  o Any NBC AE movement may be delayed due to the following:

    ♦ Aircraft decontamination time.
    ♦ Availability of noncontaminated aircrew.
    ♦ Cohorting of similarly exposed patients.
    ♦ Quarantinable diseases (eg, plague and smallpox) require special approval (command and diplomatic) before AE.

**Medical Evacuation Precedences**

• Depending on the Service and the type of evacuation assets used, the timeframes for affecting evacuation differ. Refer to Table 4-1.
Table 4-1. Evacuation Precedences.

<table>
<thead>
<tr>
<th>Movement Precedence</th>
<th>Army, Navy, Marine (MEDEVAC)</th>
<th>Air Force (AE)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urgent</td>
<td>Within 2 h.</td>
<td>ASAP</td>
<td>Immediate AE to save life, limb, or eyesight.</td>
</tr>
<tr>
<td>Priority</td>
<td>Within 4 h.</td>
<td>Within 24 h.</td>
<td>Prompt medical care not available locally. Medical condition could deteriorate and patient cannot wait for routine AE.</td>
</tr>
<tr>
<td>Routine</td>
<td>Within 24 h.</td>
<td>Within 72 h or next available mission.</td>
<td>Condition is not expected to deteriorate significantly while awaiting flight.</td>
</tr>
</tbody>
</table>

- **Concept of Operations. The USAF AE system.**
  - Command and control (C2) of casualty movement by air transport.
  - 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): 4–6 person communication team, usually collocated with an MTF, to coordinate requests with the AE system.
  - Facilities and personnel at airheads for the administrative processing, staging, and limited medical care of casualties entering or transiting the AE system. Patients are normally held only for 2–6 hours prior to evacuation.
    - USAF units provide aeromedical staging support through incrementally sized elements ranging in size/capability from forward deployed special operations forces (SOF) to 100-bed facilities.
- Reporting a Patient for AE. Originating physician consults with local FS to determine the en route care plan and timing of evacuation.
Due to the complexity of the AE system, physicians must identify points of contact (POCs) (local Flight Surgeons [FSs], AELT, aeromedical staging elements, PMRC); 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 well as possible (secure airway, controlled hemorrhage, treated shock, and immobilized fractures).
  - Communicate the condition, AE category (ambulatory or litter), and movement precedence (Table 4-1) of the patient to the PMRC, as communications assets allow. See PMRC contact information below.

<table>
<thead>
<tr>
<th>PMRC</th>
<th>Commercial telephone number</th>
<th>Military telephone number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global-Scott AFB, IL</td>
<td>1-800-303-9301 or 1-800-874-8966</td>
<td>DSN 779-4200 or 8184</td>
</tr>
<tr>
<td>EUCOM Theater-Ramstein Air Force Base, Germany</td>
<td>011-49-6371-47-2264 or 2235</td>
<td>DSN 314-480-2264 or 2235</td>
</tr>
<tr>
<td>PACOM (Hickam AFB Hawaii)</td>
<td>808-448-8734</td>
<td>DSN 448-8734</td>
</tr>
</tbody>
</table>

  - To ensure optimum care, communicate with the accepting physician, and provide diagnosis, care rendered, and subsequent medical care plan (next 24–48 h).
  - Ensure the patient has adequate quantities of supplies and medications for duration of transfer (at least 72 h).

- **Local Flight Surgeon Responsibilities.**
  - Authority for determining whether patients are physiologically ready for air transport.
  - Resource for AE system information, communication, and coordination.
### AE Process

<table>
<thead>
<tr>
<th>Activity</th>
<th>Location at Which the Activity Occurs</th>
</tr>
</thead>
</table>

- **Request versus Requirement.** AE *requests* and patient movement *requirements* are different. Physicians at originating MTFs submit requests for movement, timing, destination, suggested support therapies, and so forth. Only the validating Flight Surgeon (usually located at PMRC; not the local FS) and the PMRC can validate those requests, which then become AE requirements.

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

- **Key Steps for USAF AE Patient Request.**
  - Contact local FS 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 below). 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 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...
Aeromedical Evacuation

Care. CCATT members may be called on to consult and/or assist in the care of other patients.

- A four-person burn transport team can augment a CCATT team as required for inhalation injury and/or severe burns.
- Determine if special requirements exist for transport; eg, CAR, and splinting.
- Determine patient movement items (PMI) 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.

Critical Care Air Transport Teams

**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, anesthesiology, or emergency medicine.

**Critical care or emergency medicine nurse.**
- Experienced in managing patients requiring mechanical ventilation, invasive monitoring, and hemodynamic support.

**Cardiopulmonary technician.**
- Experienced in management of patients requiring mechanical ventilation, and invasive monitoring.
- Experienced in troubleshooting ventilatory support and monitoring systems.
Chapter 5

Airway/Breathing

Introduction
Skillful, rapid, assessment and management of airway and ventilation are critical to preventing morbidity and mortality. Airway compromise can occur rapidly or slowly and may recur. 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 (MTFs). Immediate goal: Move 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).
- 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:
  - Insert oral airway upright if a tongue depressor is used (preferred method).
  - Keep the airway inverted past the tongue then rotate 180°.
  - Too small an airway will not alleviate the obstruction.
  - Too long an airway may fold the epiglottis caudally, worsening the obstruction.
  - Estimate airway size by distance from corner of mouth to ear lobe.
  - Oral airways are not used in conscious patients.
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- Nasopharyngeal airway.
  - Pass lubricated nasal airway gently through one nostril.
  - Not used in suspected facial or basal skull injuries.
  - Is tolerated by conscious patients.
- Field expedient.
  - Pull tongue forward and safety pin or suture it to corner of mouth.
- Cricothyrotomy.

Ventilation

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

Assess air movement during mask ventilation by observing 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).

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

♦ 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

**Rapid Sequence Intubation (RSI)—7 steps.**

1. Preoxygenate with 100% oxygen by mask.
2. Consider fentanyl—titrate to maintain adequate blood pressure and effect (2.0–2.5 µg/kg).
3. Cricoid Pressure—Sellick maneuver until endotracheal tube (ETT) placement is confirmed and balloon is inflated.
4. Induction Agent: etomidate 0.1–0.4 mg/kg IV push.
5. Muscle Relaxant: succinylcholine 1.0–1.5 mg/kg IV push.
7. Verify tube placement.

- 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 (valecula). Apply force at a 30°–45° angle, lifting the entire laryngoscope/blade, without rocking it backward (Fig. 5-2).

♦ **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. 5-2. Use of curved blade laryngoscope.  
Fig. 5-3. Use of straight blade laryngoscope.

♦ Visualize the vocal cords.
♦ Consider the “BURP” maneuver when the laryngoscopic view is poor (Fig. 5-4).
  ♦ “Backward-Upward-Rightward-Pressure” of the larynx, 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 (GEB) (Fig. 5-5).
♦ 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.
Airway/Breathing

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 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, 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 breath sounds are equal.

Avoid making more than 3 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.
  - Tactile intubation.
    - Requires no instruments.
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♦ No light use—good in light control situations.
♦ Slide hand closest to patient over tongue to hold it down.
♦ Lift epiglottis with first two fingers.
♦ Slide ETT along the “v” between the two fingers into the airway.
• Lighted stylet or “light wand” intubation.
  • Flexible wand, lighted at the tip, is placed through the ETT.
  • Wand is advanced by tactile guidance into the trachea.
  • Position in trachea is verified by transillumination.
  • The ETT is advanced over the wand.
• Flexible fiberoptic oral or nasal intubation.
• Retrograde wire intubation.
• Rigid fiberoptic intubation (Bullard laryngoscope).
• Alternative Airways.
  • May NOT be definitive airways.
  • Allow for oxygenation and ventilation when standard airways cannot be placed.
  • “Fastrach” model laryngeal mask airway (LMA).
  • Esophageal-tracheal combitube (ETC).
• Perform a surgical airway.
• Wake the patient up and attempt an awake technique if possible.

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 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 (ID), to just above the balloon (Fig. 5-6c).
• Confirm tracheal intubation.
Suture the ETT in place, and secure it with ties that pass around the neck.

Laryngeal Mask Airway

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

Insert blindly without a laryngoscope. LMA rests over the laryngeal inlet (Fig. 5-7).

Fig. 5-6 a,b,c. Steps of surgical cricothyrotomy.

Fig. 5-7 a,b,c. Fastrach laryngeal mask airway placement. Illustration courtesy of LMA North America, Inc.
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- May be used alone or as a conduit to advance an ETT.
- Compared to an ETT, the LMA supports less airway pressures, and offers less aspiration protection.
- Check LMA cuff, then deflate it until the down side (inner) surface is smooth and flat; lubricate the pharyngeal (upper) side of LMA.
- The sniffing position works best, but 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 LMA tubing is seen.
  - Secure the LMA.

Blind nasal-tracheal intubation

| Contraindications: Coagulopathy, midface trauma, basilar skull fracture, and suspected elevated intracranial pressure. |

- Nasal-tracheal intubation is better tolerated than orotracheal techniques and requires less sedation and no paralysis.
- Prepare the nasopharynx and larynx (as conditions allow).
  - Spray vasoconstrictor into the nostril that appears largest and most patent.
  - Insert a nasal trumpet soaked in lidocaine gel and leave in place for a brief period.
  - Apply Cetacaine spray to oropharynx.
  - Administer a transtracheal injection of 4 cc lidocaine via cricothyroid membrane.
- Insert an ETT (~ 7.0 ID for adults) slowly into the nostril, perpendicular to the face.
- Advance the ETT slowly past the nasal turbinates and around the curve of the posterior nasopharynx.
- Do not use excessive force!
• The ETT is advanced as breath sounds of increasing volume are heard at the distal end of the tube.
• The ETT is advanced beyond the vocal cords into the trachea. If the tube fails to advance into the trachea, several maneuvers can be employed.
  o Tilt the head.
  o Apply external, downward pressure to the larynx.
  o In inflate the ETT balloon to help center the tube, then deflate and advance it once it is engaged in the glottic opening.
Chapter 6

Hemorrhage Control

“The hemorrhage that takes place when a main artery is divided is usually so rapid and so copious that the wounded man dies before help can reach him.” – COL 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 medical care.
  - Half of these casualties bleed to death, 1/5 from extremity trauma (10%–15% of all deaths).
  - Although bleeding is a main cause of death, the vast majority of wounds do not have life-threatening bleeding.

**Under Fire**

Get the patient out of the line of fire — prevent further injury. Control obvious external bleeding once out from under fire. If you must remain under fire, stop external bleeding with use of a tourniquet. **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.

**Direct Pressure Is Central to Treatment**

- Internal.
  - Chest, abdomen, pelvis, and closed extremity fractures.
Emergency War Surgery

♦ High mortality if the casualty is not expeditiously transported and salvage surgical procedures performed.
♦ Controlled (hypotensive) resuscitation may be necessary.

**Internal Torso Bleeding Requires Surgical Control**

**Treatment—First Responder**
- External hemorrhage from extremity wounds.
  - Direct pressure at site of injury is the most effective and preferred method of hemorrhage control.
  - If direct pressure fails to stop the hemorrhage, it signifies deep, massive, or arterial injury, and will require surgery or advanced hemostatic agents.
  - Hold pressure for at least 5 minutes before looking to see if it is effective.
  - Impaled foreign bodies should not be removed because profuse bleeding may occur.

**Pitfall: A Bandage Does Not Equal Direct Pressure!**

A bandage may wick blood from the wound without stopping the bleeding.
A bandage hides ongoing bleeding.
Hemostatic bandages currently being developed may stop bleeding.

♦ Elevation of the extremity will decrease most bleeding—this is an under-appreciated technique.
♦ Point compression of the proximal artery.

**Pitfalls of Blind Clamping**

Blind clamping into the wound is more likely to cause additional injury than to control bleeding.

**Risk–Benefit Decision:** Judgment that other measures are not successful should be exercised before applying clamps in a wound. Field wound exploration is not recommended.
◊ May help slow bleeding while attempting to gain better control at the wound site.
◊ May require compression at the pressure point for up to 20 minutes to provide hemostasis.
◊ Table 6-1 shows the recognized pressure points.

Table 6-1. Recognized pressure points.

<table>
<thead>
<tr>
<th>Bleeding Site</th>
<th>Hand</th>
<th>Forearm</th>
<th>Lower Arm</th>
<th>Leg</th>
<th>Thigh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artery Pressure Point</td>
<td>Radial/Ulnar</td>
<td>Brachial</td>
<td>Axillary</td>
<td>Popliteal</td>
<td>Femoral</td>
</tr>
<tr>
<td>Wrist</td>
<td>Inner</td>
<td>Axilla</td>
<td>Behind</td>
<td>Below</td>
<td>groin crease</td>
</tr>
<tr>
<td>upper arm</td>
<td>upper arm</td>
<td>knee</td>
<td>groove</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Tourniquet May Be First Choice in Combat

◊ A tourniquet should be applied if previous techniques fail.
◊ Use a tourniquet early, rather than allow ongoing blood loss. Substitutes for issued tourniquet include belt, torn cloth, gauze, and rope, among others.
◊ Rapid method to secure hemorrhage control.
◊ Does not require constant attention; allows first responder to care for others — extends resources.
◊ Tourniquets should not be removed until the hemorrhage can be reliably controlled by advanced hemostatic agents or until arrival at surgery.
◊ Tourniquet placement on the forearm or leg may not compress the vessels, which lie between the double long bones. Tourniquets on the upper extremity should be placed on the upper arm and 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.
Emergency War Surgery

**Pitfalls of Tourniquet**

Application for more than 2 hours may increase limb loss.

**Risk–benefit decision:** Don’t avoid a tourniquet in order to save a limb, and then lose a life! Use of tourniquet does not always lead to limb loss.

♦ **Clamping vessels:** If there is continued bleeding and a damaged vessel can be readily identified, a hemostat may be used to clamp the vessel.

♦ **Limb splints** will decrease bleeding associated with fractures and soft tissue injury by aligning, stabilizing, and returning the limb to length.

♦ **Military Anti-Shock Trousers (MAST) possible uses.**
  ◊ Controls hemorrhage from massively injured/mangled lower extremities.
  ◊ Provides temporary stabilization of pelvic fractures to decrease hemorrhage.
  ◊ Splints fractures of lower extremities.

**Pitfalls of MAST**

Protracted MAST use leads to compartment syndrome and ischemic limbs.

Respiratory compromise occurs due to diaphragmatic elevation.

Increased torso bleeding.

Pressure changes within aircraft (caused by altitude changes) affect inflation pressure.

Requires close monitoring in aircraft.

♦ **Scalp bleeding:** can be significant due to the rich vasculature of the scalp.
  ◊ Responds to direct pressure.
  ◊ Compression dressings must be applied if you cannot provide ongoing direct pressure.
  ◊ Difficult to apply and maintain direct pressure.
Hemorrhage Control

◊ 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.
◊ Avoid pushing fragments into 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.
◊ Stabilization of pelvic fracture with MAST garment, or by wrapping the pelvis tightly with a wide strap (such as a folded sheet), may reduce pelvic bleeding.
◊ Open torso injuries. If direct pressure does not stop the hemorrhage, consider inserting a tamponade with a balloon (Foley) catheter into the wound, and then with balloon inflated pulling 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.
  o Control all bleeding.
  o Assess neurologic status and circulation of extremity before and after applying a dressing or bandage.
  o Immobilize suspected fractures.
  o Keep dressing as clean as possible.
  o Dressings should cover the entire wound.
  o Bandages should cover the entire dressing.
  o Avoid skin-to-skin contact.
  o Leave fingers and toes exposed.
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- **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 from Table 6-2.

<table>
<thead>
<tr>
<th>Size designation</th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
<th>ABD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement (inch)</td>
<td>4 x 7</td>
<td>7.5 x 8</td>
<td>11.75 x 11.75</td>
<td>18 x 22</td>
</tr>
<tr>
<td>Saturation (mL)</td>
<td>300</td>
<td>750</td>
<td>1,000</td>
<td>2,500</td>
</tr>
</tbody>
</table>

- **Coagulopathy.** Blood loss, massive fluid resuscitation, and drop in body temperature may lead to inability to form clot.
  - Keep patient warm (above 34°C).
  - Use warm fluids.
  - Use crystalloid fluids sparingly.
  - Transfuse with fresh whole blood (less than 24 h old).

- **Hemostatic agents:** new products and bandages are available in several forms:
  - Powders: placed in wound, then covered with a dressing.
  - 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, return to the tourniquet.
Two Field Hemostatic Agents

- Two agents are recommended by the US Tactical Combat Casualty Care Committee: 1) HemCon, 2) QuikClot.
- If standard measures such as elevation and pressure dressings do not control bleeding, it is recommended that tourniquet be used and that the first agent be HemCon. If this dressing fails, it should be removed and QuikClot used if the bleeding is life threatening.
- If the bleeding is external and not at a site where a tourniquet can be applied, HemCon and QuikClot can be used if conventional pressure dressings fail.
- Both products are to be used only on external sources of hemorrhage.
- HemCon dressing is a firm 4 x 4 inch dressing that is sterile and individually packaged. It works by adherence to the bleeding wound and has some vasoconstrictive properties. The blood and clot in the wound should be removed before application.
QuikClot is a granular zeolite that absorbs fluid and causes hemostasis. It has handling properties similar to sand. When applied it can generate significant heat during the absorption process. Blood and clot should be wiped out of the wound prior to application.

Remember, pressure must be applied for 3–5 minutes at the bleeding site, after application of a hemostatic dressing.

Field Hemostatic Dressings Considerations

Use should be delayed until after a trial of conventional dressings.
Do not use on minor injuries.
Use on internal wounds is not yet recommended.
Must apply pressure to the bleeding site after application.
Risk of inadequate contact of HemCon to the bleeding tissues in deep wounds.
Heat generation from QuikClot.

Controlled resuscitation (hypotensive resuscitation).

Resuscitation as 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 accepted. Small volumes of resuscitation fluid are still required in those casualties with decreased mentation due to hypotension (ie, decreased or absent radial pulse).
Chapter 7

Shock and Resuscitation

Introduction
The goal of fluid resuscitation is to maintain adequate perfusion. Fluid resuscitation of the wounded combatant remains a formidable challenge on the modern day battlefield. Routine resuscitation using 2 L of crystalloid through two large bore IVs is not appropriate in all situations and the vast majority of the casualties do not need any IV resuscitation prior to arrival at a forward medical treatment facility (MTF).

This chapter will briefly address shock, including recognition, classification, treatment, definition, and basic pathophysiology. Initial as well as sustained fluid resuscitation and a review of currently available fluids and potential future products will be described.

Recognition and Classification ofShock
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 > 2, and lactic acidosis > 2.5 mmol/L.
• Hypovolemic shock: Diminished volume resulting in poor perfusion as a result of hemorrhage, diarrhea, dehydration, and burns (see Chapter 28, Burns). This is the most common type of shock seen in combat soldiers (see Table 7-1).

Hypotension is a late finding in shock, after 30%–40% lost blood volume. Earlier signs are tachycardia, decreased pulse pressure, and mental status changes. Tachycardia is often not reliable; however, and relative bradycardia is common.
Emergency War Surgery

Table 7-1. Clinical Correlates in Hypovolemic Shock.

<table>
<thead>
<tr>
<th>Blood Vol. Lost*</th>
<th>Heart Rate</th>
<th>Respiratory Rate</th>
<th>Blood Pressure</th>
<th>Central Nervous System</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 15%</td>
<td>Minimal tachycardia</td>
<td>No change</td>
<td>No change</td>
<td>No change</td>
</tr>
<tr>
<td>15%–30%</td>
<td>Tachycardia</td>
<td>Tachypnea</td>
<td>Decreased pulse pressure</td>
<td>Anxiety or combative ness</td>
</tr>
<tr>
<td>30%–40%</td>
<td>Marked tachycardia</td>
<td>Marked tachypnea</td>
<td>Systolic hypotension</td>
<td>Depressed mental status</td>
</tr>
<tr>
<td>&gt; 40%</td>
<td>Marked tachycardia</td>
<td>Marked tachypnea</td>
<td>Severe systolic hypotension</td>
<td>Comatose</td>
</tr>
</tbody>
</table>

*Blood volume is approximately 7%, so 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, or cardiac tamponade with distended neck veins, or unilateral absence of breath sounds.

- **Distributive** shock: Poor perfusion due to loss of vascular tone; **neurogenic** shock: **bradycardia** with hypotension, seen with spinal cord injury.
  - Treat hemorrhagic shock first.
  - Volume resuscitation to maintain systolic BP > 90 mm Hg.
  - Consider the addition of a vasopressor to address the loss in vascular tone—phenylephrine (50–300 µg/min) or dopamine (2–10 µg/kg/min).

- **Septic** shock: Fever, hypotension, and warm extremities from massive vasodilation, usually seen 5–7 days after initial trauma.

**Treatment of Traumatic 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).

- Secure the airway and administer O₂ for SaO₂ < 92%.
- Diagnose and treat tension pneumothorax.
- Control obvious bleeding and assess for occult hemorrhage.
- Assess circulation and establish IV access.
Consider cardiac tamponade even if no distended neck veins.

- Administer IV fluids.

- Hemorrhagic shock: Initially, any fluid available.
  - LR: 1,000 mL expands intravascular volume by ~ 250 mL within 1 hour after injection.
  - 6% hetastarch: 500 mL expands intravascular volume by ~ 800 mL in 1 hour, is functionally equivalent to 3 bags of LR, and is sustained for at least 8 hours.
  - 7.5% hypertonic saline (HTS) results in the same physiologic response with 1/8th the volume of LR or saline. Two infusions of 250 cc can be used. Although this recommendation has been made by the Institute of Medicine (Washington, DC) and two military consensus groups, 7.5% HTS is not commercially available. 3% and 5% HTS can be used instead and are formulary stock items.

- Nonhemorrhagic shock: Crystalloid is the fluid of choice.
  - Within 1 hour, resuscitate to a mean arterial pressure of > 60 mm Hg, a urine output of 0.5 cc/kg/h, and SaO₂ of > 92%.

- Based on response to fluids, casualties will fall into 3 groups:
  - Responders: Casualties with a sustained response to fluids probably 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 transfusion as soon as possible.
    - For nonresponders, fluids may be given to keep the patient alive, but one 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 presented below.

**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.

Fluid choices. The ideal fluid for resuscitation is still debated despite decades of research that began during WW I (see chart on next page).

**Concept of Controlled (Hypotensive/Limited/Balanced) Resuscitation**

- Raising the blood pressure with fluid resuscitation may dislodge established clots leading to more 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 ~90 mm Hg.
  - MAP of ~60 mm Hg.

Controlled resuscitation is NOT a substitute for definitive surgical control. It is an attempt to keep a very sick patient alive until he can get to definitive treatment.

- Endpoints of resuscitation.
  - **Following definitive hemorrhage control**, more traditional endpoints of resuscitation include
    - Blood pressure: SBP > 120 mm Hg, MAP > 70 mm Hg.
    - Urine output: > 0.5 mL/kg/h (approximately 30 mL/h).
    - Correction of acidosis:
      - base deficit < 2.
      - serum lactate < 2.5 mmol/L.
    - Hypothermia: It is important to maintain normal body temperature. Fluids and patient care areas should be warmed. This is often not possible in the deployed environment. Patients frequently arrive at the facility already hypothermic. Keep patients covered when on litters, radiograph tables, and operating tables. External warmers (such as contained forced warm air devices, eg, Bair Hugger) should be employed in all patient care
<table>
<thead>
<tr>
<th>Fluid/Initial Dose</th>
<th>Indication</th>
<th>Advantages</th>
<th>Cautions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Crystalloids</strong></td>
<td>Hypovolemia, dehydration, hemorrhage, shock, burns</td>
<td>Easy to store, inexpensive, proven effectiveness, isotonic</td>
<td>Weight ratio – requires 3:1 for lost blood, dilution, edema, coagulopathy</td>
</tr>
<tr>
<td>Saline</td>
<td>Hemorrhagic shock: &gt;500cc – Risk of hypernatremia, seizures</td>
<td>Longer duration of effect than plain HTS?</td>
<td>Increased cardiac contractility, longer duration 1:1 replacement for blood</td>
</tr>
<tr>
<td>Ringer’s Lactate</td>
<td>Burns – only one dose initially</td>
<td>Less weight/cube better than crystalloids</td>
<td>Recruits extravascular fluid, weight/cube better than crystalloids</td>
</tr>
<tr>
<td><strong>Hypertonic saline (HTS)</strong></td>
<td>Hemorrhagic shock: 4cc/kg or 250 cc bolus, may repeat once</td>
<td>Weight ratio – requires 3:1 for lost blood</td>
<td>Dilution, edema, coagulopathy</td>
</tr>
<tr>
<td>3%–5% HTS</td>
<td>Burns, third day</td>
<td>Isotonic</td>
<td>Isotonic</td>
</tr>
<tr>
<td>7.5% HTS</td>
<td>250-500 mL bolus</td>
<td>Lighter weight, small volume = large effect</td>
<td>Weight ratio – requires 3:1 for lost blood</td>
</tr>
<tr>
<td>Hypertonic saline–colloid combinations*</td>
<td>Hemorrhage controlled</td>
<td>Fluids of opportunity</td>
<td>Do not use for dehydration from vomiting, diarrhea, or sweating, or heat injuries</td>
</tr>
<tr>
<td>Artifical colloids</td>
<td>Oral rehydration fluids</td>
<td>Nonsterile ingredients: 4 tsp sugar, 1 tsp salt, 1 L water</td>
<td>Do not repeat without addition of other fluids</td>
</tr>
<tr>
<td>Dextran</td>
<td>Hemorrhage – Type O universal donor, transfusion reactions</td>
<td>Carries oxygen, walking blood bank</td>
<td>Experimental only, not yet available for use</td>
</tr>
<tr>
<td>6% hetastarch*</td>
<td>Blood</td>
<td>Hemoglobin based</td>
<td>Hemoglobin based</td>
</tr>
<tr>
<td>(Hextend, Hespan)</td>
<td>Artificial blood</td>
<td>Fluorocarbon based</td>
<td>Fluorocarbon require supplemental O2</td>
</tr>
<tr>
<td>10% Pentastarch*</td>
<td>Hemorrhage</td>
<td>Type O, universal donor</td>
<td>No-type and cross matching</td>
</tr>
<tr>
<td>Gelatin-based colloids*</td>
<td>Hemorrhage</td>
<td>Artificial blood</td>
<td>No-type and cross matching</td>
</tr>
<tr>
<td>HTS hetastarch*</td>
<td>Dehydration controlled</td>
<td>Hemorrhage</td>
<td>Artificial blood</td>
</tr>
<tr>
<td>1% dobutamine</td>
<td>Hemorrhage</td>
<td>Artificial blood</td>
<td>Artificial blood</td>
</tr>
</tbody>
</table>

*Not FDA approved
Emergency War Surgery

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.

Transfusion Therapy

● Blood transfusion.

Blood should be added to the resuscitation of patients who have lost 30%–40% of their blood volume. Blood may also be necessary in patients who have not reached this threshold but have ongoing blood loss. Whole blood has a greater risk for immunologic reactions than packed cells.

Blood products fielded with forward medical units (FST, CSH) are predominantly group O packed red cells and FFP. Upon reaching a stabilization phase of operations, type-specific packed cells and platelets will be supplied through theater specific channels. Storage, shelf-life, and availability of these products are outlined in Table 7-2.

Table 7-2. Blood Products Available to the Theater.

<table>
<thead>
<tr>
<th>Product</th>
<th>Unit of Issue</th>
<th>Storage</th>
<th>Shelf Life for Transfusion</th>
<th>Echelon Availability</th>
<th>Blood Group Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid PRBCs</td>
<td>~250mL</td>
<td>35d</td>
<td>35d</td>
<td>Second &amp; third (MASH)</td>
<td>100% - - - - - - - - -</td>
</tr>
<tr>
<td>Frozen/deglycerolized RBCs</td>
<td>~250mL</td>
<td>10y</td>
<td>3d (postwash)</td>
<td>Third &amp; fourth</td>
<td>100% - - - - - - - - -</td>
</tr>
<tr>
<td>FFP</td>
<td>~250mL</td>
<td>1y</td>
<td>24h (postthaw)</td>
<td>Third &amp; fourth</td>
<td>- 50% 25% 25% 25%</td>
</tr>
<tr>
<td>Platelet concentrate</td>
<td>~60mL</td>
<td>5d</td>
<td>5d</td>
<td>Third &amp; fourth</td>
<td>50% 50% - - - - - - -</td>
</tr>
</tbody>
</table>

* Will be provided by blood bank platoon and medical treatment facilities by in-theater blood collections.

CHS: combat support hospital; FFP: fresh frozen plasma; MASH: mobile army surgical hospital; PRBCs: packed red blood cells; RBCs: red blood cells

Familiarity with transfusion technique, patient-donor unit infusion connections, and walking blood bank connections, is essential and should be practiced routinely. Most serious transfusion reactions are the result of an error at the bedside, not an error in typing and cross-matching (ie, transfusing “the right unit to the wrong patient”).

- **Transfusion reactions** may be difficult to recognize in severely or multiply injured casualties. Hemolytic (ABO mismatch) reactions present acutely (< 24 hours) with fever, chills, back pain, dyspnea, and renal failure. Delayed reactions may occur. Transfusion should be halted immediately in all cases, except minor allergic reactions (urticaria, fever, +/- mild bronchospasm), which are treated with diphenhydramine (25–50 mg IV or PO), H-2 blocker, methylprednisolone, +/- epinephrine.

### Field Management of a Transfusion Reaction
- Stop the infusion of blood. Continue to infusion normal saline through the intravenous line.
- Examine the urine for hemoglobinuria. Examine plasma for hemoglobinemia.
- Maintain blood pressure and urinary output with saline. Consider administering mannitol or furosemide after volume repletion if the patient is oliguric.
- Reexamine the donor unit for seal integrity, evidence of hemolysis or infection, and recheck the transfusion log for clerical error.
- Annotate the field medical card with a description of the suspected reaction and the therapy provided. Transfer the unit suspected of causing the reaction to the next echelon of care with the casualty.

- **Clinical relevance of the Rh bloodgroup in female casualties.**
Women, military and civilian, are becoming more frequent victims of conflict. Approximately 85% of the American population is Rh positive. Serious consequences to Rh incompatible blood are rare in men. Data predict that 10% of
Emergency War Surgery

group O blood transfusions will be of Rh positive units to Rh negative female recipients. An Rh negative woman transfused with Rh positive blood is very likely (approximately 80%) to produce anti-D (Rh positive) antibodies. This seroconversion can jeopardize a subsequent pregnancy when this Rh negative mother, now sensitized by Rh positive transfusion, conceives an Rh positive fetus. Chronic hemolytic disease of the newborn may result.

Under no circumstances should a life-saving transfusion be withheld because of Rh incompatibility; saving a life takes precedence over Rh immunization.

Prevention: When the supply of group O blood permits, group O Rh negative blood should be reserved for women.

- **Massive transfusions.**
  - **Definition.**
    - >10 Units of PRBC’s in <24 hours.
    - Whole body blood volume transfusion in a 24-hour period.
  - **Consequences of massive blood loss.**
    - Shock.
    - Hypothermia.
    - Acidosis.
    - Decrease of coagulation factors.
    - Decrease of platelets.
  - **Consequences of massive blood transfusions.**
    - Dilution of coagulation factors.
    - Dilution of platelets.
    - Acidosis.
    - Hypothermia.
    - Hypocalcaemia (citrate toxicity) associated with rapid transfusions.
  - **For every 10 units of PRBCs give:**
    - 4 units of FFP.
    - 1 unit of platelets (6 pack of 1 apheresis unit).
    - Consider 1 dose of cryoprecipitate (10 single units of Cryo).
  - **What blood to use?**
Shock and Resuscitation

♦ Type specific if at all possible.
♦ O positive (preferred) in males and postreproductive females.
♦ O negative (if available) in females of reproductive age.
♦ If still using O after 8 units, stick with O, even if blood type is determined. Stick with O until the patient’s forward and back typed appropriately.

Which FFP to use?
♦ There is no such thing as emergency release FFP.
♦ Type specific if at all possible.
♦ AB when in doubt.
♦ A as a second choice.
♦ Unless you KNOW that the patient is Type O blood, **DO NOT** use Type O FFP.

Walking blood bank.
When standard blood component therapy is unavailable, the use of fresh whole blood can be lifesaving. Because whole blood contains clotting factors, it is effective for treating dilutional coagulopathy associated with massive blood loss and fluid resuscitation.

Equipment.
♦ Blood recipient set (bag), indirect Tx Y-type (NSN 6515 01 128 1407).
♦ Stopcock, IV therapy 3 way, with Luer lock (NSN 6515 00 864 8864).

Cautions.
♦ Field conditions increase the risk of bacterial contamination.
♦ Definitive testing of blood for transfusion virus diseases is not available.
♦ “Dog tag” blood typing wrong 2%–11% of the time.
♦ Donor performance may be impaired by donation.
   ◊ Good for small numbers of patients—large numbers lead to doubling of unit ineffectiveness.
   ◊ Should not be the “default” answer for standard blood program planning.
   ◊ Donate only once a month.
   ◊ Avoid donation at high altitudes.
Emergency War Surgery

Even in an emergency, try to get regularly issued blood products.

◊ Women—ideally on supplemental iron before/after donation.

o Planning.
  ♦ Predeployment.
    ◊ Develop a current prescreened donor roster.
      ▪ Blood type and Rh.
      ▪ Nonreactive transfusion transmissible disease tests (if available).
  ♦ Onsite.
    ◊ Update prescreening donor roster.
      ▪ Tent/cot location.
      ▪ Duty location.

● Emergency (no roster in place).
  o Establish blood types with local testing or previous donor history.
  o Choose prior blood donors in preference to nondonors because they have been tested for the infectious diseases in the past.
  o Rely on “dog tags” only as a last resort.
  o Draw only type “O” universal donors in mass casualty situations to reduce the confusion of handling.
  o Draw universal or type specific donors in case of single patient incidents. (Type O donors are 46% of the US population.)

● Procedure for walking blood bank.
  o Clean donor’s arm with povidone iodine for at least 1 minute.
  o Draw the blood from an arm vein into an unexpired, intact commercial blood bag.
  o The bag has a 600 ml capacity and contains 63 mL of CPD or CPDA-1 anticoagulant.
  o Draw about 450 mL, a “pint,” so that the bag is almost full.
  o Draw tubes for typing, cross-matching, and transfusion transmissible disease testing (if available).
Shock and Resuscitation

- Send tubes to a supporting laboratory (if available). Even after-the-fact testing is useful to provide reassurance of safety or explanations of untoward events.
- Label the bag clearly with blood type and donor identification information.

- Whole blood crossmatching.
  - The white tile method uses a drop of the donor blood mixed with the recipient serum on a white ceramic tile and is examined in 4 minutes.
  - If no agglutination occurs, the blood is suitable for transfusion into that recipient. A hand lens may be useful.

- Storage.
  - Keep at room temperature no longer than 24 hours.
  - Blood stored warm for more than 24 hours has a significant risk of bacterial growth and clotting factors will be lost. If the blood has been kept at room temperature for less than 8 hours, it can be kept in a refrigerator or on wet ice for up to 3 weeks.
  - Although RBCs remain viable, platelets may become inactive in whole blood stored cold (1°C–10°C) for greater than 24 hours, losing one of the main benefits of fresh whole blood.
  - Ensure that anesthetist/anesthesiologist and surgeon are aware that this is an emergency-drawn unit and tell them the history of the unit.
  - After 24 hours, destroy warm-stored, whole-blood units. (Stateside hospitals would do so after exceeding 10°C for 30 minutes.) They are no longer safe or fresh. You may save cold-stored units until a regular supply of tested blood is reestablished.
  - Keep a record of donors and patients transfused so they can be tested on return to stateside.
  - Keep a record of number of units transfused, donor names, and outcome.

- Autotransfusion.
  - Blood collected into sterile containers (eg, suction, chest tube, among others) may be returned to the patient through a blood filter.
Emergency War Surgery

- Blood from sterile cavities, such as the chest or abdomen without visceral injuries is preferred.
- Blood from contaminated abdominal wounds can be used at an increased risk of systemic infection.
- Blood may be filtered through sterile gauze as a field expedient method.

The Future
Because the definition of shock is inadequate oxygenation at the cellular level, the most ideal fluid would provide volume expansion and oxygen-carrying capacity. For this fluid to be useful in deployed settings it needs to be stable at a variety of temperatures and have a low-risk profile. Hemoglobin based oxygen carrying compounds (HBOCs) currently under investigation may be such fluids. There are HBOCs derived from either bovine or human sources that require no refrigeration, have a shelf life of up to 3 years, are disease free, and require no crossmatching.
Chapter 8

Vascular Access

Introduction
Vascular access is a critical early step in the management of trauma. Peripheral access should be attempted first; if unsuccessful, additional percutaneous central access locations include the subclavian vein, the internal and external jugular veins, and the common femoral veins. Cutdowns for the saphenous vein at ankle or femoral sites are alternative options.

- Basic Equipment.
  - Tourniquet.
  - 1%–2% Lidocaine.
  - Sterile prep solution, drape, gloves, and 4 x 4 gauze pads.
  - 3mL syringe with 25-gauge needle.
  - Scalpel, hemostat, 11 blade scalpel and fine scissors.
  - Vein introducer or “vein pick”.
  - IV catheter; IV tubing (modified with distal connector cut off), and 8 F NG tube are field expedients.
  - 3-0 or 4-0 silk ties to secure catheter in vein.
  - 2-0 or 3-0 suture to secure catheter to skin.
  - Central catheter kit (for central lines) or intraosseous device for intraosseous insertion.

Subclavian Vein Access or Internal Jugular Venipuncture
- Place the patient supine in Trendelenburg (15° head down).
- Prep and drape subclavian/jugular area. Sterile gloves should be worn.
  - 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 attached 5 mL syringe. Insert with the bevel of the needle up, directing the needle towards the contralateral clavicular head. Keep the needle horizontal to avoid a pneumothorax.
♦ While aspirating, slowly advance the needle underneath the clavicle.

ο Jugular vein line.
♦ Turn the patient’s head 45° toward the contralateral side to expose the neck.
♦ 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 10mL syringe at a 45° angle into the apex of the triangle, lateral to the carotid pulse.
♦ Carotid Puncture: Immediately withdraw the needle and place pressure on site for a minimum of 5 minutes.
♦ Advance the needle caudally, parallel to the sagittal plane and at a 30° posterior angle (eg, 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 return after advancing 5 cm, slowly withdraw the needle while aspirating. If this fails, redirect the needle.

ο 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 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.

Greater Saphenous Vein Cutdowns

♦ Contraindications.
  o Deep vein thrombosis (DVT) or severe ipsilateral lower extremity trauma.

♦ Procedure.
  o Expose, prep, and drape ankle or femoral site.
  o For ankle, administer local anesthetic proximal to the medial malleolus.
  o Make a superficial transverse incision through the skin over the entire width of the flat tibial edge (~3cm) in the area of the saphenous vein.
  o Using a curved hemostat, isolate the greater saphenous vein from the nerve and underlying bone.
  o Using the open hemostat as a platform, cut a 1–2 mm venotomy in the anterior surface of the vein with a number 11 blade (Fig. 8-1a).
  o Place the intravenous tubing (previously beveled) or angiocatheter at least 4 cm into the vein (may require use of a vein introducer) (Fig. 8-1b).
  o Secure the catheter with a proximal silk ligature, and tie off the distal vein.
  o Secure the catheter with a suture.
  o Apply a clean dressing.
  o Femoral procedure is essentially the same, with site being a handbreadth below the inguinal ligament, medial to the midline of the thigh. After skin incision, finger bluntly dissects through the fat to the fascia. Hook the finger and lift, and the vein comes up with it.
- Cutdown can also be performed on the common femoral veins, the jugular veins, and on veins of the forearm.

**IO Infusion**

- **Contraindications.**
  - Trauma or infection at insertion site.
  - Recent IO device at the same site.
  - Fracture of insertion bone.
  - Recent sternotomy.

- **Devices/Procedure.**
  - Procedures vary based on model; all IV fluids acceptable except possibly hypertonic solutions.
  - BIG, SurFast, and Jamshidi may be placed in proximal medial tibia, distal medial tibia, or the radius.
  - F.A.S.T. 1 is designed for sternal placement, 1.5 cm below the sternal notch.
  - Pediatric: Insert a bone-marrow aspiration needle or 14–19-gauge spinal needle, directing it caudally through the outer cortex. Common sites: tibia, distal femur.
  - Aspirate to confirm placement.

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Fig. 8-1a,b. Saphenous vein cutdown.
Chapter 9

Anesthesia

Introduction
Battlefield anesthesia primarily describes a state of balanced anesthesia using adequate amounts of anesthetic agents to minimize cardiovascular instability, 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. While 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 is essential.

Airway
Many methods for securing a compromised airway exist, depending on the condition of the airway, the comorbid 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/hypercapnia.
- Impending airway obstruction: facial fractures, retropharyngeal hematoma, and inhalation injury.
- Excessive work of breathing.
- Shock (bp ≤ 80 mm Hg systolic).
- Glasgow Coma Scale (GCS) ≤ 8. (See Appendix 2.)
- Persistent hypoxia (SaO₂ < 90%).
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.
  - Prominent upper incisors.

**Rapid Sequence Intubation Checklist**

- Equipment.
  - Laryngoscope, blades, and batteries (tested daily).
  - Suction, O₂ setup.
  - Endotracheal tubes and stylet.
  - Alternative tubes (oro, nasopharyngeal, LMA [laryngeal mask airway]).
  - IV access items.
  - Monitors — pulse ox, ECG, BP, end-tidal CO₂.
  - Positive pressure ventilation (Ambu bag or anesthesia machine).
- Drugs.
  - Narcotics.
  - Muscle relaxants.
  - Anxiolytics and amnestics.
  - Induction agents and sedatives.
  - Inhalation agents.
- Narcotics.
  - **Fentanyl**, 2.0–2.5 µg/kg IV bolus, then titrate to effect.
o **Morphine**, 5–10 mg IV bolus to load, then 2 mg q5min to effect.

o **Dilaudid** (Hydromorphone), 1–2 mg IV to load, then 0.5 mg q5min to effect.

- Muscle relaxants.
  - **Depolarizing.**
    - **Succinylcholine.**
      - 1.0–1.5 mg/kg.
      - Onset 30–60 sec.
      - Duration 5–10 min.
      - Can cause bradycardia, fasciculations, elevated intragastric pressure, elevated ICP, elevated intracranial pressure, potassium release (especially in “chronic” burn or immobile patients).
      - Potent trigger of malignant hyperthermia (MH).

**Succinylcholine should be 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 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 duration of action of 35–50 minutes. At 1.2 mg/kg onset similar to succinyl-choline, but, unfortunately, a duration of action that can exceed 60–90 minutes.
  - **Pancuronium:** induction dose of 0.15 mg/kg with an onset of 3.5–6 minutes and duration of action of 70–120 minutes.

- **Anxiolytics and amnestics.**
  - **Versed** (midazolam), 1–2 mg IV slowly (over 2 min).
  - **Scopolamine**, 0.4 mg IV.

- Induction agents and sedatives (Table 9-1).
## Emergency War Surgery

### Table 9-1. Induction Agents and Sedatives.

<table>
<thead>
<tr>
<th>Agent</th>
<th>Routine Dose*</th>
<th>Characteristics</th>
<th>Concerns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ketamine</td>
<td>1.0–2.0 mg/kg IV</td>
<td>Dissociative anesthetic and amnestic. Sympathomimetic effects (useful in hypovolemia). Potent bronchodilator.</td>
<td>Varying degrees of purposeful skeletal movement despite intense analgesia and amnesia.</td>
</tr>
<tr>
<td></td>
<td>4.0–8.0 mg/kg IM</td>
<td>Onset within 30–60 sec. Emergence delirium avoided with concomitant benzodiazepine use.</td>
<td>Increased salivation, consider an antialaglogue.</td>
</tr>
<tr>
<td>Barbiturates (eg, thiopental)</td>
<td>3–5 mg/kg</td>
<td>Onset within 30–60 seconds.</td>
<td>May cause profound hypotension in hypovolemic shock patients.</td>
</tr>
<tr>
<td>Propofol</td>
<td>1.5–2.5 mg/kg</td>
<td>Mixed in lipid, strict sterility must be ensured. Rapid onset and rapidly metabolized. Onset within 30–60 seconds.</td>
<td>Contraindicated in acute hypovolemic shock patients.</td>
</tr>
<tr>
<td>Etomidate</td>
<td>0.2–0.4 mg/kg</td>
<td>Onset within 30–60 seconds. Duration 3–10 min. Minimal cardiac effects. Minimal effects on peripheral and pulmonary circulation. Maintains cerebral perfusion.</td>
<td>May cause clonus.</td>
</tr>
</tbody>
</table>

* All induction agents can be used for induction of severely injured patients if reduced dosages are used (eg, 1/2 of the lower recommended dose). However, the recommended choice for hypovolemic patients would be Ketamine > etomidate >> thiopental > propofol.
Rapid Sequence Intubation (RSI) 7 steps*

1. Preoxygenate with 100% oxygen by mask.
2. Consider fentanyl—titrate to maintain adequate blood pressure and effect (2.0–2.5 µg/kg).
3. Cricoid pressure—Sellick maneuver until endotracheal tube (ETT) placement is confirmed and balloon is inflated.
4. Induction agent: etomidate 0.1–0.4 mg/kg IV push.
5. Muscle relaxant: succinylcholine 1.0–1.5 mg/kg IV push.
7. Verify tube placement.

*For children, see page 33.6.

- 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, laryngeal mask airway, lighted stylet).
  - Nasotracheal should generally not be performed.
  - Other considerations.
    - Maintain cricoid pressure until balloon inflated and tube position is confirmed.
    - Hypertension can be managed with short-acting medications such as beta blockers (labetalol, esmolol) or sodium nitroprusside.
    - May treat induction-related (transient) hypotension initially with small dose of ephedrine (5–10mg) or Neosynephrine (50 µg), but if hypotension persists after induction agents are metabolized, use fluids to treat the persistent hypovolemia. The anesthesiologist must convey this situation to the surgeon, as the need to control bleeding becomes urgent.
Emergency War Surgery

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

● Verify ETT placement.
  o Auscultate the lungs.
  o Measure the end-tidal CO₂.
  o Ensure that the SaO₂ remains high.
  o Palpate cuff of ETT in sternal notch.
  o Place the chemical CO₂ 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 and Breathing) Initially provide airway management with jaw-thrust, facemask oxygenation, and 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 airway.
● Reposition patient and anesthesia provider.
● Call for help.
● Consider alternatives to RSI.
  o Awake intubation.
  o Laryngeal mask airway.
  o Regional anesthesia or local anesthesia.
  o Surgical airway.

Maintenance of General Anesthesia

General Anesthesia Is Maintained After Intubation With

● Oxygen. Titrate to maintain SaO₂ > 92%.
● Ventilation.
  o Tidal volume (TV) 10–15 cc/kg.
  o Respiratory rate (RR) 6–10/min.
  o PEEP (positive end-expiratory pressure) if desired at 5 cm H₂O, titrate as necessary.
● Minimal alveolar concentration (MAC).
  o 0.3–0.5 MAC: awareness abolished although 50% of patients respond to verbal commands.
1 MAC: 50% of patients do not move to surgical stimulus.
1.2 MAC: 95% of patients do not move to surgical stimulus.
Common inhalation agent MACs:
- Halothane: 0.75%.
- Sevoflurane: 1.8%.
- Isoflurane: 1.17%.
- Enflurane: 1.63%.
- Nitrous Oxide ($N_2O$) = 104%.
- Additive effects (e.g., 60% $N_2O$ mixed with 0.8% sevoflurane yields 1 MAC).

- Total intravenous anesthesia (TIVA).
  - Mix midazolam 5 mg, vecuronium 10 mg, ketamine 200 mg in 50 cc normal saline (NS) and infuse at 0.5 cc/kg/h (stop 10–15 minutes before end of surgery).
  - Mix 50–100 µg of ketamine with 500 mg of propofol (50 cc of 10% propofol) and administer at 50–100 µg/kg/min (21–42 mL/h for a 70 kg patient).

- Balanced anesthesia (titration of drugs and gases) combine:
  - 0.4 MAC.
  - Versed 1–2 mg/h.
  - Ketamine 2–4 mg/kg/h.

**Conclusion of General Anesthesia**

- If the patient is to remain intubated, anesthetics may be terminated but sedatives and muscle relaxants are maintained.
- If the patient is to be extubated, ventilation is decreased to allow the patient to spontaneously breathe.
  - Anesthetic agents are stopped 5 minutes before conclusion of surgery.
  - Glycopyrrolate (Robinul) (0.01–0.02 mg/kg IV over 3–5 minutes) to decrease parasympathetic stimulation and secretions. This can be administered at the same time or before neostigmine.
  - Muscle relaxation reversal with neostigmine (0.04–0.08 mg/kg IV over 3–5 minutes, can be mixed in same syringe as glycopyrrolate).
- 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 is appropriate in small amounts so as not to eliminate the spontaneous respiratory drive.

### Regional Anesthesia

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 are listed below.

- 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 is encouraged when time and resources are available.

- Superficial cervical plexus block.
- Axillary brachial plexus block.
- IV regional anesthesia.
- 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, 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 combat support hospital (CSH) or higher level health care 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.

- **Neuraxial anesthesia.**
  - Subarachnoid block (SAB).
  - Epidural block.

*When the patient’s physical condition allows the use of spinal or epidural anesthesia those techniques are encouraged.* The sympatheticom 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 draw-over vaporizer and (2) a conventional portable ventilator machine. A schematic of the draw-over system is shown in Figure 9-1.

- **Draw-over vaporizer.**
  - Currently fielded model: Ohmeda Portable Anesthesia Complete (PAC).
  - 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 in-line vaporizer.
Optimal oxygen conservation requires a larger reservoir (oxygen economizer tube [OET]) than is described in the operator’s manual — a 3.5 ft OET optimizes $\text{FiO}_2$.

May be used with spontaneous or controlled ventilations.

Bolted-on performance chart outlines dial positions for some commonly used anesthetics (e.g., halothane, isoflu-rane, enflurane, and ether). **Ether is highly flammable; use extreme care.**

**Ohmeda UPAC Draw-Over Apparatus in Combination With the Impact Uni-Vent Eagle 754 Portable Ventilator:**

- Currently, there is no mechanical ventilator specifically designed for use with the UPAC draw-over apparatus, but use with various portable ventilators has been studied in both the draw-over and push-over configuration.
- Adding the ventilator frees the anesthesia provider’s hands while providing more uniform ventilation and more consistent concentrations of the inhalational anesthetic agent.

Fig. 9-1. Draw-over apparatus in combination with the ventilator.
The **draw-over** 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 754 in this configuration because the Uni-Vent Eagle 754 will preferentially deliver the compressed gases and will not entrain air/anesthetic gases from the UPAC draw-over.

The **push-over** 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 754 portable ventilator (Figure 9-1) 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 Draw-Over Apparatus.

The air-entrainment (side intake) port is used to create the draw-over/ventilator combination.

- The side intake port of the ventilator contains a nonreturn valve preventing back pressure on the vaporizer which could result in erratic and inconsistent anesthetic agent concentrations.

- The patient air-outlet port on the ventilator also contains a nonreturn valve, preventing back flow 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 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.

- O₂ extension tubing to attach supplemental O₂.
Two separate circuits should be constructed for use with the UPACTM/Uni-Vent Eagle 754 combination: one for induction and spontaneous ventilation and the second 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 Magellan 2000.
  - Compact version of standard OR machines, with comparable capabilities.
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

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

Diagnosis of a Wound Infection

- The four “-ors:” 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, such as clostridial gas gangrene or necrotizing fasciitis.
- Systemic effects such as 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.

The greatest threat of infection to the wounded battlefield casualty is the development of clostridial myonecrosis (gas gangrene), commonly due to *Clostridium perfringens*.

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.

*Clostridium tetani* can enter through any wound—even minor burns and corneal abrasions. Prophylaxis is required to prevent tetanus toxemia.

- **Intracranial**: Meningitis, encephalitis, and abscess, commonly due to staphylococci and Gram-negative rods, which are difficult to treat due to the impervious nature of the meninges to common antibiotics.
- **Orofacial and neck**: Gram-positive cocci and mouth anaerobes, generally responsive to surgery and clindamycin.
- **Thoracic cavity**: Empyema (usually staphylococcal) and pneumonia (*Staphylococcus, Streptococcus, Pseudomonas*), especially among those on prolonged mechanical ventilation or those casualties prone to aspiration (polymicrobial).
- **Intraabdominal**: Include posttraumatic or post-operative 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 debridement is the cornerstone of prophylaxis/treatment of war wound infections.**

**Treatment**

**General Principles**
- Surgical and antibiotic treatment should begin early 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 all dead material, bacterial contamination, and foreign material has been washed from the wound.
Emergency War Surgery

- Excessive irrigation, especially under pressure, should be avoided, because this can dilute the body’s natural immune cellular defenses and contribute to bacteremia.
- The skin is left open, and a lightly moistened sterile gauze dressing is applied.
- Antibiotics should be started ASAP 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, give antibiotics using regimen for established infection.
- The choice of empiric antibiotic is dependent on the part of the body injured (Table 10-1).
- 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 employed in abscess cavities to prevent premature closure and reformation.
  - Empiric broad-spectrum antibiotic therapy is initiated against likely pathogens and continued for 7 to 10 days.
  - Ideally, obtain cultures and tailor therapy to cover the actual pathogens recovered on Gram stain and culture. Routine bacteriology is often not available in forward medical facilities.
  - Because Bacteroides and Clostridia are difficult to culture, tailor antibiotic therapy to cover these organisms.
  - If the debrided wound still has possibly ischemic tissue or retained foreign material, the patient is returned to the OR every 1 to 2 days for redebridement, until absolute assurance of healthy, clean tissue is achieved.

Specific Infections
- Tetanus.
  - Battlefield wounds are “tetanus-prone” due to high levels of contamination with *Clostridium tetani*.
  - Bacteria grow anaerobically and release a CNS toxin that results in muscle spasm, trismus, neck rigidity, and back arching.
Table 10-1. Empiric Antibiotic Coverage for War Injuries.

<table>
<thead>
<tr>
<th>Site of Injury</th>
<th>Empiric Antibiotic</th>
<th>Covered Organisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cranium/penetrating injury</td>
<td>Ancef/Vanc + Flagyl</td>
<td>Gram positives + anaerobes</td>
</tr>
<tr>
<td></td>
<td>brain injury</td>
<td></td>
</tr>
<tr>
<td>Maxillofacial</td>
<td>Ancef + clindamycin</td>
<td>Gram positives + anaerobes</td>
</tr>
<tr>
<td>Neck</td>
<td>Ancef</td>
<td>Skin flora</td>
</tr>
<tr>
<td>Chest</td>
<td>Ancef</td>
<td>Skin flora</td>
</tr>
<tr>
<td>Abdomen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liver</td>
<td>Fluoroquinolone/2nd generation cephalosporin</td>
<td>Gram negatives, gram positives, + anaerobes</td>
</tr>
<tr>
<td>Gastrointestinal tract</td>
<td>Carbapenam/penicillin (Zosyn)</td>
<td>&quot;</td>
</tr>
<tr>
<td></td>
<td>with gross contamination</td>
<td></td>
</tr>
<tr>
<td>Gastrointestinal tract</td>
<td>2nd generation cephalosporin</td>
<td>&quot;</td>
</tr>
<tr>
<td></td>
<td>without gross contamination</td>
<td></td>
</tr>
<tr>
<td>Genitourinary</td>
<td>Aminoglycoside + 2nd generation cephalosporin</td>
<td>&quot;</td>
</tr>
<tr>
<td>Spleen</td>
<td>2nd generation cephalosporin + fluoroquinolone</td>
<td>&quot;</td>
</tr>
<tr>
<td></td>
<td>immunize splenectomy patients later for encapsulated organisms</td>
<td></td>
</tr>
<tr>
<td>Pelvic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With gastrointestinal injury</td>
<td>Carbapenam or combo penicillin</td>
<td>Gut flora + anaerobes</td>
</tr>
<tr>
<td>No gastrointestinal injury</td>
<td>2nd generation cephalosporin</td>
<td>Skin organisms</td>
</tr>
<tr>
<td>Extremity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soft tissue only</td>
<td>Ancef or 2nd generation cephalosporin</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ aminoglycoside</td>
<td></td>
</tr>
<tr>
<td>Bone/vascular involvement</td>
<td>2nd generation cephalosporin + fluoroquinolone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>aminoglycoside and fluoroquinolone</td>
<td></td>
</tr>
</tbody>
</table>

Treat gross contamination of any wound with debris from uniforms and the environment with broad spectrum Gram-negative and anaerobic coverage regardless of area of injury, e.g., Ancef + penicillin + gentamicin; or Unasyn alone.
In addition to surgical debridement of war wounds, additional prophylactic measures for tetanus-prone wounds include

- Administration of 0.5ml IM of tetanus toxoid if prior tetanus immunization is uncertain, less than three doses, or more than five years since last dose.
- Administration of 250–500 units 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).
  - Post-operative 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 under-treated cases.

♦ The diagnosis is made by history of severe unexpected wound pain 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 24–48 hours) debridement of all dead and infected tissue, combined with **antibiotics**.

♦ **Excision** of affected tissue must be as radical as necessary (including amputation or disarticulation) to remove all muscle that is discolored, noncontractile, nonbleeding, or suspicious.

♦ Identification of causative organisms often problematic: Treatment must be aimed at all possible organisms.

♦ **IV antibiotic** therapy.

♦ **Clindamycin**, 900 mg q8h; **plus penicillin G**, 4 million U q4; **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.
Emergency War Surgery

♦ Alternative regimen: penicillin G, 4 million U q4h plus imipenem, 500 mg q6h.

♦ **Intraabdominal infections.**
  ♦ **Prevention.**
    ♦ Regimens (start ASAP, continue x 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 q8h); plus gentamicin 5–7 mg/kg qd.
  ♦ **Established** intraabdominal infection (peritonitis or abscess).
    ♦ Same regimen as above, except continue for 7 to 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.
    ◇ Chest tube initially, and thoracotomy if unsuccessful.
    ◇ Cefotaxime, or ceftriaxone, or cefoxitin, or imipenem.
  ♦ **Pneumonia** is most frequently due to aspiration (eg, patients with head injury) and prolonged mechanical ventilation.
    ♦ The diagnosis is made through radiograph finding of a new pulmonary infiltrate that does not clear with chest physiotherapy, combined with
      ◇ Fever or leukocytosis.
      ◇ 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 proven effective.
    ◇ **Ventilator-associated pneumonia**: *staphylococcus, Pseudomonas*, and other nosocomial *Enterobacteiraeae*. Broad coverage is best with such agents as imipenem,
Infections
ciprofloxacin, vancomycin, and/or ceftazidime, plus an aminoglycoside.

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 manifest by systemic hypoperfusion: profound hypotension, mental obtundation, or lactic acidosis. Treatment is a three-pronged approach:
- Identify and eradicate the source.
- Broad-spectrum intravenous antibiotics for the most likely pathogens.
- ICU support for failing organ systems, such as cardiovascular collapse, acute renal failure, and respiratory failure.
It is often difficult to identify the source of sepsis, but it is the **most 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.
- Acute calcemic cholecystitis.
Intensive care support for sepsis involves vigorous resuscitation to restore perfusion to prevent multiple organ dysfunction. This requires optimization of hemodynamic parameters (pulmonary artery occlusion pressure, cardiac output, and oxygen delivery) to reverse anaerobic metabolism and lactic acidosis. Endpoints of resuscitation, such as urine output, base deficit, and blood lactate levels guide successful treatment. Until the source for sepsis is identified and actual pathogens isolated, empiric therapy with broad-spectrum intravenous antibiotics is warranted. Suitable regimens might include
• Imipenem, 500 mg q6h.
• Piperacillin and tazobactam (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 once-daily dosing strategy and no renal impairment); or ciprofloxacin, 400 mg q12h.
• Addition of vancomycin, 1.0 g q12h if methicillin-resistant *Staphylococcus aureus* is a likely pathogen.
• Addition of linezolid, 600 mg q12h if vancomycin-resistant enterococcus (VRE) is a likely pathogen.

**Conclusion**

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 in the wound. The key to avoiding wound infection is prompt and adequate wound exploration, removal of all foreign material, and excision of all dead tissue. All battlefield wounds and incisions should have the skin left open. Antibiotics play an adjunctive role in the prophylaxis of wound and other infections in the battlefield MTF. Knowledge of likely pathogens for particular infections and sites, as well as optimal antibiotics to eradicate those pathogens (Table 10-2), will aid the battlefield clinician in averting and treating infections.
Table 10-2. Spectrum and Dosage of Selected Antibiotic Agents.

<table>
<thead>
<tr>
<th>Agent</th>
<th>Antibacterial Spectrum</th>
<th>Dosage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penicillin G</td>
<td><em>Streptococcus pyogenes</em>, penicillin-sensitive <em>Streptococcus pneumonia</em>, clostridial sp</td>
<td>4 mil U IV q4h</td>
</tr>
<tr>
<td>Ampicillin</td>
<td>Enterococcal sp, streptococcal sp, <em>Proteus</em>, some <em>E coli</em>, <em>Klebsiella</em></td>
<td>2 g IV q6h</td>
</tr>
<tr>
<td>Ampicillin/sulbactam</td>
<td>Enterococcal sp, streptococcal sp, <em>Staphylococcus</em>, <em>E coli</em>, <em>Proteus</em>, <em>Klebsiella</em>, Clostridial sp, Bacteroides/Prevotella sp</td>
<td>3 g IV q6h</td>
</tr>
<tr>
<td>Nafcillin</td>
<td>Staphylococcal sp, <em>streptococcal sp</em></td>
<td>1 g IV q4h</td>
</tr>
<tr>
<td>Piperacillin/tazobactam</td>
<td>Enterococcal sp, streptococcal sp, <em>Staphylococcus</em>, <em>E coli</em>, <em>Pseudomonas</em> and other enterobacteriaceae, clostridial sp, Bacteroides/Prevotella sp</td>
<td>3.375 g IV q6h</td>
</tr>
<tr>
<td>Imipenem</td>
<td>Enterococcal sp, streptococcal sp, <em>Staphylococcus</em>, <em>E coli</em>, <em>Pseudomonas</em> and other enterobacteriaceae, clostridial sp, Bacteroides/Prevotella sp</td>
<td>500 mg IV q6h</td>
</tr>
<tr>
<td>Cefazolin</td>
<td>Staphylococcal sp, <em>streptococcal sp</em>, <em>E coli</em>, <em>Klebsiella</em>, <em>Proteus</em></td>
<td>1.0 g IV q8h</td>
</tr>
<tr>
<td>Cefoxitin</td>
<td>Staphylococcal sp, <em>streptococcal sp</em>, <em>E coli</em> and similar enterobacteriaceae, clostridial sp, Bacteroides/Prevotella sp</td>
<td>1.0 g IV q6h</td>
</tr>
<tr>
<td>Ceftriaxone</td>
<td><em>Streptococcus sp</em>, staphylococcal sp, <em>Neisseria sp</em>, <em>E coli</em> and most enterobacteriaceae (NOT <em>Pseudomonas</em>), clostridial sp</td>
<td>2.0 g q12h</td>
</tr>
<tr>
<td>Ciprofloxacin</td>
<td><em>E coli</em>, <em>Pseudomonas</em> and other enterobacteriaceae</td>
<td>400 mg q12h</td>
</tr>
<tr>
<td>Gentamycin</td>
<td><em>E coli</em>, <em>Pseudomonas</em> and other enterobacteriaceae</td>
<td>5–7 mg/kg qd (based on once-daily dosing strategy and no renal impairment)</td>
</tr>
<tr>
<td>Vancomycin</td>
<td><em>Streptococcal</em>, enterococcal, and staphylococcal species (including MRSA; not VRE)</td>
<td>1.0 g q12h</td>
</tr>
<tr>
<td>Erythromycin</td>
<td><em>Streptococcus sp</em>, clostridial sp</td>
<td>0.5–1.0 g q6h</td>
</tr>
<tr>
<td>Clindamycin</td>
<td><em>Streptococcus sp</em>, <em>Staphylococcus sp</em>, <em>clostridial sp</em>, Bacteroides, and Prevotella sp</td>
<td>900 mg q8h</td>
</tr>
<tr>
<td>Metronidazole</td>
<td>Clostridial sp, Bacteroides and Prevotella sp</td>
<td>500 mg q6h</td>
</tr>
</tbody>
</table>

*Not methicillin resistant *Staphylococcus aureus* (MRSA)

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