Chapter 11

Critical Care

Introduction
Each battlefield ICU should have a dedicated intensive care physician, due to the severity and lethality of blast and high-velocity wounds, and the need for ongoing resuscitation of casualties requiring damage control.

| Damage control is the initial control of hemorrhage and contamination followed by intraperitoneal packing and rapid closure, then resuscitation to normal physiology in the intensive care unit and subsequent definitive re-exploration. This places large logistic requirements on the ICU. This may include rewarming, large-volume resuscitation, blood products, vasoactive drugs, and mechanical ventilation. |

The ICU physician should observe the following guidelines:

- **Reexamine** (possibly, retriage) the patient, using detailed primary and secondary surveys, with attention to the “ABCs,” potential life-threatening injuries, and other injuries missed during the ER and OR phases of resuscitation (tertiary survey).

  | Trust no one’s examination before your own because the patient’s condition may have changed, or prior examinations may be inaccurate or incomplete. |

- Provide necessary available monitoring of physiology, with periodic assessment of pain control, level of consciousness, and intake and output.

- **Resuscitate** from shock, using appropriate endpoints.

- **Provide organ-specific support**, as is done for CNS injury, pulmonary failure, cardiovascular collapse, and renal dysfunction.
Emergency War Surgery

- Ensure adequate pain control.
  - Use IV (not IM) narcotic agents in sufficient doses to alleviate pain.
  - Patients on mechanical ventilation require both narcotics (morphine, fentanyl) and sedatives (propofol, lorazepam, midazolam).
- Prepare the patient for transport out of theater.
- Important caveats for the intensivist.
  - “Patients don’t often suddenly deteriorate; healthcare providers suddenly notice!”
  - The organ system approach, in which each organ system in turn is addressed in a mini-SOAP format, ensures that each of the body’s physiologic systems is addressed in a complete, comprehensive, and integral fashion.
  - The systemic inflammatory response (SIRS) is a common metabolic sequela of severe injury, not always associated with infection.

Fever or leukocytosis should prompt a thorough search for infection. Antibiotic discipline must be enforced, saving these medications for short-course prophylaxis, documented infection, or empiric treatment of rapid deterioration due to sepsis.

Resuscitation From Shock
Shock can be defined as an acute state of cardiovascular insufficiency resulting in life-threatening global hypoperfusion. Hemorrhagic shock is the most common form of shock following major trauma. Therefore, initial efforts should be directed toward correction of hypovolemia.

Hypoperfusion implies inadequate delivery of oxygen to the body’s cells. Oxygen delivery is a function of cardiac performance, arterial hemoglobin content, and arterial oxygen saturation. All attempts to correct shock involve optimizing these three variables.
Shock resuscitation is approached in two phases, based on endpoints of resuscitation:

- **In the first phase**, resuscitate to a mean arterial pressure of > 60 mm Hg, a urine output of 0.5 cc/kg/h (at least 30 ccs/h), and arterial oxygen saturation of > 92%.
- Pursue endpoints aggressively to eliminate hypoperfusion, ideally within 1 hour (see Chapter 7, Shock and Resuscitation).
- **In the second phase**, resuscitation is continued primarily with fluid, to eliminate metabolic acidosis (restore lactate to normal) within 24 hours.
- The resuscitative fluid of choice is a warmed, balanced crystalloid solution (normal saline or lactated Ringer’s) and is preferable to colloid.
- Rate of infusion for resuscitation should be 500 mL to 1,000 mL bolus over 15–20 minutes and repeated as necessary.
- After 3 L of crystalloid, blood products should generally follow at similar rates.

Vasopressor agents should **only** be considered for achieving minimal acceptable blood pressure **after** fluid boluses and confirmation of adequate intravascular volume.

- Dopamine, norepinephrine, and phenylephrine are the preferred vasoactive agents, starting in the lower dose range.
- Dobutamine should only be considered for demonstrated cardiac dysfunction, which may be seen in sepsis, the elderly, or myocardial infarction (MI).

**Specific Organ Systems**

**Traumatic Brain Injury/CNS**

Transient hypoxemia or hypotension in the patient with significant traumatic brain injury doubles the probability of death or poor neurologic outcome. The goal of treatment is to maintain cerebral perfusion pressure (CPP) and oxygenation.
Emergency War Surgery

- Identify potential intracranial surgical lesions for possible emergent craniotomy.
- Prevent hypoxemia: Maintain O₂ sat > 92%, PaO₂ > 100, and intubate for GCS ≤ 8.
- Prevent hypotension.
  - Maintain SBP > 100 mm Hg, MAP > 80.
    - MAP = DBP + ⅓ (SBP - DBP).
- Prevent, monitor, and treat intracranial hypertension.
  - Maintain intracranial pressure (ICP) = 5–15 mm Hg.
  - Maintain CPP = 70–90 mm Hg.
    - CPP = MAP – ICP
- **Measures to treat intracranial hypertension** include:
  - Elevation of head of bed 30° may be helpful.
  - Recognize that high levels of PEEP may raise ICP.
  - Control serum osmolarity.
    - Normal saline is the preferred IV solution.
    - Check serum sodium twice daily, and keep in the range of 145–150 mEq/dL.
    - IV mannitol (not in anuric patients), 0.25–1.0 g/kg, every 6–8 hours to keep serum osmolarity optimal.
  - Control PaCO₂.
    - Hypercarbia should always be prevented. Modest therapeutic hyperventilation may be used (PaCO₂ 30–35 mm Hg) for brief periods in the deteriorating patient.
      - Beneficial effects of hyperventilation/hypocarbia must be balanced: it reduces ICP through vasoconstriction, but also reduces cerebral blood flow.
      - **Prophylactic hyperventilation should not be used.**
        - Removal of cerebrospinal fluid by placement of an intraventricular catheter.
        - Barbiturates have unproven benefit but may be considered in extreme cases.
        - Craniotomy with bone and brain removal is a drastic, lifesaving procedure of last resort in the moribund patient.
  - Steroids have no role in traumatic brain injury treatment.

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Avoid hyperthermia, because this raises ICP.

- General Considerations.
  - Appropriate precautions should be taken (H₂ blocker, heparin, and oral care) to prevent development of stress gastritis, deep venous thrombosis, and aspiration pneumonitis.
  - If coagulopathy develops, use blood products as necessary to correct an elevated prothrombin time.
  - Prevent and aggressively treat pain, agitation, shivering, and fever to avoid increased cerebral metabolism and oxygen consumption.
  - Hyperglycemia has an adverse effect on outcome and should be monitored and treated aggressively to keep glucose levels between 100–150 mg/dL.
  - Seizure prophylaxis. Phenytoin/phosphenytoin should be administered to therapeutic levels in the penetrating head-injured patient, and to blunt head-injury patients with seizure.

Pulmonary System and Ventilators

- General Considerations
  - Supplemental oxygen in the early phase of resuscitation is imperative. The maximum fraction of inspired oxygen (FIO₂) delivered by:
    - Nasal cannula approaches 0.35.
    - Venturi mask is 0.50.
    - Non-rebreathing reservoir mask approaches 0.90.
  - Monitoring: May include portable chest radiographs, periodic ABGs, regular assessments of level of sedation, airway pressures, and functioning of ventilator alarms.

Airway Considerations

- Indications for endotracheal intubation and mechanical ventilation include:
  - Airway obstruction due to trauma, edema, excess secretions.
  - Apnea.
Emergency War Surgery

- Excessive work of breathing (e.g., flail chest), as indicated by accessory muscle use, fatigue, diaphoresis, or tachypnea when respiratory failure is imminent.
- Decreased level of consciousness: GSC ≤ 8.
- Hypoxia: SaO2 < 90%, PaO2 < 60 mmHg on FIO2 > 50%.
- Hypercarbia: PaCO2 > 60 mm Hg acutely (lower threshold with tachypnea).
- Shock.
- **Caution:** Patients not meeting the above criteria may still require airway protection and mechanical ventilation preceding prolonged transport.

**Field Ventilator.**
- Impact Uni-Vent Eagle 754.
  - Basic settings.
    - Turn the ventilator on and set the mode using the **Mode Selector Switch** (lower right). Most patients can be well ventilated using SIMV (synchronized intermittent mandatory ventilation).
    - Set FIO2 using the **Air/Oxygen Mixer Control**, above the Mode Selector Switch. Generally, ICU patients should be started at an FIO2 of 1.0, and weaned as appropriate to a level of 0.40.
    - Set minute ventilation using **Tidal Volume** and **Ventilation Rate** controls. The tidal volume is set at 6–10 mL/kg. Initial rate is set at 10–14 breaths/minute and titrated to normalize PaCO2.
    - Set positive end-expiratory pressure (PEEP) using the **PEEP Control** located on the upper left of the control panel. Initial PEEP is usually set at 5 cm H2O. Higher values can be set in severe respiratory failure such as adult respiratory distress syndrome (ARDS), although generally not higher than 15 cm H2O.

**Summary of typical initial settings for mechanical ventilator:** FIO2 1.0, SIMV mode, rate 12, tidal volume 800 mL, PEEP 5 cm H2O.
ARDS
- ARDS can start within days of injury, and should be suspected in any casualty with:
  - Acute hypoxemia (PaO₂/FIO₂ ratio < 200).
  - Progressive fall in pulmonary compliance (stiff lungs, increasing airway pressures).
  - Bilateral alveolar infiltrates on chest radiograph, with no clinical evidence of volume overload.

Mechanical Ventilation Priorities in ARDS
- Maintain patient analgesia and sedation to prevent agitation and ventilator/patient asynchrony.
- Keep SaO₂ > 90% by increasing FIO₂ and/or PEEP (maximum 15–18 cm H₂O).
- Avoid prolonged FIO₂ > 0.60 due to O₂ toxicity.
- Avoid respiratory acidosis. Keep PaCO₂ 35–45 mm Hg, and arterial blood pH > 7.25.
- Keep peak inspiratory pressure (PIP) < 40 cm H₂O to prevent iatrogenic pneumothorax and destruction of normal lung tissue.
  - Decrease tidal volume to 5–7 mL/kg.
  - Increase ventilator rate.
  - If other measures are unsuccessful, allow permissive hypercapnia by accepting a respiratory acidosis (PaCO₂ 55–70 mm Hg). Use bicarb to maintain pH > 7.2.

Respiratory acidosis is less dangerous than ventilator-induced lung injury caused by high PIP and high tidal volumes.

Cardiovascular System
- The patient who exhibits cardiovascular deterioration after a period of apparent stability should be evaluated to rule out the following:
  - Hypoxia or loss of airway.
  - Tension pneumothorax.
  - Recurrent bleeding from sites of injury or surgery.
  - Cardiac tamponade or direct myocardial injury.
Emergency War Surgery

- Tachyarrhythmia.
- Fluid loss due to “third-spacing,” burns, fever, diarrhea, or vomiting.
- Undiagnosed injury: intestinal injury, pancreatitis, or infection.
- Vasodilatation due to spinal shock, epidural anesthesia/analgesia, and sepsis.
- Side effect from medication.
- GI bleeding.
- Pulmonary embolus.
- Abdominal compartment syndrome.
- Excessive airway pressures from mechanical ventilation can directly decrease cardiac ventricular function and decrease venous preload.

- Management.
  - Support cardiovascular system by monitoring end-organ perfusion (urine output, capillary refill) and using four parameters of hemodynamic performance:
    - **Preload** (Best index: pulmonary capillary wedge pressure – PCWP).
    - **Afterload** (systemic vascular resistance [SVR] = [MAP − CVP]/ CO • 80).
    - **Heart rate**.
    - **Cardiac contractility** (best index: stroke volume; SV = CO/h).
  - “Make do” with the best information available—use CVP when PA catheter unavailable.
  - For hypovolemia and cardiovascular instability due to sepsis:
    - Assure adequate preload by volume repletion before adjusting other variables (eg, adding inotropes for low cardiac output).
    - In other states of cardiovascular instability, the variable manipulated is the one indicative of the major problem.

Sinus tachycardia may be a sign of an underlying problem (eg, hypoxia, hypovolemia, infection, or pain). Seek and treat the primary problem, not the tachycardia.
**Myocardial ischemia/infarction (MI)** is an uncommon battlefield problem.

- Suspicion is aroused when the patient exhibits angina-like chest pain or unexplained cardiac instability (arrhythmias or hypotension).
- The diagnosis of an acute myocardial event is made by the presence of ST segment elevation or depression on 12-lead ECG and/or an abnormal elevation of serum markers of myocardial injury (myoglobin [MB] fraction of creatine phosphokinase, Troponin I).

**Emergency treatment for MI.**

- Supplemental O₂.
- Morphine for pain, rest.
- Aspirin 325 mg tablet chewed and swallowed (then one tablet PO qd).
- NTG SL (0.4 mg tablet every 5 minutes until pain relieved, maximum 3 doses) or IV infusion depending on severity of condition.
- Beta-blocker such as metoprolol (5–15 mg IV slowly q6h or 50–100 mg PO q12h) or atenolol (50–100 mg PO) on diagnosis and daily.
- As resources and patient condition permit for MI with diagnostic ECG: Optimal therapy would also include, within 6 hours of symptoms, IV heparin and a thrombolytic such as tissue plasminogen activator.

**Renal System and Electrolytes**

- Monitor urine output, blood urea nitrogen (BUN), serum creatinine, and serum electrolytes.
- Acute renal failure (ARF) is manifested by oliguria (< 0.5 cc/kg/h) and a rise in BUN and creatinine. The most frequent causes for ARF are:
  - Hypovolemia.
  - Acute tubular necrosis (ATN) due to:
    - Hypovolemia.
    - Sepsis, IV contrast agents, aminoglycoside antibiotics, or NSAIDs.
  - Crush, massive, soft-tissue injury or compartment syndrome, with resultant rhabdomyolysis and myoglobinuria.
In ARF due to rhabdomyolysis, consider administering large volumes of IV fluid (300–800 mL/h), combined with 50 mEq NaHCO₃/L, to alkalinize the urine with the goal of achieving a urine output of 2.0 cc/kg/h.

Bilateral renal or ureteral trauma.

Two hours of oliguria (< 20cc/h) in an ICU patient (almost always due to inadequate resuscitation) warrants aggressive, immediate action.

Algorithm for hemodynamically stable ICU patient with profound oliguria or anuria:

- Irrigate or replace Foley catheter to ensure function.
- After ensuring no signs of intravascular volume overload (diffuse pulmonary crackles, S3 heart sound), administer bolus of 1–2 L IV saline over 30 minutes.
- Review medication list and medical history to elicit potential factors causing ARF; stop any agents that could contribute.
- Send any urine to lab with serum sample to calculate fractional excretion of sodium (FENA) = (UNA • P_cr)/(P_Na • U_cr); FENA < 1.0 indicates prerenal cause (eg, hypovolemia); FENA > 2.0 points to renal insult (ATN; myoglobinuria) or postrenal cause (obstruction).
- Consider sonogram of kidneys to rule out bilateral renal obstruction.
- Consider pulmonary artery catheter to optimize preload (PCWP).
- Once PCWP > 16–18 mm Hg, and urine output minimal/nonexistent, administer furosemide in escalating doses IV bolus: 40, 80, 160, 240 mg max ( > 100mg = ototoxic). Combine last dose with single dose 1.0 g chlorothiazide IV, or administer 10 mg metolazone PO given 30 minutes before last dose. Also consider furosemide drip or metolazone drip.

If ineffective or if other complications of ARF occur, arrange for dialysis as a temporizing renal support until spontaneous renal recovery occurs. This means the physician must optimize the casualty for transport out of theater, with special attention to volume status, potassium, and acid base status.
Indications for dialysis in the casualty with ARF:

- Anuria beyond 8–12 hours.
- Hypervolemia.
- Hyperkalemia.
- Acidosi.
- Complications of uremia: mental status changes, pericardial rub.
- Toxic levels of drugs/medications (eg, digoxin).

Hyperkalemia.

- Verify again hyperkalemia (serum K > 6 mEq/L) and serum pH.
- Give IV calcium chloride, 10 mL of 10% solution over 5 minutes.
- Give IV NaHCO₃, 50 mEq over 5 minutes.
- Give IV Dextrose (50g D50) 50 grams + 10 units regular insulin IV over 10 minutes.
- Recheck K⁺.
- Give beta-agonist albuterol 10–20 mg over 15 minutes by inhalation.
- Consider enteral K-binding with enema of sodium polystyrene sulfonate, 25–50 g, in sorbitol.

Hypokalemia: Treatment: 10–20 mEq KCl IV/hour in monitored setting; difficult to treat hypokalemia unless concomitant hypomagnesemia is first corrected.

Hypernatremia: Usually indicative of free water deficit. Water deficit (L) = 0.6 • weight (kg) • [(measured serum Na)/(normal serum Na of 140) – 1]. Half of this deficit should be replaced over first 12–24 hours, and the remainder over the next 1–2 days.

Hyponatremia: Indicative of excess of free water or vasopressin (SIADH). Levels of serum sodium < 125 mEq/L are associated with mental status changes or seizures. Treatment should involve free water restriction or use of IV normal saline, with goal of correction of sodium level no more than 15 mEq/L over 24 hours, to prevent complication of central pontine myelinolysis.

Hypophosphatemia: Phosphate is important as an energy source, and should be repleted to level of 2.5 mg/dL with IV KPO₄ or NaPO₄, 30 mMol over 1 hour.
Emergency War Surgery

- **Hyperphosphatemia** (usually associated with ARF): Phosphate levels over 6.0 mg/dL should be treated by enteral binding agents, such as calcium acetate or sucralfate.

- **Hypomagnesemia**: Administer 2 g magnesium sulfate IV in solution over 60 minutes to goal of serum level of 2.0 mEq/dL.

- **Metabolic acidosis**: Primarily lactic (most commonly due to hypovolemia) and ketoacidosis. Neither should be treated with sodium bicarbonate (it is contraindicated in lactic acidosis). Sodium bicarbonate has very limited role in ICU disorders: hyperkalemia, alkalinization of urine in myoglobinuria, bicarbonate-responsive renal tubular acidosis (RTA), and for massive gastrointestinal losses of bicarbonate (profound diarrhea, enterocutaneous fistula).

- **Metabolic alkalosis**: NG suction of stomach acid causes a hypochloremic alkalosis, responsive to replacement of NG losses with crystalloid. Excessive loop diuretic use can also cause metabolic (contraction) alkalosis. If further diuresis is needed, use a carbonic anhydrase inhibitor (acetazolamide 250 mg IV every 6 h) for 1–2 days.

**Hematologic System**

- Most common coagulation disorder: dilutional coagulopathy.
  - Others include heparin-induced thrombocytopenia, disseminated intravascular coagulation, coagulopathy due to hypothermia or diffuse hepatic damage, and thrombocytopenia.
  - Most require replacement transfusion of appropriate blood products.

- To prevent trauma-related deep venous thrombosis (DVT) and pulmonary embolism, prophylactic measures (subcutaneous heparin or sequential compression devices) are required.

**Gastrointestinal System and Nutrition**

- Prolonged shock can lead to GI dysfunction.
  - **Stress gastritis**: Increased risk of severe head injuries or burns, mechanical ventilation, systemic anticoagulation therapy, or sepsis. Prevention: sucralfate, histamine-2 receptor antagonist (eg, ranitidine) or a proton pump inhibitor (eg, omeprazole).
O Acalculous cholecystitis: Suspect with right upper quadrant abdominal pain, abnormalities in liver function tests, or fever/leukocytosis of unclear cause. Ultrasound shows gallbladder inflammation with wall thickening or pericholecystic fluid. Treatment: broad-spectrum antibiotics and ultrasound-guided percutaneous drainage or operation.

O Hepatic failure portends a dire prognosis. Initial signs include hyperbilirubinemia, elevation of the prothrombin time, hypoalbuminemia, profound hypoglycemia, obtundation. Massive amounts of fresh frozen plasma are required to prevent exsanguination from coagulopathy.

- **Nutrition** can prove problematic in the battlefield ICU patient.
  - Systemic inflammation induced by severe injury often results in catabolism and protein wasting, making early nutritional support imperative.
  - Nutrition should commence within 24–48 hours of injury.
  - Enteral feedings are superior to parenteral nutrition (TPN), offering a lower infection rate and shorter ICU stays.
  - The following goals serve to guide nutritional management:
    - Caloric requirement: 25–30 kcal/kg/d.
    - Protein requirement: 1.0–1.5 g/kg/d.
    - 30%–40% of total caloric intake per day should be as fat.
  - Nutrition should include a balanced electrolyte solution containing supplemental potassium, calcium, magnesium, phosphate, multivitamins and trace elements (zinc, copper, manganese, and chromium).
  - The two most common problems associated with enteral nutrition are diarrhea and aspiration.
    - Aspiration can be associated with severe pneumonitis, but can be prevented by:
      - Keeping the head of the bed up.
      - Feeding into the jejunum or duodenum rather than the stomach.
      - Checking gastric residuals every 4 hours (feedings should be stopped if residual greater than 200 mL).
    - Diarrhea can be alleviated by:
      - Decreasing the osmolarity of the enteral solution.
      - Adding fiber.
      - Agents such as loperamide in small doses.
Immune System and Infections

- Differential diagnosis of ICU infections.
  - Pneumonia (nosocomial or aspiration).
  - Central venous catheter infection – if considered, remove catheter.
  - UTI.
  - Wound or soft-tissue infection.
  - Intra-abdominal abscess (especially following laparotomy).
  - Systemic fungal infection.
  - Sinusitis.
  - Acalculous cholecystitis.
  - Pancreatitis.

- Prophylactic antibiotics.
  - A short course of prophylactic antibiotics (24–48 h) is warranted after penetrating injury on the battlefield.
  - After this, antibiotics should be withheld unless a documented infection is confirmed, or a severe deterioration in clinical status suggestive of sepsis is encountered.
  - Sepsis warrants a short course of broad spectrum IV antibiotics, but they must be stopped in 72 hours if no microbiologic pathogens are confirmed by culture.
  - Fever and leukocytosis, by themselves, are not sufficient justification for antibiotics.

Endocrine System

- Hyperglycemia.
  - Control, to prevent ketoacidosis, hyperosmolar coma, and intravascular volume loss due to osmotic diuresis.
  - The two most common causes are uncontrolled or unrecognized infections and the use of TPN.
  - The best technique for control of hyperglycemia is a constant IV infusion of insulin, usually 1.0–10 units per hour.
    - Due to frequent problems with patient perfusion, subcutaneous injections are less reliable in the ICU patient.
    - Patients with profound hyperglycemia (serum glucose > 800 mg/dL) and volume depletion, due to osmotic diuresis, should receive fluid resuscitation with crystalloid
before receiving insulin, to prevent further shifts in intravascular volume as the glucose shifts intracellularly.

- Limit correction rate to 100 mg/dL per hour (700 mg/dL takes 7 h to correct) and assess for resultant hypokalemia.
- Corticosteroids are rarely indicated after major trauma.
  - There is no proven benefit to steroid treatment for closed head injury or sepsis.
  - Steroids are indicated for proven adrenocortical deficiency (a rare occurrence among battlefield casualties) and spinal cord injury with neurologic deficit.

Musculoskeletal System
- Monitor for the development of compartment syndrome, vascular ischemia, and rhabdomyolysis.
- Distal extremities should be assessed regularly for neurovascular status: presence of pulses, sensation, motor function, warmth, and skin color.

Preparation for Evacuation
- Optimally, the combat casualty will be medically stabilized before transport out of theater.
  - Native or mechanical airway is maintained.
  - Sufficient blood pressure, to allow organ perfusion, that has been stable for at least 8 hours.
  - Both primary and secondary phases of shock resuscitation have been completed.
  - All sources of bleeding have been identified and controlled.
  - Life-saving or definitive surgery not required for the next 24 hours.
- Transfer out of a battlefield ICU requires a USAF Critical Care Air Transport Team (CCATT) with physician-to-physician and nurse-to-nurse communication to summarize condition of the patient, operations performed, treatment being given, and support required during flight (in particular, need for oxygen, mechanical ventilation, suction, blood products, and monitoring).
- Copies of medical records, radiographs, 3 days of IV fluid, and all medications should accompany the patient.
Chapter 12

Damage Control Surgery

Introduction
The traditional approach to combat injury care is surgical exploration with definitive repair of all injuries. This approach is successful when there are a limited number of injuries. Prolonged operative times and persistent bleeding lead to the lethal triad of coagulopathy, acidosis, and hypothermia, resulting in a mortality of 90%.

What might increase the life and limb salvage rate in troops in the field setting is the application of the damage control concepts described above in patients with favorable physiology.

Tactical Abbreviated Surgical Control (TASC).
- Damage control techniques in a tactical environment.
- Abbreviated, focused operative interventions for peripheral vascular injuries, extensive bone and soft tissue injuries, and thoracoabdominal penetrations in patients expected to survive, instead of definitive surgery for every casualty.
- This may conserve precious resources, such as time, operating table space, and blood.

This TASC philosophy relies on further definitive surgical care at the next echelon of care.
Damage control techniques should be considered in all multi-system casualties at the onset of surgical therapy. When initially rejected, reconsideration should occur when unexpected findings are discovered or natural breaks in the surgical therapy occur, following an initial decision to perform a definitive repair.

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

1. **Primary Operation and Hemorrhage Control** – surgical control of hemorrhage and removal of contamination; laparotomy terminated, abdomen packed and temporary closure; definitive repair is deferred.

2. **Critical Care Considerations** – normal physiology restored in ICU by core rewarming, correction of coagulopathy, and hemodynamic normalization.

3. **Planned Reoperation** – re-exploration to complete the definitive surgical management or evacuation.

**General Considerations**

- Philosophy of damage control is “a live patient above all else.”
  - Avoid hypothermia.
  - Rapidly achieve hemostasis.
  - Perform only essential bowel resections.
  - Close or divert all hollow viscus injuries, only performing reconstruction at the second operation after the patient has stabilized and can tolerate a prolonged operation.

- **When to employ damage control.**
  - Use damage control in patients who are present with or at risk for developing:
    - Multiple life-threatening injuries.
    - Acidosis (pH < 7.2).
    - Hypothermia (temp < 34°C).
    - Hypotension and shock on presentation.
    - Combined hollow viscus and vascular or vascularized organ injury.
    - Coagulopathy (PT > 19 sec and/or PTT > 60 sec).
Damage Control Surgery

♦ Mass casualty situation.
  o Take into account ability to control hemorrhage, severity of liver injury, and associated injuries.
  o Pack **before** massive blood loss (10–15 units of pRBCs) has occurred.
  o Injuries that typically require damage control techniques.
    ♦ Upper abdominal injuries that are not isolated spleen injuries (duodenal, large liver injuries, pancreas, and so forth).
    ♦ Major penetrating pelvic trauma of more than one system.
    ♦ Any retroperitoneal vascular injury.

To reiterate, damage control is practiced in three phases:
  1. Primary operation and hemorrhage control.
  2. Critical care resuscitation.
  3. Planned reoperation.

Phase 1: Primary Operation and Hemorrhage Control
Phase 1 of damage control includes 5 distinct steps:
  1. Control of hemorrhage.
  2. Exploration to determine extent of injury.
  3. Control of contamination.
  4. Therapeutic packing.
  5. Abdominal closure.

♦ Control of hemorrhage/Vascular injury repair.
  o Control of hemorrhage is best done with ligation, shunting, or repair of injured vessels as they are encountered.
  o The primary goal is hemorrhage control, not maintenance of blood flow.
  o For the patient in extremis, clamping or shunting of major vessels is recommended over repair.
    ♦ THINK: ligate/shunt ⇒ fasciotomy.
  o Additional methods of hemorrhage control include balloon catheter tamponade of vascular or solid viscus injuries.

♦ Exploration to determine extent of injury.
  o Damage control laparotomy.
    ♦ Rapidly achieve hemostasis.
Perform only essential resections or pack solid organs to diminish blood loss.

Close or divert all hollow viscus injuries.

Rapidly terminate the procedure to correct hypovolemia, hypothermia, and acidosis to prevent coagulopathy.

Perform definitive reconstruction only after the patient has stabilized and can tolerate a prolonged operation.

- Control of Contamination.
  - Contamination control also proceeds as injuries are encountered, utilizing clamps, primary repair or resection without reanastomosis.
  - With multiple enterotomies, if the area of injury represents less than 50% of the length of the small bowel, a single resection can be undertaken.
  - At this stage of the operation, the surgeon must decide whether or not to proceed with definitive repair of the identified and controlled injuries. Careful communication with the anesthesiologist is critical to this decision.
  - If aggressive resuscitation has been successful in maintaining normal temperature, coagulation, and acid base status, then definitive repair may proceed.
  - If any of these interrelated factors are abnormal, the procedure should be terminated (contamination controlled without reanastomosis) and the patient taken to the ICU for further resuscitation.
  - The presence and status of extra-abdominal injuries needs to be taken into consideration when deciding how much physiologic reserve the patient has left.

- Therapeutic Packing.
  - Resuscitative vs Therapeutic Packing.
    - Resuscitative packing is manual compression of the bleeding site as an initial measure in controlling or minimizing blood loss.
    - Therapeutic packing provides long-term tamponade of liver, pelvic, and retroperitoneal bleeding.
  - Do not use the “pack and peek” technique wherein the liver is packed and the patient resuscitated; the packs are removed to identify the source of bleeding, but rebleeding
occurs before the site can be identified; the liver is packed again; the patient is resuscitated again; and the entire cycle is repeated.

- Definitive therapeutic packing is based on three basic principles.
  - Pressure stops bleeding.
  - Pressure vectors should recreate tissue planes (attempt to recreate the pressure vectors created by the capsule of a solid organ or fill the space of that organ, not random pack placement).
  - Tissue viability must be preserved.
- 6–12 laparotomy pads are the best commonly available packing material.
- An intervening layer, such as a bowel bag, sterile drape, absorbable mesh, or omentum, can be placed between packs and the tissue to aid in easy pack removal at relaparotomy.

- Abdominal Closure.
  - Leave the fascia open.
  - Vacuum pack (preferred technique — easy, keeps patient dry, allows for expansion).
    - With fascia open, place fully plastic-covered (bowel bag, X-ray cassette bag, Ioban drape) sterile operating room (OR) towel circumferentially under the fascia to cover the viscera. Place a small number of central perforations to allow fluid to egress to the drains.
    - Place closed-suction drains (Jackson-Pratt, modified Foley, small chest tube) above the plastic at the level of the subcutaneous tissue brought out through separate stab wounds or the inferior portion of the wound.
    - Place lap sponges to fill in the wound.
  - Cover the entire wound with a large Ioban drape.
  - Place drains on low suction and secure to the skin.
- A silastic sheet or 3-liter IV bag, sewn to the skin or fascia, can accomplish abdominal closure in virtually every instance.
- Skin closure is not recommended, but may be quickly accomplished with skin staples, towel clips (reliably stronger), or running monofilament suture.
Skin closure may lead to abdominal compartment syndrome.

Thoracic injuries
- **The goal of abbreviated thoracotomy is to stop the bleeding and restore a survivable physiology; contamination is usually not a problem.**
- In the exsanguinating patient, formal lung resection gives way to using large staplers in a nonanatomic wedge resection to rapidly achieve hemostasis and control of air leaks.
- In pulmonary tractotomy, the lung bridging the wound tract is opened between long clamps or with a linear stapler. The tract can thus be directly inspected, bleeding points selectively ligated, and air leaks controlled.
- Vascular injuries can be treated with intraluminal shunts or Fogarty balloons to achieve distal control in inaccessible areas.
- Tracheal injury can be treated with airway control placed through the site of injury.
- Extensive bronchial repairs are not feasible in the patient in extremis; therefore, rapid resection of the affected lobe or lung would be best.
- When dealing with esophageal injury, diversion, and wide drainage, not definitive repair, is the best course of action.
- A single en masse suture closure of the chest wall is best because wound closure of skin with towel clips may result in significant blood loss from the musculature.

Phase 2: Critical Care Considerations
- Physiologic support in the post-op TASC patient is paramount to survival.
  - **Core rewarming:** warmed resuscitative fluids, blankets, ventilator air, and environment, or commercially available products such as Bair Hugger, Chill Buster.
  - **Reversal of acidosis:** appropriate/aggressive resuscitation with crystalloid, colloid, and blood products.
  - **Reversal of coagulopathy:** at many locations, only ultra-fresh whole blood is available to correct coagulopathy.
- Abdominal compartment syndrome.
Abdominal compartment syndrome is a condition in which increased intra-abdominal pressure adversely affects the circulation and threatens the function and viability of the viscera.

Measurement is performed using urinary bladder pressure (normal = zero).

Several methods are available for performing bladder pressure:
- Place 100–150 cc of sterile saline in the bladder and clamp the foley.
- Access the needle port on the catheter and attach to a pressure monitor (central venous pressure transducer).
- Access the needle port and create a column of water via plain IV tubing held vertically or use of the pressure gauge from a lumbar puncture kit.
- If there is no needle port, clamp the foley proximal and the distal end of regular IV tubing in the usual drainage end of the catheter until firmly in place.

Measurement of bladder pressure is a good variable to test and follow; however, intervention for abdominal compartment syndrome (ACS) should occur when suspected or clinically indicated.

Occurs in abdominal trauma accompanied by visceral swelling, hematoma, or abdominal pack use.

Physiology of abdominal compartment syndrome.
- Cardiac output and venous return are decreased.
- Reduction in blood flow to liver, intestines, and kidneys can result in anuria.
- The two hemidiaphragms push upward, decreasing thoracic volume, and compliance leading to elevated peak airway pressures.
- Central venous, pulmonary capillary wedge, and right atrial pressures increase with intra-abdominal pressure (can lead to false PA catheter pressures).
- $PO_2$ is decreased due to increases in airway pressures and ventilation/perfusion abnormalities that worsen with positive end-expiratory pressure (PEEP).
Emergency War Surgery

<table>
<thead>
<tr>
<th>Abdominal Pressure</th>
<th>Degree of Elevation</th>
<th>Clinical Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>10–20 mm Hg</td>
<td>Mild</td>
<td>Insignificant</td>
</tr>
<tr>
<td>20–40 mm Hg</td>
<td>Moderate</td>
<td>Oliguria and organ dysfunction</td>
</tr>
<tr>
<td>&gt;40 mm Hg</td>
<td>Severe</td>
<td>Requires immediate attention</td>
</tr>
</tbody>
</table>

Phase 3: Planned Reoperation

- Packs should be left in place until the patient’s hemodynamics are stable and all major sites of hemorrhage have had time to clot.
- Reoperation should be scheduled when the probability of achieving definitive organ repair and complete fascial closure are highest.
- Timing must coincide with reversal of hypotension, acidosis, hypothermia, and coagulopathy. Typically occurs 24–48 hours following the primary insult when brisk diuresis, negative fluid balance, diminishing abdominal girth, and decreasing peripheral edema indicate reduction in visceral and parietal edema.
- **This surgery may occur at the next echelon of care.**
  - Stratevac should be weighed carefully because transit operative care is minimal. Surgical expertise is generally not available and transit times are often greater than 24 hours.
  - Timing can, however, be dictated by other pressing clinical concerns such as abdominal compartment syndrome, limb ischemia, and suboptimal control of spillage at primary operation.
- In cases of a packed and drained duodenum, pancreas, kidney or bladder, or liver injuries with gross bowel contamination, packs should be retrieved within 36–48 hours.
- It is sometimes necessary to perform this type of operation at the bedside, as the patient’s cardiopulmonary status does not allow a trip to the OR.

Conduct of Relaparotomy

- It is to be presumed that injuries were missed.
- A complete laparotomy must be performed in search of missed injury.
● The surgeon must exercise caution and sound judgment before performing full reconstruction of the GI tract because the patient is typically still critically ill and catabolic, making the patient less likely to heal anastomoses and even less likely to tolerate a leak or uncontrolled fistula.
● Feeding tube placement, either transabdominal or nasoenteric, should be placed at this time.
● Repacking may be re-employed if other measures fail to control hemorrhage.
● An abdominal film should be obtained to insure all packs have been removed from the abdomen. Sponge counts should be considered unreliable in this situation.

● **Unplanned Reexploration.**
  o Emergent, unplanned reexploration should be performed in any:
    ◆ Normothermic patient with unabated bleeding (> 2 units of PRBCs/h).
    ◆ Patient who develops severe intra-abdominal compartment syndrome.
    ◆ Patient requiring postoperative transfusion of > 10 units of PRBCs.
    ◆ Patient with persistent lactic acidosis.

**Austere Field and Military Surgical Considerations**
● Due to severe physiological insult, the typical civilian damage control patient requires 2 surgeons and 1 nurse, at a minimum, at the bedside for the first 6 hours. An example of the magnitude of the ICU problem that may be encountered is a casualty who requires a pulmonary artery catheter, 3 operations, 33 units of PRBCs, and an ICU stay of 23 days. In mass casualty scenarios, this patient would likely be triaged as expectant.

Tactical Abbreviated Surgical Control philosophy allows the surgeon to apply damage control techniques when the limitations of reserve exist outside the patient, in the tactical environment, not just to patients about to exhaust their physiological reserve (classic damage control scenario).
Summary Points

- Damage control is not a procedure of last resort. The consideration of damage control techniques should be made at the initiation of operative intervention in any multitrauma casualty and reconsidered during any case where extensive injuries are involved.

- Consider damage control in patients with severe liver injury, combined vascular and hollow viscus injuries, multiple sites of hemorrhage, diminished physiological reserve, and combinations of severe injury involving multiple organ systems (e.g., CNS, orthopedic, vascular, or thoracoabdominal).

- Consider damage control early, ISS > 35, pH < 7.2, temperature < 34°C, shock, or coagulopathy.


- Think: vascular shunts/fasciotomy, abdominal packing, external fixators, angiographic embolization (when available), temporary closure, nonanatomic resections, and missed injury.

- Plan sequence of operation in stable patients to allow for use of damage control if instability develops.
Introduction

Immediate recognition and appropriate management of airway compromise is critical to survival.

- Face and neck injuries can be the most difficult-to-manage wounds encountered by health care providers in the combat zone. **Focusing on ABC priorities is vital.**
- During airway control, maintain cervical spine immobilization in bluntly injured patients. (Unstable C-spine injury is very rare in neurologically intact penetrating face and neck wounds.)
- **Bleeding** should be initially controlled with direct pressure. If bleeding cannot be controlled, immediate operative intervention is necessary.
- **Complete assessment** of remaining injuries (fractures, lacerations, esophageal injury, ocular injuries).

Immediate Management of Facial Injuries

- Airway.
  - Airway distress due to upper airway obstruction above the vocal cords is generally marked by inspiratory stridor:
    - Blood or edema resulting from the injury.
    - Tongue may obstruct the airway in a patient with a mandible fracture.
    - A fractured, free-floating maxilla can fall back, obstructing the airway.
    - Displaced tooth fragments may also become foreign bodies.
  - Maneuvers to relieve upper airway obstruction:
Emergency War Surgery

- Remove foreign bodies (strong suction, Magill forceps, among others).
- Anterior jaw-thrust maneuver.
- Place adjunctive airway device (nasal trumpet or oropharyngeal airway).
- Endotracheal intubation and assisted ventilation.
- Cricothyroidotomy or emergent tracheotomy may become necessary.

- Cervical spine.
  - Up to 10% of patients with significant blunt facial injuries will also have a C-spine injury.
  - In awake patients, the C-spine can be cleared clinically by palpating for point tenderness.
  - Obtunded patients with blunt facial trauma should be treated with C-spine immobilization.

- Vascular Injury.
  - Injuries to the face are often accompanied by significant bleeding.
  - Control of facial vascular injuries should progress from simple wound compression for mild bleeding to vessel ligation for significant bleeding.

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

- Foley catheter inserted blindly into a wound may rapidly staunch bleeding.
- Intraoral bleeding must be controlled to ensure a patent and safe airway.
- Do not pack the oropharynx in an awake patient due to risk of airway compromise: first secure the airway with an endotracheal tube.
- Copious irrigation and antibiotics with gram-positive coverage should be used liberally for penetrating injuries of the face.
Face and Neck Injuries

- Evaluation.
  - Once the casualty is stabilized, cleanse dried blood and foreign bodies gently from wound sites in order to evaluate the depth and extent of injury.
  - The bony orbits, maxilla, forehead, and mandible should be palpated for stepoffs or mobile segments suggestive of a fracture.
  - A complete intraoral examination includes inspection and palpation of all mucosal surfaces for lacerations, ecchymosis, stepoffs, and malocclusion as well as dental integrity.
  - In the awake patient, abnormal dental occlusion indicates probable fracture.
  - Perform a cranial nerve examination to assess vision, gross hearing, facial sensation, facial muscle movement, tongue mobility, extraocular movements, and to rule out entrapment of the globe.
  - Consult an ophthalmologist for decreased vision on gross visual field testing, diplopia, or decreased ocular mobility.
  - If the intercanthal distance measures > 40 mm (approximately the width of the patient’s eye), the patient should be evaluated and treated for a possible naso-orbital-ethmoid (NOE) fracture.
- If a NOE fracture is present, do not instrument the nose if possible. There may be a tear in the dura, and instrumentation may contaminate the CSF via the cribiform.

Facial Bone Fracture Management
The goals of fracture repair are realignment and fixation of fragments in correct anatomic position with dental wire (inferior, but easier) or plates and screws.

With the exception of fractures that significantly alter normal dental occlusion or compromise the airway (eg, mandible fractures), repair of facial fractures may be delayed for two weeks.

- Fractures of the mandible.
  - Second most commonly fractured bone of the face.
  - Most often fractured in the subcondylar region.
Multiple mandible fracture sites present in 50% of cases.

Patients present with limited jaw mobility or malocclusion.

Dental Panorex is the single best plain film (but is unavailable in the field environment); mandible serves as a less reliable but satisfactory study (might overlook subcondylar fractures).

Fine cut (1–3 mm) CT scan will delineate mandibular fractures.

Treatment is determined by the location and severity of the fracture and condition of existing dentition.

Remove only teeth that are severely loose or fractured with exposed pulp.

Even teeth in the line of a fracture, if stable, and not impeding the occlusion, should be maintained.

Nondisplaced subcondylar fractures in patients with normal occlusion may be treated simply with a soft diet and limited wear of Kevlar helmet and protective mask.

Immediate reduction of the mandibular fracture and improvement of occlusion can be accomplished with a bridle wire (24 or 25 gauge) placed around at least 2 teeth on either side of the fracture.

More severe fractures with malocclusion will require immobilization with maxillary-mandibular fixation (MMF) for 6–7 weeks.

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

The arch-bars are then fixed to the teeth with simple circumdental (24 or 25 gauge) wires (Fig. 13-1).

After proper occlusion is established, the maxillary arch bar is fixed to the mandibular arch bar with either wire or elastics.

If the patient’s jaws are wired together, it is imperative that wire cutters be with the patient at all times.

If portions of the mandible have been avulsed or the mandibular fragments are extremely contaminated, an external biphase splint should be placed to maintain alignment.
Face and Neck Injuries

- Open reduction and internal fixation with a mandibular plate across fracture sites may obviate the need for MMF.

- **Nasal fractures.**
  - Most common fracture.
    - Control of epistaxis: anterior pack-gauze/balloon/tamponade.
  - Diagnosed clinically by the appearance and mobility of the nasal bones.

  The patient’s septum should be evaluated for the presence of a septal hematoma, which if present, must be immediately drained by incision, followed by packing.

  - Treat by closed reduction of the fractured bones and/or septum into their correct anatomic positions up to 7 days after fracture.
Place a blunt elevator (Sayer) into the nasal cavity in order to elevate the depressed bony segment while simultaneously repositioning the bone with the surgeon’s thumb placed externally. The nose may then be fixed with tape or a splint in order to maintain the reduction (Fig. 13-2).

![Fig. 13-2. (a) Anterior and (b) posterior packing of the nose.](image)

- **Maxillofacial Trauma.**
  - Life-threatening due to loss of airway, hemorrhage, or spinal injury.
  - Fragment wound of maxillary sinus is commonly seen and requires surgical removal of retained fragments (can delay until specialist is available).

- **Bleeding.**
  - Common from epistaxis, oral hemorrhage or combination bleeding.
  - Nasal fracture—most common fracture.
  - Control Epistaxis with Anterior Pack (gauze/balloon/tampon).
  - Mandibular fracture fixation (wires/archbars, **with wire cutters at bedside**).
  - Facial and scalp lacerations.
  - Mid-face fracture (Le Fort)—The most difficult bleeding to control.
Face and Neck Injuries

♦ Requires “significant” trauma.
♦ Be aware of associated CNS and orbital injury.
♦ Significant hemorrhage due to laceration of IMA and branches.
  ◦ Is difficult to control.
  ◦ May be life-threatening.
  ◦ Treat by controlling airway, reducing fracture, and placing a pressure dressing such as packing or balloon.
♦ Edema may cause loss of airway, which may be immediate or delayed.
♦ Can be difficult to diagnose. Criteria:
  ◦ Mobile hard palate and mid-face while stabilizing the skull.
  ◦ Penetrating injury may not follow classic Le Fort patterns but may have a significant soft tissue injury component (base of tongue, soft palate).

● Treatment.
  o ABCs.
  o Check CNS and vision.
  o Can immobilize maxilla by using the mandible as a splint (wires/archbars, with wire cutters at bedside).
  o Control hemorrhage by tamponade.
    ◦ Nasopharynx, nasal cavity.
    ◦ Oropharynx.

● Surgical Repair.
  o Not an emergency once hemorrhage is controlled.
  o Requires ENT, oral, plastic, and ophthalmology surgical expertise.
  o Time consuming.
  o Open and closed reductions with hardware that is usually unavailable in the field.

● Fractures of Facial Bones.
  o Potentially life-threatening due to loss of airway, hemorrhage, or spinal injury.
  o Fragment wound of maxillary sinus is commonly seen, and requires surgical removal of retained fragments (can delay until specialist available).
  o Mid-face fracture (Le Fort)—The most difficult bleeding to control.
  ◦ Requires “significant” trauma.
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♦ Be aware of associated CNS and orbital injury.
♦ Significant hemorrhage due to laceration of IMA and branches.
  ◊ Is difficult to control.
  ◊ May be life threatening.
  ◊ Treat by controlling the airway, reducing fractures, and placing pressure dressings such as packing or balloon tamponade.
♦ Edema may cause loss of airway, which may be immediate or delayed.
♦ Can be difficult to diagnose.
  ◊ Mobilize the hard palate and mid-face while stabilizing the skull. Place thumb and forefinger of one hand on nasal bridge to stabilize, then with the other hand, determine mobility of maxilla by placing the thumb on alveolus and forefinger on the palate and attempting gentle distraction in an anterior-posterior direction.
  ◊ Penetrating injury may not follow classic Le Fort patterns but may have a significant soft tissue injury component (base of tongue, soft palate).
  ◊ Apply principles of systemic palpation and inspection, looking for crepitus, tenderness, internal and external ecchymosis, and subconjunctival hemorrhage that might suggest fractures.

ο Classification by Le Fort (Fig. 13-3).

Fig. 13-3. Le Fort facial fracture classifications.
Face and Neck Injuries

- I–Fracture separates the entire alveolar process from maxilla.
- II–Separation of mid-face, including the nasal bone, from the orbit (pyramidal).
- III–Detachment of the face from the skull (craniofacial disarticulation).

Treatment.
- ABCs.
- If nasal intubation is used, extremely careful placement is mandatory to avoid cribiform plate or anterior cranial fossa penetration.
- Classification by Le Fort.
- Check CNS and vision.
- Can immobilize maxilla by using the mandible as a splint (wires/arch bars, with wire cutters at bedside). It is much easier to place patient into maxillomandibular fixation if either a nasal airway or tracheostomy is employed.
- Control hemorrhage by tamponade as previously described.
  - Nasopharynx, nasal cavity.
  - Oropharynx.

Definitive Surgical Repair.
- Not an emergency once hemorrhage is controlled.
- Requires expertise in ENT, oral and maxillofacial, plastic, and ophthalmology surgery.
- Time consuming.
- Open and closed reductions require hardware usually unavailable in the field.

Soft Tissue Injuries
- General principles.
  - Avoid injury to surrounding structures such as the facial nerve or parotid duct.
  - Wounds should be gently cleansed with saline and light scrub solutions; foreign bodies should be meticulously cleaned from wounds prior to closure.
  - Sharply debride devascularized wound edges minimally.
  - Facial lacerations should be closed in layers within 24 hours.
    - Use 4-0 or 5-0 absorbable suture for subcutaneous/dermal layers.
Emergency War Surgery

- Use 5-0 or 6-0 nonabsorbable sutures on the skin of the face.
- Remove sutures in 5–7 days.

**Facial nerve injuries.**

- Carefully examine for facial nerve function in all **five** branches (Fig. 13-4).

![Facial nerve diagram](image)

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

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

- The severed ends of the nerve may be located in the wound with a nerve stimulator, for up to 3 days.
- Cut nerve ends should be reapproximated primarily with three or four fine (9-0) nylon sutures placed through the epineurium.
- If a gap exists between severed ends of the facial nerve due to tissue loss, an interposition graft may be placed using a section of the great auricular nerve to bridge the gap.
If the wound is heavily contaminated and cannot be closed primarily, the severed ends of the nerve should be located and tagged for identification and repair at the time of wound closure.

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

- Introduction.
  - Vascular injuries occur in 20% and aerodigestive tract in 10% of cases.
  - Mortality is primarily due to exsanguinating hemorrhage.
  - Esophageal injury, which results in mediastinitis and intractable sepsis, may also be fatal.

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

- Zone 1 (clavicle to cricoid membrane): The structures of concern include large vessels of the thoracic outlet (subclavian artery and vein, common carotid artery), the lung, and the brachial plexus.
- Zone 2 (cricoid membrane to angle of mandible): Structures of concern include the common carotid artery, internal jugular vein, esophagus, and trachea.
- Zone 3 (angle of mandible to base of skull): The structure of concern is primarily the internal carotid artery.
• Immediate management.
  o Initially, same as above.
  o Obtain chest and soft tissue neck radiographs.
  o Address tetanus and antibiotic prophylaxis.

• Operative strategy.
  o If no platysma violation, surgical intervention is not indicated.
  o Zone 2 injuries that penetrate the platysma should undergo routine exploration to rule out life threatening vascular, esophageal or tracheal injuries via an incision along the anterior border of the sternocleidomastoid muscle (Fig. 13-7).

**Fig. 13-7.** Neck exposure of zone 2.

  o Zone 1 and 3 injuries require selective management, based on clinical signs and chest radiograph findings, making an incision dependent on the vascular structure most probably injured.
  ♦ Zone 1 and 3 penetrations without clinical signs of injury (see below) may be evacuated without operative intervention.
  o The most important clinical signs pointing to probable injuries (pertinent to all 3 zones):
Emergency War Surgery

♦ Signs of vascular injury.
◊ Current or history of significant bleeding.
◊ Expanding hematoma.
◊ Bruit or thrill in the neck.
◊ Hypotension.
◊ Dyspnea, hoarseness, or stridor.
◊ Absent or decreased pulses in neck or arm.
◊ Focal neurologic deficit or mental status change.
◊ Chest radiograph findings of hemothorax or mediastinal widening.

♦ Signs of aerodigestive injury (esophagus, trachea, larynx).
◊ Crepitus or subcutaneous emphysema.
◊ Dyspnea or stridor.
◊ Air bubbling from wound.
◊ Tenderness or pain over trachea; odynophagia.
◊ Hoarse or abnormal voice.
◊ Hematemesis or hemothysis.

Surgical Principles
● The groin and upper thigh should be surgically prepped for greater saphenous vein interposition graft or patch angioplasty.
● Exsanguinating hemorrhage from injured vessels at the base of the skull (Zone 3) can often be controlled with inflation of a directed catheter (Fogarty, Foley), left in place and inflated for 48–72 hours, then deflated in the OR under controlled visualization for rebleeding.
● Repair esophageal injuries in a single-layer and place closed suction drains. The drain tip should not be placed near a concomitantly repaired carotid artery. A muscle flap should be interposed between repaired esophageal and tracheal injuries to prevent fistula. Obtain an oral contrast swallow radiograph seven days after repair before feeding.
● Repair laryngotracheal injuries with single-layer monofilament absorbable suture. Must search for concomitant esophageal injuries.
● Unreconstructable (significant segmental loss, or > 50% diameter loss) tracheal injuries should be managed with an endotracheal tube placed through the defect.
Face and Neck Injuries

- **Vertebral artery injury.**
  - Suspect if bleeding continues from a posterolateral neck wound despite pressure on the carotid artery.
  - Preoperative angiography localizes site of injury and establishes the existence of a patent contralateral vertebral artery, aplasia of which is most commonly located on the left side.
  - Exposure of vertebral artery may be difficult. When contralateral vertebral artery is intact, ligation proximal and distal to the injury will likely be necessary.
  - Bone wax or a Foley catheter may be useful for control of bleeding.

- **Intraoral injuries**
  - Penetrating injuries to the oral cavity LATERAL to the tonsillar fossa are at a significant risk of causing occult internal carotid injury. Neurologic testing/monitoring is critical and CT scanning and/or angiography should be considered. If after a penetrating lateral oral injury the patient bleeds a small amount only to stop, this may signify a “sentinel” bleed. A carotid blowout may follow.

- **Internal carotid artery injury.**
  - Should be repaired primarily unless there is profound hemiplegia with deep coma Glasgow Coma Scale (GCS < 8). All other carotid branches can be ligated.
  - The use of carotid shunts during repair has no proven benefit.
  - In small perforations, debride minimally, and close with 6-0 polypropylene.
  - With loss of vascular tissue, vein angioplasty is required.
  - If there is extensive destruction, segmental resection and restitution of flow is established by:
    ♦ End-to-end anastomosis (if the vessel is sufficiently elastic to permit).
    ♦ Interposition vein graft.
    ♦ External carotid swing-over and interposition.
    ♦ Temporary (24–48 h) shunt as part of damage control maneuver.
  - The mortality is high in patients with severe neurologic deficit; carotid ligation is justifiable in complete occlusion of the entire carotid system and depending on the triage situation.
  - Distal clot may be removed by extremely gentle use of a balloon catheter prior to shunt insertion or repair.
Emergency War Surgery

- **Internal jugular vein injury.**
  - Preferably repaired by lateral suture.
  - Ligation OK, if the contralateral internal jugular is patent.
  - Larynx.
  - After immediate control of the airway has been achieved by intubation or tracheotomy (not through the wound in the larynx!), a complete airway evaluation by direct laryngoscopy and bronchoscopy must be performed.
  - Debridement of laryngotracheal injuries must be careful and conservative. A fragmented larynx or trachea should be reapproximated and sutured with extraluminal, absorbable sutures for tracheal injuries and nonabsorbable sutures or micro-plates used for laryngeal fractures.
  - The management of laryngeal trauma includes accurate reduction and stabilization of fractures, mucosa-to-mucosa closure of lacerations, and use of a soft stent if there is extensive cartilaginous damage and structural support is decreased or the anterior commissure is involved. The stent may need to be temporarily placed for 4–6 weeks to maintain correct anatomic architecture and requires a complementary tracheotomy.
  - The excessive removal of cartilage and mucosa must be avoided to prevent tracheal or laryngeal stenosis.

- **Laryngotracheal injuries.**
  - If laryngotracheal separation is suspected (massive crepitis over the larynx/trachea) in an otherwise “stable” airway, endotracheal intubation should not be undertaken as this may cause a partial separation to become a complete separation and/or blind passage of the endotracheal tube may occur with resulting impending airway emergency.
  - It is best to perform an awake tracheotomy/cricothyroidotomy under local anesthesia without paralysis. Good anesthesia can be achieved with a 4% (40mg/cc) lidocaine nebulizer, 2cc in 3cc of saline, and direct administration of 4% lidocaine into the trachea for an awake tracheotomy (in addition to local anesthetic infiltration into the skin and subcutaneous tissues). When instilling anesthesia into the airway, aspirate and ensure air enters the syringe before injecting.
Face and Neck Injuries

- **Tracheal injury and reconstruction.**
  - Small anterior wounds can have tracheostomy tube placed through them after debridement.
  - Repair simple lacerations with absorbable monofilament suture.
  - Up to 5 cm can be resected with proximal and distal mobilization.
  - Mobilize anteriorly and posteriorly to preserve lateral blood supply.
  - Remove endotracheal tube as soon as possible post-op.
  - May need to suture chin to chest for 10 days to avoid extension injury.

- **Esophageal injury and repair.**
  - Difficult to diagnose.
  - 25% may be asymptomatic.
  - Missed injury is a major source of late morbidity/mortality.
  - Insufflation with air may aid in identification during exploration.
  - Debride devitalized tissue.
  - Wound closure in two layers with absorbable sutures.
  - Viable muscle flap to protect repairs from leak.
  - Drainage with closed suction drain.
  - Barium swallow 7 days post-op, prior to oral intake.
  - Oral intake prior to drain removal.
  - Extensive injuries may require lateral cervical esophagostomy.
  - Cervical esophagostomy is preferred to closure under tension.

- **Combined injuries.**
  - All esophageal injuries combined with airway or vascular injury require separation with healthy tissue. Strap muscles are ideal, but can use pedicle of sternocleidomastoid if straps are devitalized.

- **Esophageal fistula.**
  - 10%–30% incidence.
  - Due to inadequate debridement, devascularization of remaining esophageal wall, closure under tension, or infection.
  - Treatment.
Emergency War Surgery

♦ Maintain nutrition.
♦ Assure control with drains.
♦ Weekly barium swallow to assess closure.
♦ Oral intake prior to removing drain.

Skull Base, Temporal Bone and Otologic Injury

 skl Ensure that the facial nerve is assessed and documented on an awake patient and at the earliest convenience in a patient who has regained consciousness. Delineation between delayed onset and acute facial paralysis is critical for management and outcome of facial nerve injuries. Also critical is delineation between a distal and proximal nerve injury. If a distal injury is present, one or more branches may be affected.

o Be as concise as possible in describing facial motion even if not technically accurate; be complete in the description. A more proximal injury (proximal to the Pes Anserinus) will most likely result in all branches being equally affected. Accurate documentation may spare the patient from unwarranted surgical intervention to explore the entire length of the facial nerve. It is desirable to accurately describe the motion of EACH branch of the facial nerve. Eyelid movement does not ensure that the facial nerve is intact since the levator palpebrae is innervated by the oculomotor nerve and will remain intact despite facial nerve injury.

o If there is no contraindication for systemic steroids, they should be administered for suspected facial nerve paralysis. Crush injuries to the facial nerve may present with delayed onset paralysis and the severity and course of the paresis may be improved with systemic administration of steroids.

♦ Skull base fractures are often occult. Assess the patient for evidence of basilar skull fractures (Battle’s sign, raccoon eyes).

♦ Ensure that the external auditory canal is examined. Do not instrument the external auditory canal, however. If a temporal bone fracture is present and the dura is not intact, instrumentation may introduce bacteria and/or a foreign body into the CSF.
The external auditory canal should be inspected for a tear of the lining of the canal. A tear of the lining of the canal suggests a temporal bone fracture.

- If a temporal bone fracture is suspected, it is critical that the facial nerve be assessed.

Tympanic membrane perforations can be managed expectantly. The vast majority of them will heal spontaneously, but the patient should be followed for evidence of cholesteatoma formation from traumatic implantation of the squamous epithelium. This may occur months to years after the injury. Acutely, application of otic antibiotic drops will prevent the perforation from desiccating, but this is not required. The patient should be instructed to keep the ears dry (avoid water contamination).

Hemotympanum may be seen with acoustic & temporal bone trauma. These patients will have hearing loss. If available, perform a gross audiological evaluation with tuning forks. Hemotympanum with hearing loss (conductive) should resolve in about 6 weeks.

- Examination for hearing in the field can be accomplished with a single 512 tuning fork.
  - With the tuning fork placed on the mastoid tip and then alternately in front of the external canal (Rinne). Documentation as A>B (air > bone) or B>A is sufficient – do not report as “positive” or “negative”:
    - Air conduction greater than bone conduction with a 512 tuning fork is normal.
    - Bone conduction greater than air is suggestive of a conductive hearing loss.
  - With the 512 tuning fork on the frontal bone/ nasal dorsum/ or central incisors (best) (Weber):
    - If the Rinne test suggests a conductive hearing loss – the 512 should lateralize to the side with the conductive loss.
    - If the Rinne is NORMAL (A>B) – the 512 should lateralize to the ear with a sensorineural loss

Any otologic blast injury or injury to the temporal bone may result in tinnitus. Management is expectant and it may resolve.
Emergency War Surgery

spontaneously. Accurate documentation is critical for future management of these patients, however.

- If sensorineural hearing loss is suspected and documented after a blast injury or noise trauma, steroids are indicated. 1mg/kg of prednisone is appropriate. If after five days there is no improvement, the patient can be taken off of the steroids. If improvement is noted, a taper over 3–4 weeks is indicated. Be mindful that steroids may affect a patient’s affect and impair judgment.

- Dizziness and vertigo may result from acoustic trauma. If true vertigo exists after an otologic injury (observed nystagmus), the patient may have a perilymphatic fistula from depression of the stapes into the oval window or rupture of the round window. These patients may have tinnitus and hearing loss with vertigo. If a perilymphatic fistula is suspected, this patient should be seen by an Otolaryngologist as soon as possible to prevent further damage to the inner ear.
Chapter 14

Ocular Injuries

Introduction
The preservation of the eyes and eyesight of service personnel is an extremely important goal. Despite comprising as little as 0.1% of the total body surface area, injuries to the eye are found in 5–10% of all combat casualties. In the Vietnam War almost 50% of casualties with penetrating eye wounds eventually lost vision in the injured eye. Improvements in ophthalmic care in the last 30 years offer hope that blindness in combat casualties will be less common in future wars.

Triage of Patients With Eye Injuries
- ABCs (airway, breathing, and circulation) and life-threatening injuries have priority, then treat eyesight and limbs.
- Soldiers with mild eye injuries may be treated and returned to duty by nonspecialized personnel.
- Soldiers with more severe injuries should be evacuated to save vision.
- Distinguishing major ocular injuries from minor ones may be difficult.
- At the FST level, due to time and equipment restraints, surgeons will likely ‘patch and evacuate’.

Identifying Severe Eye Injuries
- Associated injuries.
  - Shrapnel wounds of the face — think intraocular foreign body (IOFB).
  - Lid laceration — check for underlying globe laceration.
- Vision.
Emergency War Surgery

- Use book print, medication labels, finger counting, and the like, to evaluate vision.
- Compare sight in the injured eye to the uninjured eye.
- Severe vision loss is a strong indicator of serious injury.

- Eyeball structure.
  - Obvious corneal or scleral lacerations.
  - Subconjunctival hemorrhage — may overlay an open globe.
  - Dark uveal tissue presenting on the surface of the eye indicates an open globe.
  - Foreign body — did it penetrate the eye?
  - Blood in the anterior chamber (hyphema) indicates severe blunt trauma or penetrating trauma.

- Proptosis — may indicate a retrobulbar hemorrhage.

- Pupils.
  - Pupillary distortion — may be associated with an open globe.

- Motility.
  - Decreased motility on one side may be caused by an open globe.
  - Other causes include muscle injury, orbital fracture, and orbital hemorrhage.

Open Globe
- May result from penetrating or blunt eye trauma.
- May cause loss of vision from either disruption of ocular structures or secondary infection (endophthalmitis).
- Biplanar radiographs or a CT (computed tomography) scan of the head may help to identify a metallic intraocular fragment in a casualty with severe vision loss, a traumatic hyphema, a large subconjunctival hemorrhage, or other signs suspicious for an open globe with an IOFB.

Immediate Treatment of an Open Globe
- Tape a rigid eye shield (NOT a pressure patch) over the eye.
- Do not apply pressure on or manipulate the eye.
- Do not apply any topical medications.
- Start quinolone antibiotic PO or IV (eg, ciprofloxacin 500 mg bid).
Ocular Injuries

- Schedule an urgent (within 24–48 h) referral to an ophthalmologist.
- Administer tetanus toxoid if indicated.
- Prevent emesis (Phenergan 50 mg or Compazine 10 mg IM/IV).

Treatment of Other Anterior Segment Injuries

Subconjunctival Hemorrhage

- Small subconjunctival hemorrhages (SCH) may occur spontaneously or in association with blunt trauma. These lesions require no treatment.
- SCH may also occur in association with a rupture of the underlying sclera.
- Warning signs for an open globe include a large SCH with chemosis (conjunctiva bulging away from globe) in the setting of blunt trauma, or any SCH in the setting of penetrating injury. Casualties with blast injury and normal vision do not require special care.
- Suspected open globe patients should be treated as described above.

Treatment of Chemical Injuries of the Cornea

- Immediate copious irrigation (for 30 minutes) with normal saline (NS), lactated Ringer’s (LR), or balanced salt solution.
- Nonsterile water may be used if it is the only liquid available.
- Use topical anesthesia before irrigating, if available.
- Measure the pH of tears to ensure that if there is either acid or alkali in the eye, the irrigation continues until the pH returns to normal. Do not use alkaline solutions to neutralize acidity or vice versa.
- Remove any retained particles.
- Using fluorescein test, look for epithelial defect.
  - If none, then mild chemical injuries or foreign bodies may be treated with artificial tears.
  - If an epithelial defect is present, use a broad-spectrum antibiotic ophthalmic ointment (Polysporin, erythromycin, or bacitracin) 4 times per day.
- Noncaustic chemical injuries usually resolve without sequelae.
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- More severe chemical injuries may also require treatment with prednisolone 1% drops 4–9 times per day and scopolamine 0.25% drops 2–4 times per day.
- Pressure patch between drops or ointment if a large epithelial defect is present.
- Monitor (daily topical fluorescein evaluation) for a corneal ulcer until epithelial healing is complete.
- Severe acid or alkali injuries of the eye (recognized by pronounced chemosis, limbal blanching, and/or corneal opacification) can lead to infection of the cornea, glaucoma, and possible loss of the eye. Refer to an ophthalmologist within 24–48 hours.
- Treat mustard eye injuries with ophthalmic ointments, such as 5% boric acid ointment, to provide lubrication and minimal antibacterial effects. Apply sterile petrolatum jelly between the eyelids to provide additional lubrication and prevent sealing of the eyelids.
- Treat nerve agent ocular symptoms with 1% atropine sulfate ophthalmic ointment, repeat as needed at intervals of several hours for 1–3 days.

Corneal Abrasions

- Diagnosis.
  - Be alert for the possibility of an associated open globe.
  - The eye is usually very symptomatic with pain, tearing, and photophobia.
  - Vision may be diminished from the abrasion itself or from the profuse tearing.
  - Diagnose with topical fluorescein and cobalt blue light (Wood’s lamp).
  - A topical anesthetic may be used for diagnosis, but should NOT be used as an ongoing analgesic agent — this delays healing and may cause other complications.
- Treatment.
  - Apply broad spectrum antibiotic ointment (Polysporin, erythromycin, or bacitracin) qid.
  - Options for pain relief.
    - Pressure patch (usually sufficient for most abrasions).
    - Diclofenac 0.1% drops qid.
Larger abrasions may require a mild cycloplegic agent (1% Mydriacyl or Cyclogyl) and a pressure patch.
More severe discomfort can be treated with 0.25% scopolamine one drop bid, but this will result in pupil dilation and blurred vision for 5–6 days.
- Small abrasions usually heal well without patching.
- If the eye is not patched
  - Antibiotic drops (fluoroquinolone or aminoglycoside) may be used qid in lieu of ointment.
  - Sunglasses are helpful in reducing photophobia.
- Casualties who wear contact lenses should have the lens removed and should not be treated with a patch because of the higher risk of developing a bacterial corneal ulcer.
- Abrasions will normally heal in 1–4 days.
- Initial treatment of thermal burns of the cornea is similar to that for corneal abrasions.

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

Corneal Ulcer and Bacterial Keratitis

- Diagnosis.
  - Corneal ulcer and bacteria keratitis are serious conditions that may cause loss of vision or even loss of the eye!
  - A history of corneal abrasion or contact lens wear.
  - Increasing pain and redness.
  - Decreasing vision.
  - Persistent or increasing epithelial defect (positive fluorescein test).
  - White or gray spot on the cornea seen on examination with penlight or direct ophthalmoscope.
- Treatment.
  - Quinolone drops (eg, Ocuflox), 1 drop every 5 minutes for 5 doses initially, then 1 drop every 30 minutes for 6 hours, then 1 drop hourly around the clock thereafter.
  - Scopolamine 0.25%, one drop bid may help relieve discomfort caused by ciliary spasm.
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- Patching and use of topical anesthetics for pain control are contraindicated (see pain control measures above).
- Expedited referral to an ophthalmologist within 3–5 days unless patient is not improving within 48 hours. Infection may worsen, leading to permanent injury.

Conjunctival and Corneal Foreign Bodies
- Diagnosis.
  - Abrupt onset of discomfort and/or history of suspected foreign body.
  - If an open globe is suspect, treat as discussed above.
  - Definitive diagnosis requires visualization of the offending object, which may sometimes be quite difficult.
    ♦ A hand-held magnifying lens or pair of reading glasses will provide magnification to aid in the visualization of the foreign body.
    ♦ Stain the eye with fluorescein to check for a corneal abrasion.
  - The casualty may be able to help with localization if asked to indicate the perceived location of the foreign body prior to instillation of topical anesthesia.
  - Eyelid eversion with a cotton-tipped applicator helps the examiner identify foreign bodies located on the upper tarsal plate.
- Treatment.
  - Superficial conjunctival or corneal foreign bodies may be irrigated away or removed with a moistened sterile swab under topical anesthesia.
  - Objects adherent to the cornea may be removed with a spud or a sterile 22-gauge hypodermic needle mounted on a tuberculin syringe (hold the needle tangential to the eye).
  - If no foreign body is visualized, but the index of suspicion is high, vigorous irrigation with artificial tears or sweeps of the conjunctival fornices with a moistened cotton-tipped applicator after topical anesthesia may be successful in removing the foreign body.
  - If an epithelial defect is present after removal of the foreign body, treat as discussed above for a corneal abrasion.
Hyphema: Blood in the Anterior Chamber

- Treatment (to prevent vision loss from increased intraocular pressure).
  - Be alert for a possible open globe and treat for that condition if suspected.
  - Avoidance of rebleeds is a major goal of management.
    - **Avoid** aspirin or nonsteroidal antiinflammatory drugs (NSAID).
    - No strenuous activity (bedrest) for 14 days.
    - No reading for 7 days.
  - Prednisolone 1% drops 4 times a day.
  - Scopolamine 0.25% drops twice a day.
  - Cover eye with protective shield.
  - Elevate head of bed to promote settling of red blood cells (RBC) in anterior chamber.
  - Provide a 24–48 hour referral to an ophthalmologist to monitor for increased intraocular pressure (which may cause permanent injury to the optic nerve) and to evaluate for an associated open globe.
  - If evaluation by an ophthalmologist is delayed (> 24 hrs), treat with a topical B-blocker (timolol or levobunolol) bid to help prevent intraocular pressure elevation.
  - If intraocular pressure is found to be markedly elevated (above 30 mm Hg) with a tonopen or other portable tonometry device, other options for lowering intraocular pressure include acetazolamide 500 mg PO or IV and mannitol 1–2 g/kg IV over 45 minutes.

Retrobulbar (Orbital) Hemorrhage

- Keys to recognition: Severe eye pain, proptosis, vision loss, decreased eye movement.
  - Marked lid edema may make the proptosis difficult to appreciate.
  - Failure to recognize may result in blindness from increased ocular pressure.
- Perform an immediate lateral canthotomy.
- Provide an urgent referral to an ophthalmologist, within 24–48 hours.
If evaluation by an ophthalmologist is delayed (>24 hrs), treat with a topical B-blocker (timolol) bid to help lower intraocular pressure elevation.

If intraocular pressure is found to be elevated (>30 mm Hg), treat as discussed above.

**Lateral Canthotomy/Cantholysis**

Do not perform such procedures if the eyeball structure has been violated. If the eye is sliced open, apply a Fox shield for protection and seek immediate ophthalmic surgical support.

- Inject 2% lidocaine with 1:100,000 epinephrine into the lateral canthus (Fig. 14-1a).
- Crush the lateral canthus with a straight hemostat, advancing the jaws to the lateral fornix (Fig. 14-1b).
- Using straight scissors make a 1-cm long horizontal incision of the later canthal tendon, in the middle of the crush mark (Fig. 14-1c).
- Grasp the lower eyelid with large toothed forceps pulling the eyelid away from the face. This pulls the inferior crus (band of the lateral canthal tendon) tight so it can be easily cut loose from the orbital rim (Fig.14-1d).
  - Use blunt tipped scissors to cut the inferior crus.
  - Keep the scissors parallel (flat) to the face with the tips pointing toward the chin.
  - Place the inner blade just anterior to the conjunctiva and the outer blade just deep to the skin.
  - The eyelid should pull freely away from the face, releasing pressure on the globe.
  - Cut residual lateral attachments of the lower eyelid if it does not move freely.
  - Do not worry about cutting 1/2 cm of conjunctiva or skin.
  - The lower eyelid is cut, relieving orbital pressure. If the intact cornea is exposed, apply, hourly, copious erythromycin ophthalmic ointment or ophthalmic lubricant ointment to prevent devastating corneal dessication and infection. Relief of orbital pressure must be followed by lubricating protection of the cornea and urgent ophthalmic surgical support. Do NOT apply absorbent gauze dressings to the exposed cornea.
Orbital Floor (Blowout) Fractures

These fractures are usually the result of a blunt injury to the globe or orbital rim, often associated with head and spine injuries. Blowout fractures may be suspected on the basis of enophthalmos, diplopia, decreased ocular motility, hypoesthesia of the V2 branch of the trigeminal nerve, associated subconjunctival hemorrhage, or hyphema. Immediate treatment includes pseudoephedrine 60 mg q 6 hours and a broad-
Emergency War Surgery

spectrum antibiotic for 7 days, ice packs, and instructing the casualty not to blow his nose. Definitive diagnosis requires CT scan of orbits with axial and coronal views. Indications for repair include severe enophthalmos and diplopia in the primary or reading gaze positions. The surgery may be performed 1–2 weeks after the injury.

Lid Lacerations

Treatment guidelines for lid lacerations not involving the lid margin

- Excellent blood supply — delayed primary closure is not necessary.
- Eyelid function (protecting the globe) is the primary consideration.
- Begin with irrigation, antisepsis (any topical solution), and a check for retained foreign bodies.
- Superficial lacerations of the eyelid, not involving the eyelid margin, may be closed with running or interrupted 6-0 silk (preferred) or nylon sutures.
- Horizontal lacerations should include the orbicular muscle and skin in the repair.
- If skin is missing, an advancement flap may be created to fill in the defect. For vertical or stellate lacerations, use traction sutures in the eyelid margin for 7–10 days.
- Antibiotic ointments qid.
- Skin sutures may be removed in 5 days.

Treatment guidelines for lid lacerations involving the lid margin

- Repair of a marginal lower-eyelid laceration with less than 25% tissue loss (Fig. 14-2).
  - The irregular laceration edges may be freshened by creating a pentagonal wedge — remove as little tissue as possible (Fig. 14-2b).
  - A 4-0 silk or nylon suture is placed in the eyelid margin (through the meibomian gland orifices 2 mm from the wound edges and 2 mm deep) and is tied in a slipknot. Symmetric suture placement is critical to obtain post-op eyelid margin alignment (Fig. 14-2c).
The slipknot is loosened and approximately two or three absorbable (Vicryl or gut) 5-0 or 6-0 sutures are placed internally to approximate the tarsal plate. The skin and conjunctiva should not be included in this internal closure (Fig. 14-2d).

Fig. 14-2. Lid margin repair.
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- Anterior and posterior marginal sutures (6-0 silk or nylon) are placed in the eyelid margin just in front and behind the previously placed 4-0 suture (Fig. 14-2e).
- The middle and posterior sutures are left long and tied under the anterior suture. Ensure that the wound edges are everted (Fig. 14-2f).
- The skin is closed with 6-0 silk or nylon sutures. The lid is placed on traction for at least 5 days. The skin sutures are removed at 3–5 days and the marginal sutures are removed at 10–14 days (Fig. 14-2g).

Additional Points in Lid Laceration Repair
- Tissue loss greater than 25% will require a flap or graft.
- If there is orbital fat in the wound or if ptosis is noted in an upper lid laceration, damage to the orbital septum and the levator aponeurosis should be suspected.
- If the eyelid is avulsed, the missing tissue should be retrieved, wrapped in moistened Telfa, and preserved on ice. The tissue should be soaked in a dilute antibiotic solution prior to reattachment. If necrosis is present, minimal debridement should occur in order to prevent further tissue loss. The avulsed tissue should be secured in the anatomically correct position in the manner described for lid margin repair above.
- Damage to the canalicular system can occur as a result of injuries to the medial aspect of the lid margins. Suspected canalicular injuries should be repaired by an ophthalmologist to prevent subsequent problems with tear drainage. This repair can be delayed for up to 24 hours.

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

Enucleation
A general surgeon in a forward unit should not remove a traumatized eye unless the globe is completely disorganized. Enucleation should only be considered if the patient has a very severe injury, no light perception using the brightest light source available, and is not able to be evacuated to a facility with an ophthalmologist. Sympathetic ophthalmia is a condition that may result in loss of vision in the fellow eye if a severely traumatized, nonseeing eye is not removed, but it rarely develops prior to 21 days after an injury. **Delaying the enucleation until the patient can see an ophthalmologist is thus relatively safe.**
Introduction
The prognosis of brain injuries is good in patients who respond to simple commands, are not deeply unconscious, and do not deteriorate. The prognosis is grave in patients who are rendered immediately comatose (particularly those sustaining penetrating injury) and remain unconscious for a long period of time. Any subsequent neurologic improvement may indicate salvageability and should prompt reevaluation.

Neurosurgical damage control includes early intracranial pressure (ICP) control; cerebral blood flow (CBF) preservation; and prevention of secondary cerebral injury from hypoxia, hypotension, and hyperthermia.

A motor examination of the most salvageable severely brain-injured patients will demonstrate localization to central stimulation and these patients will require expedited treatment. Immediate intubation with adequate ventilation is the most critical first line of treatment for a severely head-injured patient. Evacuation to the nearest neurosurgeon, avoiding diagnostic delays, and initiating cerebral resuscitation allow for the best chance for ultimate functional recovery.

Combat Head Injury Types
- Blunt (closed head injury).
- Penetrating.
  - Penetrating with retained fragments.
  - Perforating.
  - Guttering (grooving the skull).
  - Tangential.
  - Cranial facial degloving (lateral temple, bifrontal).
Blast over-pressure CNS injuries.
- A force transmitted by the great vessels of the chest to the brain; associated with unconsciousness, confusion, headache, tinnitus, dizziness, tremors, increased startle response, and occasionally (in the most severe forms) increased ICP. Bleeding may occur from multiple orifices including ears, nose, and mouth.

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

![Diagram of common vectors of penetrating injury](image)

**Fig. 15-1.** Common vectors of penetrating injury.

The subocciput, occiput, and retroauricular regions are overlooked most. Injuries to these areas can indicate underlying injury to the posterior fossa, major venous sinus, or carotid artery, as fragments pass through the skull base. Reconstructing the fragment path based on combination of plain films and
Head Injuries

Computed tomography (CT) can be challenging. In transorbital, transtemple, or penetrating injuries that cross the midline, an underlying injury to intracranial vessels should be suspected with associated pseudoaneurysms, dissections, or venous sinus injury.

Explosion results in flying fragments, with possible vehicular-collision–associated blunt injuries. Depending on the proximity to the explosion, a blast over-pressure phenomenon may also result. In a severely brain-injured patient, more deficits than indicated by the CT scan may be due to possible underlying injury to brachiocephalic vessels, shear injury, or the effects of blast over-pressure with resulting cerebral vasospasm. Plain films, more useful in penetrating than blunt trauma, may reveal a burst fracture of the skull indicating the tremendous perforating force of a penetrating missile. Transventricular bihemispheric fragment tracts portend a poor prognosis.

Severe head injuries are often seen in combination with significant chest, abdomen, and extremity injuries. Very rapid hemorrhage control is the priority in the noncranial injuries; utilizing damage control concepts and focusing attention on the head injury. All efforts should be directed toward early diagnosis and intervention of the head injury.

Traditional Classification of Head Injuries

- **Open** injuries are the most commonly encountered brain injuries in combat.
- **Closed** injuries, seen more often in civilian settings, may have a higher frequency in military operations other than war.
- **Scalp** injuries may be closed (eg, contusion) or open (eg, puncture, laceration, or avulsion).
  - Any scalp injury may be associated with a skull fracture and/or underlying brain injury.
  - Open scalp injuries bleed profusely, even to the point of lethal blood loss, but usually heal well when properly repaired.
- **Skull fractures** may be open or closed, and are described as linear, comminuted, or depressed.
  - Skull fractures are usually associated with some degree of brain injury, varying from mild concussion, to devastating diffuse brain injury, to intracranial hematomas.
Open skull fractures are prone to infection if not properly treated.

**Mechanisms of Injury**

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

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

- Other etiologies include seizures (seen in 30%–40% of patients with penetrating brain injuries), fever, electrolyte disturbances (specifically, hyponatremia or hyperglycemia), and infection.
- **All of the above conditions can be treated.**
  - Elevations of ICP may occur early as a result of a space-occupying hematoma, or develop gradually as a result of brain edema or hydrocephalus.
  - Normal ICP is 5–15 mm Hg, with normal cerebral perfusion pressure (CPP = MAP-ICP) usually around 70–80 mm Hg.
  - Decreases in perfusion pressure as a result of systemic hypotension or elevated ICP gradually result in alteration of brain function (manifested by impairment of consciousness), and may progress to global brain ischemia and death if not treated.

**Patient Assessment and Triage**

During the primary and secondary assessment, attention should be placed on a complete examination of the scalp and neck. Fragments that enter the cranial vault with a transtemple, transorbital, or cross midline trajectory should be suspected as having associated neurovascular injuries. Wounds are typically contaminated by hair, dirt, and debris.
Head Injuries

and should be copiously irrigated clean with control of scalp hemorrhage **but not at the expense of delaying definitive neurosurgical treatment**! Scalp hemorrhage can be controlled with a head wrap, scalp clips, or surgical staples; a meticulous plastic surgical closure is only appropriate after intracranial injuries have been ruled out.

- The most important assessment is the **vital signs**.
- Next is the **level of consciousness**, best measured and recorded by the Glasgow Coma Scale (GCS) (see below).

---

**GLASGOW COMA SCALE**

<table>
<thead>
<tr>
<th>Component</th>
<th>Response</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Response (best extremity)</td>
<td>Obeys verbal command</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Localizes pain</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Flexion-withdrawal</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Flexion (decortication)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Extension (decerebration)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>No response (flaccid)</td>
<td>1</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td><strong>(1–6)</strong></td>
</tr>
<tr>
<td>Eye Opening</td>
<td>Spontaneously</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>To verbal command</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>To pain</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>1</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td><strong>(1–4)</strong></td>
</tr>
<tr>
<td>Best Verbal Response</td>
<td>Oriented and converses</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Disoriented and converses</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Inappropriate words</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Incomprehensible sounds</td>
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<td></td>
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<td>1</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td><strong>(1–5)</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>(3–15)</strong></td>
</tr>
</tbody>
</table>

- Triage decisions in the patient with craniocerebral trauma should be made based on admission GCS score.
  - A GCS ≤ 5 indicates a dismal prognosis despite aggressive comprehensive treatment and the casualty should be considered expectant.
A GCS $\geq 8$ indicates that a casualty may do well if managed appropriately.

♦ In general, neurologically stable patients with penetrating head injury can be managed effectively in the ICU with airway and ventilatory support, antibiotics, and anticonvulsants while awaiting surgery.

♦ An exception to this would be a deteriorating patient with a large hematoma seen on CT—this should be considered a surgical emergency.

♦ Casualties with GCS 6–8 can be the most reversible, with forward neurosurgical management involving control of ICP and preservation of CBF.

♦ Another important assessment is pupillary reactivity.

A single dilated or nonreactive pupil adds urgency and implies the presence of a unilateral space-occupying lesion with secondary brain shift. Immediate surgery is indicated.

The presence of bilateral dilated or nonreactive pupils is a dismal prognostic sign in the setting of profound alteration of consciousness.

Radiographic evaluation.

♦ Deployable CT scanners in standard ISO shelters are increasingly available in the field environment. To keep the scanner operational, a qualified maintenance chief should be married to the scanner (“crew-chief” concept).

♦ CT is the definitive radiographic study in the evaluation of head injury, and should be employed liberally as it greatly improves diagnostic accuracy and facilitates management.

♦ Skull radiographs still have a place in the evaluation of head injury (especially penetrating trauma).

♦ In the absence of CT capability, AP and lateral skull radiographs help to localize foreign bodies in cases of penetrating injuries and can also demonstrate skull fractures.

♦ This can help direct otherwise “blind” surgical intervention initially to the side of the head where the fracture is identified.
Cervical spine injury is uncommon in the setting of penetrating head injury.
- Closed head injury is commonly associated with injury of the cervical spine.
- Assume the presence of cervical spine injury and keep the cervical spine immobilized with a rigid collar until standard AP, lateral, and open-mouth radiographs can be obtained to exclude injury.
- CT once again is useful in evaluating casualties with a high suspicion for spinal injury.

Management

Medical.
- Primary tenets are basic but vital; clear the airway, ensure adequate ventilation, and assess and treat for shock (excessive fluid administration should be avoided).
- In general, patients with a GCS ≤ 12 should be managed in the ICU.
- ICU management should be directed at the avoidance and treatment of secondary brain injury.
  - PaO₂ should be kept at a minimum of 100 mm Hg.
  - Pco₂ maintained between 35 and 40 mm Hg.
  - The head should be elevated approximately 30°.
  - Sedate patient and/or pharmacologically paralyze to avoid “bucking” the ventilator and causing ICP spikes.
  - Broad-spectrum antibiotics should be administered to patients with penetrating injuries (a third-generation cephalosporin, vancomycin or Ancef, Unasyn or meropenen if acinetobacter suspected).
  - Anaerobic coverage with metronidazole should be considered for grossly contaminated wounds or those whose treatment has been delayed more than 18 hours.
  - Phenytoin should be administered in a 17-mg/kg load, which may be placed in a normal saline piggyback and given over 20–30 minutes (no more than 50 mg/min, because rapid infusion may cause cardiac conduction disturbances).
◊ A maintenance dose of 300–400 mg/d, either in divided doses or once before bedtime, should be adequate to maintain a serum level of 10–20 µg/L.

◊ Measure serum chemistries daily to monitor for hyponatremia.

◊ Monitor and treat coagulopathy aggressively.

◊ Monitoring of ICP is recommended for patients with GCS ≤ 8 (in essence, it is a substitute for a neurologic examination).

◊ A simple fluid-path monitor usually works well and allows CSF drainage. It may then be coupled to a manometer or to a multifunction cardiac monitor similar to a central venous catheter or arterial line.
  - Administer prophylactic antibiotic.
  - Make an incision just at or anterior to the coronal suture, approximately 2.5–3 cm lateral to the midline (Fig. 15-2a,b).
  - A twist drill craniostomy is performed, the underlying dura is nicked, and a ventricular catheter placed into the frontal horn of the lateral ventricle (encountered at a depth of 5 to 6 cm) (see Fig. 15-2b,c). Catheter should be directed toward the medial epicanthion on the coronal plane, and the tragus in the sagittal plane.
  - Even small ventricles can be easily cannulated by aiming the tip of the catheter toward the nasion in the coronal plane.
  - Ventricular catheters are highly preferable; acceptable substitutes are an 8 F Robinson catheter or pediatric feeding tube.
  - A key feature of this technique is to tunnel the drain out through a separate incision 2–3 cm from the primary one, thus reducing the risk of infection.

◊ The goal of management is to maintain a CPP of 60–90 mm Hg.

◊ A sustained ICP > 20 mm Hg should be treated (Fig. 15-3).
Fig. 15-2. Placement of intracranial ventricular catheter.
Emergency War Surgery

Fig. 15-3. Levels of intervention to reduce ICP.

- Sedation, head elevation, and paralysis.
- CSF drainage if a ventricular catheter is in place.
- **Hyperventilation to a $\text{Pco}_2$ of 30 to 35 mm Hg only until other measures take effect.** (Prolonged levels below this are deleterious as a result of small vessel constriction and ischemia.)
- Refractory intracranial hypertension should be managed with an initial bolus of 1g/kg of **mannitol** and intermittent dosing of 0.25–0.5 g/kg q4h as needed.
  - Aggressive treatment with mannitol should be accompanied by placement of a CVP line or even a PA catheter because hypovolemia may ensue.
- Any patient who develops intracranial hypertension or deteriorates clinically should undergo prompt repeat CT.
  - ♦ Mild hypothermia may be considered in isolated head injury, but avoid in the multitrauma patient.
  - ♦ Treat hypovolemia with albumin, normal saline, hypertonic saline, or other volume expanders to create a euvoelemic, hyperosmolar patient (290–315 mOsm/L).
  - ♦ Blast over-pressure CNS injuries.
Supportive medical therapy is usually sufficient. Only in rare cases is an ICP monitor, ventriculostomy, or cranial decompression necessary. In the absence of hematomas the use of magnesium has been beneficial. Structures particularly sensitive include optic apparatus, hippocampus, and basal ganglia. Delayed intracranial hemorrhages have been reported. Additionally, these patients have a higher susceptibility to subsequent injury and should be evaluated at a level 4/5 facility. Repetitive injury and exposure to blast over-pressure may result in irreversible cognitive deficits.

**Surgical**

- **Goals:** prevent infection and relieve/prevent intracranial hypertension.
- **Indications for emergent exploration.**
  - Space-occupying lesions with neurological changes (eg, acute subdural/epidural hematoma, abscess).
  - Intracranial hematoma producing a > 5 mm midline shift or similar depression of cortex.
  - Compound depressed fracture with neurological changes.
  - Penetrating injuries with neurological deterioration.
- **Relief of ICP with hemicraniectomy/ duraplasty / ventriculostomy.**
  - A large trauma flap should be planned for the evacuation of a mass lesion with significant underlying edema in the supratentorial space.
  - The flap should extend a minimum of 4 cm posterior to the external auditory canal and 3–4 cm off midline. Exposing the frontal, temporal, and parietal lobes allows for adequate cerebral swelling and avoids brain herniation at the craniotomy edge.
  - A capacious duraplasty should be constructed with a subdural ICP/ventricular catheter in place, allowing monitoring and drainage from the injured hemisphere.
- **Shave hair widely and scrub and paint the scalp with betadine.**
- **General anesthesia for major cases.**
Administer empiric antibiotics (third-generation cephalosporin).

Positioning can be adequately managed with the head in a doughnut or horseshoe-type head holder. For unusual positioning of the head, such as to gain access to the subocciput, use a standard three-point Mayfield fixation device.

Make a generous scalp incision to create an adequate flap. ♦ The flap should have an adequate pedicle to avoid ischemia. ♦ Retraction of the scalp flap over a rolled laparotomy sponge will avoid kinking the flap, which also may lead to ischemia.

The skull should be entered through a series of burr holes (Fig. 15-4) that are then joined to create a craniotomy flap (Fig. 15-5a).

Fig. 15-4. Cranial landmarks and location of standard burr holes.
Burr holes alone are inadequate to treat acute hematomas, but are of diagnostic utility in the absence of CT scanner. Exploratory burr holes may miss subfrontal or interhemispheric hematomas (Fig. 15-6).
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♦ The bone work may be done with a Hudson brace and Gigli’s saw, though a power craniotome is certainly preferable if available (see Fig. 15-5a).

☐ A dural opening, using the entire expanse of the cranial opening (with enough edge left to close the dura at the end of the case), should be created.

♦ The base of the dural opening should be on the side near any neighboring major venous sinus to avoid injury to large draining veins and aggravation of cerebral edema.

☐ The hematoma should then be gently evacuated with a combination of suction, irrigation, and mechanical removal (see Fig. 15-5b).

☐ Meticulous hemostasis should be achieved and the dura closed.

☐ Approach to **penetrating injury with neurologic changes** is aimed at removal of devitalized brain and easily accessible foreign bodies.

♦ Perform copious irrigation with an antibiotic solution (such as bacitracin) and a concerted attempt made to achieve watertight dural closure (again, using pericranium, among others, as needed).

♦ Tension-free scalp closure is also essential, but replacement of multiple skull fragments in an attempt to reconstruct the skull defect is not appropriate in the battlefield setting.

◊ Excellent results can be achieved with cranioplasty after evacuation out of the theater and a sufficient delay to minimize risk of infection.

☐ If a duraplasty is required, pericranium, temporalis fascia, or tensor fascia lata may be used.

☐ Tack-up sutures should be placed around the periphery and in the center of the dural exposure to close the dead space and discourage post-operative epidural hematoma formation.

☐ Replace bone flap and secure with wire or heavy suture.

♦ If severe brain swelling precludes replacement of the bone flap it can be discarded or preserved in an abdominal-wall pocket.
Head Injuries

- The galea of the scalp should generally be closed separately with an absorbable suture, and with staples used to close the skin.
  - A single layer closure with heavy monofilament nylon is acceptable but should definitely include the galea, with the sutures remaining in place at least 10 days.
  - A subgaleal or epidural drain may be used at the discretion of the surgeon.
- Apply a snug dressing using roller bandages around the entire head.

Evacuation of the Severely Head-Injured Patient

The trip is always longer than advertised. Transport only patients who can be expected to survive 12–24 hour movements, due to unexpected delays, route changes, or diversion in the tactical situation. A post-operative, craniotomy patient should first be observed for 12–24 hours prior to transport. Evacuating immediately may lead to the inability to treat delayed post-operative hematomas that may occur.

- All patients with GCS < 12 are ventilated.
- Patients with GCS < 8T require ICP monitoring.
- Ventriculostomies should be placed, position confirmed, secured, and working prior to departure.
- The critical care evacuation team must be confident in the ability to medically treat increased ICP and troubleshoot the ventriculostomy.
- Medical management of ICP in flight is limited to the use of head-of-bed elevation (30°–60°), increased sedation, thiopental, ventricular drainage, and mild hyperventilation. Loading a patient head-of-bed first limits the effect of takeoff on ICP.
- The escort of a severely head-injured patient must be able to manage the airway, ventilator, IV pumps, IV medicines, suction, in addition to ICP and CBF.
- Patients with possible intracranial pathology who may deteriorate in flight should be neurosurgically maximized on the ground prior to departure (eg, placement of a ventriculostomy or evacuation of a hematoma).
If a head-injured patient (GCS > 12) deteriorates in flight and is not already intubated, intubation should be performed and planned. Ensure rapid sequence intubation medicines, IV access, and airway equipment (especially Ambu bag, ventilator) are working and available.

The most difficult part of an evacuation is from the CSH to the CASF/MASF. Typically, battery life of the ventilator and monitors, and supplies of oxygen can be depleted before the exchange of the patient to the CASF/MASF. Although electric power is available on Black Hawks and FLA (ground ambulance), it is rarely used.

Prior to departure from the CSH the following precautions must be taken by the escort:

- Ensure knowledge of patient injuries and clinical course. (Have narrative summary and pertinent radiographs in hand.)
- Ensure adequate medicines for minimum of 3 days.
- Ensure monitors, ventilators, and suction and IV pumps all have adequate battery life.
- Ensure adequate oxygen supplies, and that the escort has the familiarity with and the ability to switch oxygen tanks.
- Have an alternate battery-operated, tactical light source to read monitors during transport.
- Assemble patients on the stretcher to avoid iatrogenic injuries to limbs, organizing tubes, lines, electrical leads, and wires so as not to become snared during movements. (When available, a SMEAD shelf attached to the stretcher allows monitors to be secured and elevated off the patient’s body.)
- Ensure that limbs (toes and fingers) and torso are covered and insulated during the trip to prevent hypothermia.
- During movements ensure central lines, a-lines, and ventricular catheters do not become dislodged. Ensure lines and tubes are sutured or otherwise secured.
- Ensure the ventriculostomy does not develop an air-lock. Venting the tublet can be performed with a 21-gauge needle.
Chapter 16

Thoracic Injuries

Introduction
About 15% of war injuries involve the chest. Of those, 10% are superficial (soft tissue only) requiring only basic wound treatment. The remaining 90% of chest injuries are almost all penetrating.

Those injuries involving the central column of the chest (heart, great vessels, pulmonary hilum) are generally fatal on the battlefield. Injuries of the lung parenchyma (the vast majority) can be managed by the insertion of a chest tube and basic wound treatment. Although penetrating injuries are most common, blunt chest trauma may occur and can result in disruption of the contents of the thorax as well as injury to the chest wall itself. Blast injuries can result in the rupture of air-filled structures (the lung) as well as penetrating injuries from fragments.

The immediate recognition and treatment of tension pneumothorax is the single most important and lifesaving intervention in the treatment of chest injuries in combat. Distended neck veins, tracheal shift, decreased breath sounds, and hyperresonance in the affected hemithorax, and hypotension are the cardinal signs. None or all may be present. Immediate decompression is lifesaving.

With the advent of body armor, it is hoped that the majority of thoracic injuries seen in past conflicts will be avoided. Unfortunately, there will be individuals who will not have such protection, as well as others who will sustain chest injuries despite protection.
Anatomic Considerations

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

Penetrating thoracic injuries below the T4 level (nipple line) have a high probability of involving abdominal structures (Fig. 16-1).

Evaluation and Diagnosis

Knowledge of the mechanism of injury (eg, blast, fragment, among others) may increase the index of suspicion for a particular injury. A complete and accurate diagnosis is usually not possible because of the limited diagnostic tools available in the setting of combat trauma. Nonetheless, because injuries to the chest can profoundly affect breathing and circulation (and on rare occasion, the airway), a complete and rapid assessment of each injury is mandatory.

- If the casualty is able to talk, there is reasonable assurance that the airway is intact.
Life-Threatening Injuries

Injuries not immediately obvious, yet requiring urgent attention, include tension pneumothorax, massive hemothorax, and cardiac tamponade.

- **Tension Pneumothorax.**
  - A patient with a known chest injury presenting with an open airway and difficulty breathing has a tension pneumothorax until proven otherwise and requires rapid decompression and the insertion of a chest tube.

- **Massive Hemothorax.**
  - The return of blood may indicate a significant intrathoracic injury. Generally, the immediate return of 1,500 cc of blood mandates thoracotomy (especially if the wound was sustained within the past hour). With less blood initially, but a continued loss of 200 cc/hour for over 4 hours, thoracotomy is indicated.
  - Casualties with massive thoracic hemorrhage require damage control techniques (see Chapter 12, Damage Control Surgery).

- **Cardiac Tamponade.**
  - Distended neck veins (may be absent with significant blood loss) in the presence of clear breath sounds and hypotension indicate the possibility of life-threatening cardiac tamponade.
  - Fluid resuscitation may temporarily stabilize a patient in tamponade.
  - Perform an ultrasound (US) with a stable patient.
    - If positive, proceed to the OR (pericardial window, sternotomy, thoracotomy). Any pericardial blood mandates median sternotomy/thoracotomy.
    - A negative US requires either repeat US or pericardial window, depending on level of clinical suspicion.
  - Pericardiocentesis is only a stopgap measure on the way to definitive surgical repair.
• **Open pneumothorax** (hole in chest wall) is treated by placing a chest tube and sealing the hole. Alternatives include one-way valve chest dressings or a square piece of plastic dressing taped to the chest on three sides.

• **Flail chest** (entire segment of the chest wall floating due to fractures of a block of ribs, with two fractures on each rib) will require treatment (either airway intubation or observation) based on the severity of the underlying lung injury. In cases where intubation is not required, repeated intercostal nerve blocks with a long-acting local anesthetic such as Marcaine may be very helpful in relieving pain and limiting atelectasis and other pulmonary complications.

**Surgical Management**

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

**Tube thoracostomy** (chest tube).

• **Indications.**
  o Known or suspected tension pneumothorax.
  o Pneumothorax (including open).
  o Hemothorax.
  o Any penetrating chest injury requiring transport (mandatory in case of aeromedical evacuation).

• **Procedure (Fig. 16-2).**
  o In cases of tension pneumothorax, **immediate decompression with a large bore needle is lifesaving.** An IV catheter (14/16/18 gauge at least 2–3 inches in length) is inserted in the midclavicular line in the second interspace (approximately 2 fingerbreadths below the clavicle on the adult male). Entry is confirmed by the sound of air passing through the catheter. **This must be rapidly followed by the insertion of a chest tube.**
  o In a contaminated environment, a single gram of IV cefazolin (Ancef) is recommended.
  o If time allows, prep the anterior and lateral chest on the affected side with povidone-iodine.
- Identify the incision site along the anterior axillary line, intersecting the 5th or 6th rib.
- Inject a local anesthetic in the awake patient, if conditions allow.
- Make a transverse incision, 3–4 cm in length, along and centered over the rib, carrying it down to the bone.

Fig. 16-2. Procedure for tube thoracostomy.
Insert a curved clamp in the incision, directed over the top of the rib, and push into the chest through the pleura. A distinct pop is encountered when entering the chest and a moderate amount of force is necessary to achieve this entry. A rush of air out of the chest will confirm a tension pneumothorax. Insertion depth of the tip of the clamp should be limited by the surgeon’s hand to only 3 or 4 cm to make sure that the clamp does not travel deeper into the chest, resulting in damage to underlying structures.

Spread the clamp gently and remove. The operator’s finger is then inserted to confirm entry.

Insert a chest tube (24 to 36 French) into the hole. All chest tube side-holes must be in the chest. If no chest tubes are available, an adult endotracheal tube may be used.

Attach a chest tube to a Heimlich valve, sealed pleurovac, or bottles. In a resource constrained environment, a cut-off glove or Penrose drain may be attached to the end of the chest tube.

Secure the tube with suture, if possible, and dress to prevent contamination.

**Resuscitative Thoracotomy**

- Only indicated in penetrating chest injury in extremis or with recent loss of vital signs.
- These patients are generally unsalvageable, even with unlimited resources and no other significant casualties.
- If performed, a rapid assessment of injuries should be made, and in the case of unsalvageable injuries, the procedure should be immediately terminated.

**Procedure**

- With the patient supine, make an incision in the left inframammary fold starting at the lateral border of the sternum extending to the midaxillary line (Fig. 16-3).
- The procedure should be abandoned upon the discovery of devastating injuries to the heart and great vessels.
- If no injury is found in left chest, rapidly extend the incision across the midline, crossing through the sternum with a Lebsche sternum knife, performing a mirror-image thoracotomy (clamshell, Fig. 16-4). When doing this procedure you will cut across both internal mammary arteries, which will be a significant source of bleeding.
- Elevating the anterior chest wall will expose virtually all mediastinal structures.
- Open the pericardium and assess the heart.
- **Priorities are to stop bleeding and restore central perfusion.**
  - Holes in the heart and/or great vessels should be temporarily occluded.
    - Temporary occlusion can be achieved with fingers, side-biting clamps or Foley catheters with 30 cc balloons. Any other sterile device of opportunity is acceptable.
  - Major pulmonary hilar injuries should be cross-clamped en masse.
  - Descending aorta located, cross-clamped, and cardiac function restored via defibrillation or massage. (Make sure to open the mediastinal pleura over the aorta to securely apply the vascular clamp.)
  - If unable to restore cardiac function rapidly, abandon the operation.
- With successful restoration of cardiac function, injuries should be more definitively repaired.

**Subxiphoid Pericardial Window**

Subxiphoid pericardial window should not be attempted in an unstable patient. Unstable patients with penetrating injuries suspicious for cardiac injury should undergo immediate median sternotomy/thoracotomy.
Procedure
- With the patient supine, make a 4–5 cm longitudinal incision just on and below the xiphoid process through the skin and fascia.
- Bluntly dissect superiorly toward the heart exposing the phrenopericardial membrane below the heart.
Thoracic Injuries

Place two stay sutures into the membrane and sharply incise between them, with care to avoid the heart, opening the pericardial sac and exposing the underlying beating heart.

**Median Sternotomy**

- **Indications.**
  - Suspected cardiac injury in an unstable patient.
  - Positive pericardiocentesis/subxiphoid pericardial window.
  - Suspected injury to the great vessels in the chest.
  - Suspected distal tracheal injury.

- **Procedure.**
  - In the supine position, make a midline skin incision from the sternal notch to just below the xiphoid.
  - Through blunt/sharp dissection, develop a plane for several centimeters both superiorly and inferiorly beneath the sternum.
  - Divide the sternum with a sternal saw or Lebsche knife. Keep the foot of the knife/saw tilted up toward the undersurface of the sternum to avoid cardiac injury. Bone wax can be used to decrease bleeding on the cut edges of the sternum.
  - Separate the halves of the sternum using a chest retractor.
  - Carefully divide the pericardium superiorly, avoiding the innominate vein, exposing the heart and base of the great vessels.

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

  - Close with wire suture directly through the halves of the sternum, approximately 2 cm from the edge, or around the sternum through the costal interspaces using wire sutures.
  - Place one or two mediastinal tubes for drainage, exiting through a midline stab wound inferior to the mediastinal skin incision.
Other Approaches

- **Supraclavicular.**
  - **Indication.**
    - ♦ Mid to distal subclavian artery injury.
  - **Procedure.**
    - ♦ Make an incision 2 cm above and parallel to the clavicle, beginning at the sternal notch and extending laterally 8 cm.

- **Trap door** (Fig. 16-5).
  - **Indication.**
    - ♦ Proximal left subclavian artery injury.
  - **Procedure.**

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**Fig. 16-5.** Trap door procedure.
♦ Perform supraclavicular approach as above.
♦ Perform a partial median sternotomy to the fourth intercostal space.
♦ At the fourth intercostal interspace, incise the skin laterally in the submammary fold to the anterior axillary line.
♦ Divide the sternum laterally and continue in the 4th intercostal space (ICS) to the anterior axillary line. The internal mammary artery will be divided and must be controlled.
♦ It may be necessary to either fracture or remove a section of clavicle to gain adequate exposure of the proximal left subclavian artery.
♦ Approach distal left subclavian artery injuries through a supraclavicular incision.

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

### Specific Injuries

• **Vascular.**
  o Initially, holes in vessels should be digitally occluded. Stopgap measures include placing Fogarty or Foley catheters, side-biting clamps, or in the case of venous injuries, sponge sticks.
  o Total occlusion or clamping may temporarily be necessary to allow resuscitation to continue and restore cardiac function.
If cardiac function cannot be restored within 5 to 10 minutes, the procedure should be abandoned (on-the-table triage).

Repair of vessels should follow the principles detailed in vascular repair: attempting primary repair if possible, with the use of prosthetics if primary repair is not feasible. Consider shunting as an alternative.

Heart.

The usual result of high-velocity injuries to the heart is irreparable destruction of the muscle.

Isolated punctures of the heart should be exposed (opening the pericardium) and occluded by finger pressure. Other methods include the use of a Foley catheter or skin staples.

Use pledged horizontal mattress sutures (2-0 prolene) on a tapered needle for definitive repair. Care must be taken to avoid additional injury to coronary vessels. Extreme care must be taken to avoid tearing the cardiac muscle.

Atrial repairs may include simple ligature, stapled repair, or running closures (Fig. 16-6).

Temporary inflow occlusion may prove helpful in repair.

More complex repairs are impractical without cardiac bypass.

Lung.

Tube thoracostomy alone is adequate treatment for most simple lung parenchymal injuries.

Large air leaks not responding to chest tubes or that do not allow adequate ventilation will require open repair (see tracheobronchial tree below).

Posterolateral thoracotomy is preferred for isolated lung injuries. Anterior thoracotomy may also be used.

Control simple bleeding with absorbable suture on a tapered needle. Alternatively, staples (TA-90) may be used for bleeding lung tears.
Thoracic Injuries

- **Tractotomy**: Open any bleeding tracts (through and through lung penetrations) with a GIA stapler and ligate bleeding points.

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

- Resection for bleeding may be indicated with severe parenchymal injury. Anatomic resections are **not** indicated and simple stapled wedge excisions recommended.

- Uncontrolled parenchymal/hilar bleeding, or complex hilar injuries with massive air leak should be controlled with hilar clamping and repair attempted. Pneumonectomy is performed as a last resort (90% mortality).

Fig. 16-6. Repair of penetrating cardiac injury.
Emergency War Surgery

- **Tracheobronchial tree.**
  - Suspect the diagnosis with massive air leak, frothy hemoptysis, and pneumomediastinum.
  - Confirm by bronchoscopy.
  - Airway control is paramount.
  - Median sternotomy is best approach.
  - Repair over endotracheal tube with absorbable suture — may require segmental resection. Bolster with pleural or intercostal muscle flap.
  - Temporizing measures include:
    - Single lung ventilation.
    - Control the airway through the defect.

- **Esophagus.**
  - Isolated thoracic esophageal injuries are exceedingly rare. They will usually be diagnosed incidentally associated with other intrathoracic injuries.
  - Diagnostic clues include pain, fever, leucocytosis, cervical emphysema, Hamman’s sign, chest X-ray (CXR) evidence of pneumothorax, mediastinal air, and pleural effusion. Contrast swallow may confirm the diagnosis.
  - Start IV antibiotics as soon as the diagnosis is suspected, and continue post-op until fever and leucocytosis resolve. This is an adjunctive measure only. Surgery is the definitive treatment.
  - For stable patients in a forward location, chest tube drainage and a nasogastric tube placed above the level of injury is a temporizing measure. Ideally, primary repair is performed within 6–12 hours of injury. Beyond 12 hours, isolation of the injured segment may be necessary.

  The preferred approach for intrathoracic esophageal injuries is posterolateral thoracotomy; right for upper esophagus and left for lower esophagus.

  - Locate the injury by mobilizing the esophagus. Primarily repair with a single layer of 3-0 absorbable suture and cover with pleural or intercostal muscle flap.
- Drainage with chest tubes (one apical, one posterior) is recommended.
- If unable to primarily repair (as with a large segmental loss or severely contaminated/old injury), staple above and below the injury, place a nasogastric (NG) tube into the upper pouch and place a gastrostomy tube into the stomach. Drain the chest as indicated above. Complex exclusion procedures are not indicated in a forward operative setting.
- An alternative when the esophageal injury is too old for primary repair is to close the injury over a large T-tube, which converts the injury to a controlled fistula. The mediastinum is then widely drained using chest tubes or closed suction catheters placed nearby. After a mature fistula tract is established, slowly advance the T-tube and later the mediastinal drains can be slowly advanced.

- **Diaphragm.**
  - All injuries of the diaphragm should be closed.
    - Simple small lacerations (< 2 cm) should be reapproximated with interrupted nonabsorbable 0 or 1-0 horizontal mattress sutures.
    - Lacerations larger than 2 cm should be approximated as above, then reinforced with a running suture to assure an airtight closure.
    - Care should be exercised in the central tendon area to avoid inadvertent cardiac injury during the repair.
  - If there is significant contamination of the pleural space by associated enteral injuries, anterior thoracotomy and pleural irrigation and drainage with two well-placed chest tubes should strongly be considered.
    - Inadequate irrigation and drainage leads to a high incidence of empyema, especially of the fungal variety.
Emergency War Surgery
Introduction
Changing patterns of warfare together with improvements in protective body armor combine synergistically to minimize truncal trauma incidence, severity, and mortality, despite increasingly lethal weapons systems. Despite these advances, penetrating abdominal trauma still occurs and treatment of these injuries will always be an important component of war surgery.

Trauma to the abdomen, both blunt and penetrating, can lead to occult injury that can be devastating or fatal if not treated. In the unstable patient with abdominal injury, the decision to operate is usually straight forward and should be acted on as soon as it is made. In a few rapidly hemorrhaging patients with thoracoabdominal injuries, a rapid decision must be made as to which cavity to enter first. This chapter addresses some of these issues.

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

- Posterior truncal penetrating injuries from the tip of the scapula to the sacrum may also have caused retroperitoneal and intra-abdominal injuries. A low threshold for exploratory laparotomy in these patients is warranted when there are not other diagnostic modalities available.

Diagnosis of Abdominal Injury
- Document a focused history to include time of injury, mechanism of injury, previous treatments employed, and any drugs administered.
Emergency War Surgery

- Inspection of the chest and abdomen will be the most reliable part of the physical examination, especially regarding penetrating injuries.
- Determine if the patient requires laparotomy, not the specific diagnosis.

Indications for Laparotomy – Who, When, and Where
First imperative is to determine who needs surgery.

- Patients who have
  - Penetrating abdominal wounds as described in box above.
  - Other penetrating truncal injuries with potential for peritoneal penetration and clinical signs/symptoms of intraperitoneal injury.
  - Blunt abdominal injuries presenting in shock.

- When and Where.
  - When aeromedical evacuation is uncertain and will involve substantial distance, unstable patients with life or limb threatening circumstances should undergo laparotomy at the nearest forward surgical team (FST).
  - Stable patients who can tolerate transport and delay of 6 hours or so, should undergo initial controlled resuscitation, presurgical care (including antibiotics), and be transported to the next level of care for surgery.

When the tactical situation is static, aeromedical evacuation effective, and the distance between FST and combat support hospital (CSH) or higher level hospitals is short, all casualties, including those who are unstable, should bypass the FST and be taken directly to a higher level hospital.

Diagnostic Adjuncts
Minimally invasive adjuncts to diagnosis—computed tomography (CT) scan, diagnostic peritoneal lavage (DPL), and ultrasound (US)—have been used to decrease the number of negative laparotomies in stable, blunt abdominal trauma patients in peace-time settings with good follow-up of patients. Some have been used in lieu of laparotomy to evaluate those with penetrating injuries, when the suspicion is high that no intra-abdominal injury has occurred. This practice has the
Abdominal Injuries

potential of missing injuries. These diagnostic screening procedures are primarily used in stable patients with a mechanism of injury suggesting abdominal injury, but without an obvious operative indication. They should be relied on only when good follow up is possible. US and, to a limited extent, DPL have some use in the unstable patient to indicate which cavity should be entered first. US and DPL may also serve as triage tools in the mass casualty situation.

Abdominal Ultrasound

- Advantages: Noninvasive, may repeat frequently, quick, easy, identifies fluid in the abdomen reliably.
- Disadvantages: Operator dependant, may miss small amounts of fluid associated with hollow-viscous injuries.
- Sonography (focused abdominal sonography for trauma [FAST]) has become an extension of the physical examination of the abdomen and should be performed whenever available and when abdominal injury is suspected.
  - 3.5 to 5 MHz curved probe is optimal.
  - The abdomen is examined through four standard sonographic windows.
- A FAST examination assists the surgeon to determine the need for laparotomy in blunt-injured patients but does NOT identify specific injuries.
  - A FAST examination does not identify or stage solid organ or hollow-viscous injury, but reliably identifies free intraperitoneal fluid.
- FAST aids in prioritization of penetrating injury patients for the OR.
- FAST aids in identifying which cavity to open first in patients with thoracoabdominal injuries.
- A FAST examination identifies pericardial fluid, and may assist in the diagnosis of hemopneumothorax.

Ultrasound Views

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

**Fig. 17-2 a,b.** The standard four locations for sonographic windows.
Fig. 17-3 a,b,c. Normal and abnormal negative sonographic examinations for the right upper quadrant.

Fig. 17-4 a,b,c. Normal and abnormal negative sonographic examinations for the cardiac window.
Fig. 17-5 a,b,c. Normal and abnormal negative sonographic examinations for the left upper quadrant.

Fig. 17-6 a,b,c,d. Normal and abnormal negative sonographic examinations for the pelvic window.
Abdominal Injuries

Diagnostic Peritoneal Lavage
DPL has been a mainstay of blunt abdominal trauma diagnosis for many years. Unfortunately, in-theatre combat medical units from Level 1 to Level 3 are not routinely outfitted with microscopic laboratory functions to provide cell counts or fluid enzyme determinations. Thus, the only reliable information obtained from DPL is the aspiration of 10 cc of gross blood. Gross blood aspiration is the most infrequently positive criterion of DPL, and its value is probably supplanted by FAST.

- May be useful when US or CT are not available, or as triage tool.
- Requires laboratory for most sensitivity.
  - Blunt: Aspiration of 10 cc of gross blood, RBCs > 1,000,000/mL, WBCs > 500/mL, fecal material.
  - Penetrating: not recommended to ruling out (R/O) injury in penetrating combat wound.
- May help determine which body cavity to enter first in an unstable patient with truncal injury.
- Advantages: Sensitive to small amounts of fluid, including hollow-visceral leaks; fairly quick.
- Disadvantages: Invasive, not repeatable, slower than US.
- Kits allow Seldinger technique.
  - Arrow (AK-09000).
  - Baxter Lazarus-Nelson (MLNK9001).
- Field Expedient substitution: Open technique with small, vertical infraumbilical incision and any tubing (IV, straight or balloon catheter). Cut at least a dozen extra side holes.

CT Scan
- Advantages: Defines injured anatomy in stable patients.
- Disadvantages: Slow; requires contrast use and equipment availability; may miss small hollow organ leaks; requires transport away from emergency care area; operator/interpreter dependant; difficult to repeat.
Wound Exploration
- Blast injuries and improvised explosive devices (IEDs) create many low-velocity fragments that may penetrate the skin but not the abdominal cavity. Operative wound exploration in the stable patient with a normal or equivocal examination can help determine the need for formal exploratory laparotomy.
  - When possible wound exploration should be performed in the operating room with adequate instruments and lighting.
  - Finding the fragment in the abdominal wall precludes laparotomy.
  - If the tract is not adequately identified or the fragment seen on plain film cannot be identified, formal laparotomy should be performed.

Operative Planning and Exposure Techniques
- Give broad spectrum antibiotic pre-op, continue for 24 hours.
  - Redose short half-life antibiotics intraoperatively and consider redosing antibiotics with large amounts of blood loss.
- Perform laparotomy through a midline incision.
  - When wide exposure is needed, extend the incision superiorly just lateral to the xiphoid process and inferior to the symphysis pubis.
- Quickly pack all 4 quadrants while looking for obvious injuries.
- Control hemorrhage.
- Assess physiologic status.
  - Considering casualty physiology, create operative plan to control contamination and complete operation.
    - Consider damage control (see Chapter 12, Damage Control Surgery) early and often.
    - If stabilized/improving, proceed with definitive surgery.
- Identify all organ and hollow-viscus injuries.
Abdominal Injuries

- Eviscerate the small bowel to increase workspace.
- Divide the ligamentous attachments of the liver to improve exposure in the right upper quadrant or upper midline.
- Fold the left lateral segment of the liver down and to the right to improve exposure at the gastroesophageal junction.
- Improve exposure to the liver by extending the incision into the inferior sternum and across into the lower right chest (thoracoabdominal).

Stomach Injuries
- The stomach is a vascular organ and will do well after almost any repair.
  - Always enter the lesser sac to determine posterior wall injuries.
- Encircle the distal esophagus with a Penrose drain to provide traction and improve visibility in high midline injuries.
- Minimally debride and primarily close stomach defects.

Duodenum Injuries
Injuries to the Duodenum are associated with massive upper abdominal trauma. Early consideration for damage control surgery should be considered (see Chapter 12, Damage Control Surgery).

- Missed injuries of the duodenum have devastating morbidity.
- Bile staining or hematoma in the periduodenal tissues mandates full exploration of the duodenum (Kocher maneuver).
- Minor injuries can be repaired primarily.
- Major injuries should be repaired if the lumen will not be narrowed by more than 50%. Options for closing injuries of greater than 50%:
  - Close duodenal wall around a tube duodenostomy.
    - Use a No. 2-0 absorbable suture (Vicryl).
    - Use the largest malecot catheter available.
  - Bring up a Roux-en-Y jejunal limb and create an anastamosis between the limb and the injury (Fig. 17-7).
  - The procedure of last resort is pancreaticoduodenectomy.
For major injuries, divert the gastric stream with a gastrostomy and close the pylorus—two options:
- Through a gastrotomy, ligate the pylorus with No. 0 absorbable suture.
- Using a noncutting stapling device, staple but **do not divide** the pylorus. Place a feeding jejunostomy for nutrition at this controlled reconstruction.

- Widely drain all injuries with closed-suction drains.
- Any method used to close the pylorus will last only 14–21 days. The possibility of injury to the biliary and pancreatic ducts should be considered when injuries involve the 2nd portion of the duodenum or the pancreatic head.

**Pancreas Injuries**
- Any injury to the pancreas/duct requires drainage.
Abdominal Injuries

- Even if ductal injury is not identified, it should be presumed and drained.
- Resect clearly nonviable pancreatic body/tail tissue.
- Transection or near-transection of the pancreatic duct can be treated by
  - Distal end of proximal pancreas segment oversewn/stapled.
  - Proximal end of distal segment oversewn/stapled and entire distal segment left in-situ.
  - Distal segment resection (typically requires splenectomy).
  - Distal segment drainage by Roux-en-Y anastomosis to small bowel.

Major injuries to the head of the pancreas may require pancreaticoduodenectomy, which SHOULD NEVER BE ATTEMPTED in an austere environment but instead treated by the principles of damage control surgery— DRAIN, DRAIN, DRAIN.

Liver Injuries

- Most liver injuries can be successfully treated with direct pressure and packing followed by aggressive resuscitation and correction of coagulopathy.
- Generous exposure is required and should be gained early and aggressively.
  - Mobilize triangular and coronary ligaments for full exposure
  - Use extension into right chest if needed.
  - Place several laparotomy pads above the dome of the liver to displace it down into the field of view.
- Short duration clamping of hepatic artery and portal vein (Pringle maneuver) may be required to slow bleeding while gaining other control. If bleeding continues despite Pringle maneuver, especially from behind the liver, this indicates a retrohepatic venous injury or retrohepatic vena caval injury. The injuries should be approached in only the most advanced settings with extraordinary amounts of resources. On table retriage or aggressive packing and intensive care unit (ICU) resuscitation should be employed.
- Use finger fracture of liver parenchyma to expose deep bleeding vessels.
- Large exposed injuries of the liver parenchyma can be controlled in a number of ways:
  o Exposed large vessels and ducts should be suture-ligated.
  o Overlapping mattress sutures of No. 0-Chromic on a blunt liver needle is fast and effective for controlling raw surface bleeding.
  o Placement of Surgicel on the raw surface and high-power electrocautery to “weld” it in place is also effective.
- Bleeding tracts through the liver can be controlled by tying off the end of a Penrose drain, placing it through the tract, and “inflating” it with saline to tamponade the tract.
- Urgent surgical resection is strongly discouraged:
  o Indicated only when packing/pressure fails.
  o Follows functional or injury pattern, not anatomic lines.
- Use a pedicle of omentum in a large defect to reduce dead space.

Avoidance of coagulopathy, hypothermia and acidosis is essential in successful management of major liver injuries. APPLY DAMAGE CONTROL TECHNIQUES EARLY.

- Retrohepatic vena cava and hepatic vein injuries require a tremendous amount of resources (blood products, OR time, equipment) typically unavailable in a forward surgery setting (on-table triage in mass casualty).
  o Packing is most successful option.
  o If packing fails, consider an atrio-caval shunt. (see Figure 17-8).
- Provide generous closed suction drainage around major liver injuries.

Biliary Tract Injuries
- Injuries to the gall bladder are treated by cholecystectomy.
- Repair common bile duct injuries over a T-tube.

Fig. 17-8. Atrio-caval shunt.
Abdominal Injuries

- A No. 4-0 or smaller absorbable suture is used on the biliary tree.
- Extensive segmental loss requires choledochoenterostomy or tube choledochostomy (depending on time and patient physiology).
- Drain widely.

Splenic Injuries
- Splenic salvage has no place in combat surgery.
- Drains should not be routinely placed postsplenectomy if the pancreas is uninvolved.
- Splenic injury should prompt exploration for associated diaphragm, stomach, pancreatic, and renal injuries.
- Immunize post-op with pneumococcal, haemophilus, and meningococcal vaccines (may defer until Level 3/CONUS MTF, but must not be forgotten).

Small-Bowel Injuries
- Debride wound edges to freshly bleeding tissue.
- Close enterotomies in one or two layers (skin stapler is a rapid alternative).
- With multiple enterotomies to one segment of less than 50% of small-bowel length, perform single resection with primary anastomosis. Avoid multiple resections.

Colon Injury
Simple, isolated colon injuries are uncommon. In indigenous populations and enemy combatants (eg, patients who cannot be readily evacuated), diversion with colostomy should be the procedure of choice, especially at Level 2. The often poor nutritional status of these populations does not support primary repair. The presence of any of the complicating factors listed below mandates colostomy.
- Simple, isolated colon injuries should be repaired primarily.
  - Debride wound edges to normal, noncontused tissue.
  - Perform two-layer closure or anastomosis.
- For complex injuries, strongly consider colostomy/diversion, especially when associated with:
  - Massive blood transfusion requirement.
  - On-going hypotension.
  - Hypoxia (severe pulmonary injury).
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- Reperfusion injury (vascular injury).
- Multiple other injuries.
- High-velocity injuries.
- Extensive local tissue damage.
- Potential breakdown of a repair or anastomosis is highest in the setting of concomitant pancreatic injury.
- Damage control technique: control contamination with ligation/stapling of bowel, delay creation of the stoma to the definitive reconstruction.
- Clearly document treatment for optimal follow-up throughout Levels of Care.
- At the time of formation, a colostomy should be matured.

Rectal Injuries
Rectal injuries can be difficult to diagnose unless very dramatic. Any question of an injury raised by proximity of another injury, rectal examination, or plain abdominal film radiography MANDATES proctoscopy. Gentle distal washout with dilute Betadine solution is usually required to be able to perform rigid proctoscopy. Findings can be dramatic disruptions of the rectal wall but more commonly are subtle punctuate hemorrhages of the mucosa. All abnormal findings should prompt corrective intervention.
- Consider the traditional 4 “Ds” of rectal injury: Diversion, Debridement, Distal washout, and Drainage.
  - Of these, diversion is the most important.
    - Transabdominal sigmoid colostomy is easiest.
    - If the injury has not violated the peritoneum, exploration of the extraperitoneal rectum should NOT be done at laparotomy unless indicated for an associated nonbowel injury. This avoids contaminating the abdominal cavity with stool.
  - Debridement and closure of small- to medium-sized wounds is unnecessary in patients who have been diverted and drained. In any but the lowest of wounds, debridement and closure are difficult and troublesome.
  - Distal washout is usually necessary to assess the injury. Use gentle pressure when irrigating to minimize contamination of the perirectal space.
Abdominal Injuries

- Fecal contamination of the perirectal space mandates presacral drainage. Presacral drains should be placed any time the patient will leave your immediate care.
  - Drains are placed through the perineum into the retrorectal space (Fig. 17-9).
- Peritonealized rectal injuries are easily accessed transabdominally and should be repaired and protected with diversion.
- Hematoma in the perirectal space should be drained either transluminally by leaving the injury open or by placing presacral and/or intraabdominal drains.

Retroperitoneal Injuries
- Left medial visceral rotation moves the colon, pancreas, and small bowel to expose the aorta rapidly. Proximal aortic control can be rapidly obtained with compression or a clamp on the aorta at the hiatus, or through the left chest.
- Right medial visceral rotation (colon plus Kocher maneuver to elevate duodenum) exposes the subhepatic vena cava.
- Three zones of the retroperitoneum (Fig. 17-10).
  - I-Central, supracolic: explore for all injuries.
  - II-Central, infracolic: penetrating trauma, explore; blunt trauma, explore for expanding hematoma.
  - III-Lateral: blunt trauma, avoid exploration if possible because exploration increases the likelihood of opening a stable hematoma and, thus, precipitating nephrectomy. Explore for penetrating trauma.
- Gain proximal vascular control before entering the hematoma.
Abdominal Closure

- Close fascia if possible.
  - Massive swelling associated with large amounts of blood loss and resuscitation and large injuries may necessitate temporary closures (see Chapter 12, Damage Control Surgery). Otherwise, closure is usually possible.
  - A few penetrating battlefield wounds are isolated, small, and without visceral contamination, and it is perhaps safe to close the skin. Most are not, and these patients will be passed quickly from one surgeon to the next, so the risk of missed and catastrophic infection is increased; the skin should not be closed.
- Retention sutures are strongly recommended for the same reasons.
Chapter 18

Genitourinary Tract Injuries

Introduction
Genitourinary (GU) injuries constitute approximately 5% of the total injuries encountered in combat. Their treatment adheres to established surgical principles of hemostasis, debridement, and drainage. Proper radiographic evaluation prior to surgery may replace extensive retroperitoneal exploration at the time of laparotomy in the diagnosis of serious GU injuries.

GU wounds, aside from injuries of the external genitalia, are typically associated with serious visceral injury.

Renal Injuries
- Most renal injuries, except for those of the renal pedicle, are not acutely life threatening. Undiagnosed or improperly treated injuries, however, may cause significant morbidity.
- While the vast majority of blunt renal injuries will heal uneventfully with observation and conservative therapy, a significant number of renal injuries in combat will come from penetrating wounds and require exploration.

The evaluation of a suspected renal injury is based on the type of injury, physical examination, and urinalysis.

- Hematuria is usually present in patients with renal trauma, and gross hematuria in the adult patient is concerning for a significant injury. The absence of hematuria, however, does not exclude renal trauma. Renal injury must be suspected in patients who have sustained significant concurrent injuries such as multiple rib fractures, vertebral body or transverse process fractures, crushing injuries of the chest or thorax, or penetrating injury to the flank, chest, or upper abdomen.
Adult patients who present with gross hematuria, microscopic hematuria with shock at any time following the injury, and significant concurrent injury require further evaluation of their kidneys. Computed tomography (CT) provides excellent staging of renal injuries and aids in the decision whether or not to explore the injured kidney.

In the combat setting, many patients require rapid exploration before definitive radiographic staging can be completed. An intraoperative single-shot intravenous pyelogram (IVP) is useful in their evaluation.

- Procedure for one-shot IVP:
  - 2 cc/kg of high-dose contrast is injected in either the ED or OR setting.
  - A single standard KUB radiograph is obtained 10 minutes following the contrast injection.
- While high-osmolality contrast (Renografin, Hypaque, or Conray) is adequate, low-osmolality contrast (Omnipaque, Isovue, Optiray) is less likely to generate a reaction and is less toxic to the kidney.

Major renal injuries usually appear as obscured renal shadows on IVP.
- Detailed anatomic information regarding the degree of renal injury or presence of urinary extravasation should not be expected on the trauma IVP. Delayed films, however, may improve detection of urinary extravasation.
- The study should confirm the presence and function of the contralateral kidney and may demonstrate congenital anomalies such as renal ectopia or fusion. Understanding the function of the contralateral kidney is imperative to sound intraoperative decision making during exploration and possible salvage of the injured kidney.

Renal trauma is categorized by the extent of damage to the kidney.
- Minor injuries.
  - Consist of renal contusions or shallow cortical lacerations.
  - Most common after blunt trauma and usually resolve safely without renal exploration.
  - Hydration, antibiotics, and bed rest are the cornerstones of successful nonoperative management.
Genitourinary Tract Injuries

- Major injuries.
  - Consist of deep cortical lacerations (with or without urinary extravasation), shattered kidneys, renal vascular pedicle injuries, or total avulsion of the renal pelvis.
  - There is an 80% incidence of associated visceral injuries with major renal trauma. Most cases will require a laparotomy for evaluation and repair of concurrent intraperitoneal injuries.
  - Operative intervention includes debridement of nonviable renal tissue (partial nephrectomy), closure of the collecting system, and drainage of the retroperitoneal area.
  - Kidney preservation should be considered if at all possible, although total nephrectomy may be required for the severely damaged kidney or the unstable patient.

Vascular control of the renal pedicle can be obtained prior to opening the perirenal fascia when control of hemorrhage from the kidney requires exploration of the retroperitoneum.

- Operative Technique.
  - Obtain vascular control from a periaortic approach to the renal vascular pedicle.
    - The small intestine is retracted laterally and superiorly, and the posterior peritoneum is incised over the aorta.
    - The left renal vein, crossing anterior to the aorta, must be mobilized to gain control of either renal artery.
    - Atraumatic vascular clamps are used to occlude the appropriate artery.
  - While vascular control in this fashion may provide the safest approach against renal hemorrhage and reduce the likelihood of nephrectomy, it is not a commonly performed maneuver by either urologists or general surgeons. Direct reflection of the colon to expose the kidney is feasible (Fig. 18-1). A kidney pedicle clamp should be readily available for this approach.
Damaged renal parenchyma can be locally debrided (Fig. 18-2), excised in a partial nephrectomy (Fig. 18-3), or removed in a total nephrectomy depending on the degree of injury and the condition of the patient.

Nephrectomy may be the best solution for major renal injuries when associated life-threatening injuries are present.

- Watertight closure of the collecting system with absorbable suture prevents the development of a urine leak.
  - Urinary diversion is typically unnecessary if formal renal reconstruction is accomplished.
◊ For the sake of expedience or in the presence of associated injuries of the duodenum, pancreas, or large bowel, diversion may be required.
◊ Tube nephrostomy, ureteral stent, or ureterostomy may be utilized.
ο The reconstructed kidney should be covered by perirenal fat, omentum, or fibrin sealant.
ο A closed suction drain should be left in place.

Fig. 18-2. Steps in renal debridement.

Fig. 18-3. Steps in partial nephrectomy.
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Ureteral Injuries

Ureteral injuries are rare but are frequently overlooked when not appropriately considered. They are more likely in cases of retroperitoneal hematoma and injuries of the fixed portions of the colon, duodenum, and spleen.

- Isolated ureteral injuries are rare and usually occur in conjunction with other significant injuries. They can represent a difficult diagnostic challenge in both the preoperative and intraoperative settings.
  - Ureteral injuries are not reliably diagnosed by the preoperative IVP.
  - Hematuria is frequently absent.
  - Blast injury to the urethra may produce significant delayed complications even when the IVP is normal and the ureter appears visibly intact. Placement of an indwelling stent is reasonable when a high-velocity or blast injury occurs in proximity to the ureter.
  - If a ureteral injury is initially missed and presents in a delayed fashion, urinary diversion with a nephrostomy tube and delayed repair at 3–6 months is a safe approach.

- Operative Technique.
  - Intraoperative localization of the ureteral injury is facilitated by IV injection of indigo carmine or direct injection into the collecting system under pressure.
  - Basic principles of repair.
    ♦ Minimal debridement.
    ♦ Primary tension free, 1 cm spatulated anastomosis using an interrupted single-layer absorbable suture (4–0 or 5–0) closure technique.
    ♦ Internal (double J ureteral stent) and external drainage.
  - Lengthening maneuvers.
    ◊ Ureteral mobilization.
    ◊ Kidney mobilization.
    ◊ Psoas hitch (Fig. 18-4).
    ◊ Boare flap.
Fig. 18-4. The psoas hitch.

Fig. 18-5. Ureteroureterostomy.
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♦ Isolate repairs with omentum or posterior peritoneum.

o The type of repair is based on the following:
  ♦ Anatomical segment of the traumatized ureter (upper, middle, and lower third).
  ♦ Extent of segmental loss.
  ♦ Other associated injuries.
  ♦ Clinical stability of the patient.

o Upper or Middle ureteral injuries:
  ♦ Short segment loss/transection: Perform a primary ureteroureterostomy (Fig. 18-5).
  ♦ Long segment loss: May require a temporizing tube/cutaneous ureterostomy with stent placement or ureteral ligation with tube nephrostomy.

o Lower ureteral injuries.
  ♦ When the injury occurs near the bladder, an ureteroneocystostomy should be performed (Fig. 18-6). This is typically completed by fixing the bladder to the fascial covering of the psoas muscle using permanent suture such as 2.0 or 3.0 Prolene. A transverse cystotomy assists in elongating the bladder to that location and facilitates the development of a submucosal tunnel for the reimplanted ureter.
  ♦ When a distal ureteral injury is associated with a rectal injury, ureteral reimplantation is not recommended; temporary diversion should be performed.

Fig. 18-6. Ureteroneocystostomy.
Ureteral injuries in the combat setting may be best managed with temporary tube drainage with a small feeding tube or ureteral stent followed by delayed reconstruction.

Bladder Injuries

Bladder wounds should be considered in patients with lower abdominal gunshot wounds, pelvic fractures with gross hematuria, or those patients unable to void following abdominal or pelvic trauma.

- Bladder disruptions can occur on the intraperitoneal or extraperitoneal surface of the bladder. The location may change the symptoms, complications, and management of this injury.
- After ensuring urethral integrity in appropriate cases (see Urethral Injuries, below), evaluation of the bladder is performed radiographically with a cystogram.
  - Cystography is performed using a 3-film technique: (1) scout or plain film KUB concentrating on the pelvis, (2) full-bladder radiograph after retrograde filling of the bladder with contrast, and (3) a postdrainage radiograph.
  - **Technique:** Fill the bladder by gravity with a urethral catheter using radiopaque contrast medium elevated 20–30 cm above the level of the abdomen. At least 300 cc (5–7 cc/kg in children) are required for an adequate study. Take a full-bladder radiograph.
  - Drain the bladder using the catheter and take a postdrainage radiograph. Small extraperitoneal areas of extravasation may be apparent only on the postevacuation film.
- Operative Technique.
  - Intraperitoneal Injuries.
    - Cystography reveals contrast medium interspersed between loops of bowel.
    - Management consists of immediate exploration, multilayer repair of the injury with absorbable suture, suprapubic tube cystostomy, and drainage of the
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perivesical extraperitoneal space.

**Extraperitoneal injuries.**

♦ Bladder laceration is most often the result of laceration by bony fragments from a pelvic fracture.

♦ Cystography reveals a dense, flame-like extravasation of contrast medium in the pelvis on the postevacuation film.

♦ The bladder usually heals with 10–14 days of Foley catheter drainage without the need for primary repair. If the urine is clear, catheter drainage alone is preferred for treatment of most extraperitoneal ruptures.

♦ In cases of abdominal exploration for other injuries, primary repair and drainage are necessary if the extraperitoneal space is entered. Repair can be completed from inside the bladder through a cystotomy to avoid disturbing any pelvic hematoma. Patients with concurrent rectal injuries should be managed more aggressively and may benefit from hematoma evacuation and primary bladder repair.

**Urethral Injuries**

A urethral injury should be suspected in patients with a scrotal hematoma, blood at the meatus, or a floating/high-riding prostate. Catheterization is contraindicated until urethral integrity is confirmed by retrograde urethrography.

- Retrograde urethrography is performed to evaluate the anatomy of the urethra.
  - Take oblique radiographs of the pelvis to avoid “end-on” imaging that obscures the bulbar urethra.
  - Insert the end of a sterile catheter tip syringe (60 cc) into the urethral meatus while grasping the glans to prevent leakage. Alternately, insert an unlubricated Foley catheter into the fossa navicularis (approximately 3 cm) and inflate the balloon with 3 cc of water.
  - Gently instill 15–20 cc of water-soluble contrast. The radiograph is taken during injection.
• Contrast must be seen flowing into the bladder to clear the proximal urethra of injury. Posterior urethral injuries seen in pelvic fractures may be missed otherwise.
• If no injury is identified, carefully place a Foley catheter.

If any difficulty in passing the catheter is encountered, the urethra should not be instrumented and a suprapubic tube cystostomy is performed.

• Operative Technique.
  • The urethra is divided into anterior and posterior (prostatic) segments by the urogenital diaphragm.
  ◦ Anterior urethral injuries may result from blunt trauma, such as results from falls when astride an object (straddle) or from penetrating injuries.
  ◦ Blunt trauma resulting in minor nondisruptive urethral injuries may be managed by gentle insertion of a 16 French Foley catheter for 7–10 days.
  ◦ Penetrating wounds should be managed by exploration and judicious debridement.
    • Small, clean lacerations may be repaired primarily by reapproximation of the urethral edges using interrupted 4-0 chromic suture.
    • Do not mobilize the entire urethra for a primary anastomosis, because the shortened urethral length in the pendulous urethra may produce ventral chordee and an anastomosis under tension.
    • Instead, marsupialize the injured urethral segment by suturing the skin edges to the cut edges of the urethra. Marsupialization should be performed until healthy urethra is encountered both proximally and distally. Closure of the marsupialized urethra is subsequently performed at 6 months to reestablish urethral continuity.
  ◦ Posterior urethral disruption commonly occurs following pelvic fracture injuries.
    ◦ Rectal examination reveals the prostate to have been avulsed at the apex.
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◊ Improved continence and potency rates are attained when suprapubic tube cystostomy is used as the initial management.
◊ Suprapubic urinary diversion is maintained for 10–14 days and urethral integrity is confirmed radiographically prior to removal of the suprapubic tube.
◊ With expectant observation, virtually all these injuries will heal with an obliterative prostatomembranous urethral stricture, which can be repaired secondarily in 3–6 months after reabsorption of the pelvic hematoma.
◊ Initial exploration of the pelvic hematoma is strictly reserved for patients with concomitant bladder neck or rectal injury.

External Genitalia Injuries

The management of wounds to the penis, scrotum, testes, or spermatic cord should be as conservative as possible and consists of hemorrhage control, debridement, and early repair to prevent deformity.

- Injuries to the penis that disrupt Buck’s fascia should be sutured to prevent further bleeding and avoid future penile curvature with erection. When extensive penile skin is lost, the penis may be placed in a scrotal tunnel until a plastic repair can be performed.
- The scrotum is highly vascularized, and extensive debridement is usually not necessary for scrotal wounds.
  - Most penetrating scrotal injuries should be explored to evaluate the testicle for injury and reduce the risk of hematoma formation.
  - Most partial scrotal avulsions are best treated by primary closure with absorbable 3-0 sutures in two layers.
  - Primary closure is selected for patients without associated life-threatening injuries who sustained injury less than 8 hours prior. A Penrose drain or small closed drain can be placed to reduce hematoma formation. The testes can be
placed in protective pockets in the medial thigh for complete scrotal avulsion.
- It is essential, when dealing with testicular wounds, to conserve as much tissue as possible.
  - Herniated parenchymal tissues should be debrided, and the tunica albuginea closed by mattress sutures.
  - The testicle is placed in the scrotum or in a protective pocket in the medial thigh.
  - A testicle should never be resected unless it is hopelessly damaged and its blood supply destroyed.
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Chapter 19

Gynecologic Trauma and Emergencies

Introduction
The current active duty population consists of 14% women, many of whom are subject to the same risks of combat injury as their male colleagues. This chapter deals with OB/GYN emergencies that may present to a deployed medical treatment facility (MTF), particularly in military operations other than war (MOOTW).

Gynecologic Trauma
Vulva
- Vulvar injuries include lacerations and hematomas.
  - Lacerations that are superficial, clean, and less than 6 hours old can be primarily closed with absorbable suture. Debridement of obviously devitalized tissue is recommended.
  - Deep lacerations should be examined and explored to rule out urethral, anal, rectal mucosa, or periclitoral injuries.
  - Placing a urethral catheter will assist in determining injury. If found, single-layer closure with fine (4-0 or smaller), absorbable suture, leaving the catheter in place, is recommended. Rectal and periclitoral injuries are closed in a similar fashion.
  - Anal lacerations should be repaired by approximating the cut ends of the anal sphincter with size 0 or 1 absorbable suture.
  - Antibiotics (2nd generation cephalosporin) are recommended with contaminated wounds.
Vulvar trauma may cause infrafascial (below the pelvic diaphragm) hematoma.

- Because the deeper layer of subcutaneous vulvar fascia is not attached anteriorly to the pubic rami, hematoma can spread freely into the anterior abdominal wall.
- Most vulvar hematomas are treated conservatively.
- **External compression** and ice packs should be applied until hemostasis is ensured by serial examination of the vulva, vagina, and rectum.
- **Signs of shock in association with a decreasing hematocrit should prompt consideration of extraperitoneal expansion.** Ultrasound or computed tomography is useful for detecting expansion not diagnosed by clinical exam.

A vulvar hematoma continuing to expand despite external pressure, or presenting acutely with a size greater than 10 cm, should be incised and evacuated, with ligation of bleeding vessels and packing placed to secure hemostasis.

**Vagina**

- Trauma to the vagina can cause lacerations, and less commonly, suprafascial (above the pelvic diaphragm) hematoma.
- Vaginal trauma has been reported in approximately 3.5% of women with traumatic pelvic fractures. Concomitant urologic trauma, most often involving the bladder and/or urethra, has been described in about 30% of patients with vaginal trauma.
- Thorough inspection and palpation of the vagina and rectovaginal exam are necessary for detection of vaginal trauma and to determine the need for further urologic evaluation/imaging. **Due to pelvic instability (in fracture cases) or pain, examination under sedation or anesthesia may be necessary.**
- Patients with vaginal lacerations typically present with bleeding, sometimes profusely, from the well-vascularized vagina.
● Lacerations are repaired using the guidelines given above for vulvar lacerations.
● Vaginal hematoma is usually accompanied by severe rectal pressure and is diagnosed by palpation of a firm, tender mass bulging into the lateral vagina. **Vaginal hematoma should be treated by incision, evacuation, ligation, and packing.**
● Unrecognized vaginal trauma can result in dyspareunia, pelvic abscess, and fistula formation.

**Uterus/Cervix**

● Trauma to the uterus and cervix is most commonly found in association with pregnancy, but may be seen as a result of penetrating vaginal or abdominal trauma.
● Noninfected simple cervical lacerations should be repaired to optimize restoration of normal anatomy (and possibly decrease the risk of cervical incompetence or stenosis with dysmenorrhea from poor healing). Absorbable 0 grade suture can be used.
● Acute penetrating trauma involving the uterine fundus usually causes little bleeding and can be managed expectantly without repair. Damage to the uterine wall with bleeding can be repaired with size 0 absorbable suture.
● **Trauma involving the lateral wall of the uterus may cause significant bleeding,** but can usually be controlled by successive ligation of the ascending and descending branches of the uterine artery as described below in the obstetrical section “uterine atony.”

<table>
<thead>
<tr>
<th>Hemorrhage not responding to ligation, or extensive mutilating damage to the cervix or uterus, is best treated by hysterectomy.</th>
</tr>
</thead>
</table>

● Prophylactic antibiotics should be given. **Adnexa should be retained unless there is an indication for removal** (see next page).
Basic steps for performing an emergent total abdominal hysterectomy.

- Ligate/cauterize round ligaments (Fig. 19-1).
- Incise anterior leaves of broad ligaments bilaterally, then continue across midline to incise vesicouterine fold.
- Mobilize bladder downward by blunt dissection (and sharp dissection if necessary) from lower uterine segment and cervix.
- To **retain** adnexa, clamp/cut/ligate utero-ovarian ligaments and fallopian tubes near their connections to uterine fundus (Fig. 19-2).
- To **remove** adnexa with uterus, clamp/cut/ligate infundibulopelvic ligaments after making windows in posterior leaves of broad ligaments above ureters.
- Incise posterior peritoneum to mobilize adnexa either away from (if being retained) or toward (if being removed) uterus.
- Incise peritoneum overlying rectovaginal space, then mobilize rectum downward and away from posterior vagina by blunt dissection (Fig. 19-3).
- Clamp/cut/ligate uterine arteries along lateral surface of uterus at uterocervical junction, staying within 1 cm of uterus to avoid damaging ureters.
- Clamp/cut/ligate remainder of cardinal ligaments, paracervical tissue, and uterosacral ligaments by taking successive inferior bites until cervicovaginal junction is reached; each bite should be placed medial to previous bite to avoid injuring ureter and bladder.
- Crossclamp vagina below cervix.
- Transect vagina, removing uterus (and attached adnexa, if applicable).
- Suture vaginal cuff closed, ensuring bladder is not incorporated.

*In case of dense adhesions between cervix and bladder or rectum in emergent setting, or ongoing hemorrhage with poor visualization, supracervical hysterectomy can be performed. After mobilizing bladder and rectum from uterus and ligating uterine arteries, uterine fundus is transected from cervix with a knife. Cervix is then oversewn with a baseball stitch, staying medial to ligated uterine arteries.
Adnexa

- **Fallopian Tubes.**

  Damage to the wall of the fallopian tube by ruptured ectopic pregnancy or penetrating abdominal trauma should be treated by salpingectomy if there is significant damage to the tube, due to the risk of subsequent or recurrent ectopic pregnancy if left in situ. If the damage is
Emergency War Surgery

equivalent to a linear salpingotomy (see below), achieve hemostasis, then allow healing by secondary intention.

- The mesosalpinx is ligated or cauterized, then the tube ligated and cut at its connection with the uterine fundus.
- Unruptured ampullary/isthmic ectopic pregnancy can be treated by linear salpingotomy, with extraction of the ectopic gestation. The tubal incision is left open to heal by secondary intention.
- An unruptured or ruptured corneal/interstitial ectopic pregnancy requires wedge resection of the uterine cornu-num with salpingectomy.
- An ectopic pregnancy spontaneously aborted into the abdominal cavity through the end of the tube should be removed, but the tube may be left in situ if hemostasis is attained.

- **Ovaries.**
  - A **ruptured ovarian cyst** should be treated via cystectomy by shelling the cyst wall out of the ovary, then cauterizing or ligating any bleeding vessels, usually at the base of the cyst.
Gynecologic Trauma and Emergencies

- **Torsion of an ovarian mass** is first treated by assessing the ovary. Untwist the ovary and or fallopian tube. If it appears healthy with some continuing blood supply, it can be left in situ. If the ovary contains a large (> 4 cm) simple appearing cyst, the cyst can be drained and the cyst wall removed. Interrupted sutures using a fine monofilament or electrocautery can be used to obtain hemostasis. If the ovary appears dark and dusky after untwisting, perform a salpingo-oophorectomy by ligating the infundibulopelvic ligament first (after identifying the ureter), then the utero-ovarian ligament and fallopian tube.

- Hemorrhage from an infundibulopelvic ligament, as a result of penetrating abdominal trauma, is best treated by ligation with salpingo-oophorectomy.

Retroperitoneal Hematoma

- **Laceration of an arterial branch of the hypogastric artery can cause a retroperitoneal hematoma.**

- A large amount of blood may collect in the broad ligament with few symptoms. Dissection of the hematoma can extend up to the level of the renal vessels. The hematoma may be discovered during emergency surgery for trauma or during re-operation or post pelvic surgery, or can be prompted by signs of shock suggesting internal bleeding.

- Retroperitoneal hematoma can be treated by hypogastric artery ligation on the affected side. **Bilateral hypogastric artery ligation may be necessary for hemostasis.** The uterus, tubes and ovaries may be left in situ if viable and without other indication for removal.

Gynecologic/Obstetric Emergencies

- **Acute Vaginal Hemorrhage Unrelated to Trauma.**

  - Bright red vaginal bleeding filling more than one large perineal pad per hour is considered vaginal hemorrhage. A pregnancy test and pelvic exam direct initial therapy.

    - **If the patient is not pregnant,** hormonal management with 25 mg IV Premarin or 50 mcg estrogen-containing oral birth control pills (OCPs) should be given every 6 hours.
If the bleeding responds to hormonal management, OCPs should be continued qid for 5–7 days while more definitive diagnosis and management plans are made.

If the bleeding has not decreased significantly within 24 hours, dilatation and curettage is reasonable. If the heavy bleeding continues, imaging studies and possibly coagulation studies will be needed to help direct further therapy.

In the pregnant patient, heavy bleeding from the cervical os with uterine size < 20 weeks (fundus at/or below the level of patient’s umbilicus) suggests spontaneous abortion. Dilatation and suction curettage should be performed.

Ectopic pregnancy uncommonly presents with acute hemorrhage, but should be considered if the patient has an acute abdomen or if scant tissue is obtained on curettage.

In a pregnant patient with uterine size consistent with a third trimester gestation (> 4 cm above the umbilicus in a singleton pregnancy), vaginal hemorrhage is usually an indication of placental abruption or placenta previa.

Emergent cesarean section will be necessary if the uterine hemorrhage does not spontaneously resolve within several minutes.

After delivery of the fetus and placenta, persistent hemorrhage unresponsive to more conservative measures may require hysterectomy (see emergent cesarean and uterine atony below).

Pregnant patients (mothers) with acute vaginal hemorrhage who have Rh negative bloodtype, or if their Rh status is unknown, should be given RhoGAM 300 mcg IM.

A hemorrhaging mass in the vagina is most likely cervical cancer. The vagina should be packed to tamponade the bleeding after placing a urethral catheter. Placing sutures is generally futile and may make the bleeding worse.
Precipitous Vaginal Delivery

**Preparation.**
- Supplies needed for the delivery, include povidone-iodine sponges, a 10 cc syringe, lidocaine, 2 Kelly clamps, ring forceps, dry towels, a bulb syringe, and scissors.
- The mother should be placed on her left side for labor.
- The fetal heart rate should be determined every 15 minutes prior to pushing, and following each contraction during the pushing phase using a vascular Doppler. **Normal heart rate is between 120–160 bpm.** The heart rate often drops with the contraction, but should recover to normal prior to the next contraction.

### If the heart rate drops below 100 and stays low for more than 2 minutes, a cesarean section should be considered.

- When the patient presents, the cervix should be examined to determine dilation and fetal position. For the woman to begin pushing, the cervix should be completely dilated (10 cm) and no cervix should be felt on either side of the fetal head. If the baby’s head is not presenting, move to cesarean section immediately. If there is any question, and ultrasound is available, it should be used to determine the presentation.

**Delivery.**
- Once the patient begins pushing, flex the hips to optimally open the pelvis. The patient may be on her back, or tilted slightly to the left. Assistants should support the legs during pushing and relax them between contractions.
- Clean the perineum with sterile Betadine solution. If this is the patient’s first delivery, the perineum should be anesthetized with lidocaine in case an episiotomy is needed. There is little support for prophylactic episiotomy, but may be necessary if the fetus is large, or tearing is anticipated.
- The fetal head delivers by extension. Pushing upward on the fetal chin through the perineum can assist this process.
Additionally, it is extremely important to control the rate of delivery of the head with the opposite hand.

- If an episiotomy is needed, it should be cut in the posterior midline from the vaginal opening approximately \( \frac{1}{2} \) the length of the perineum, and extend about 2–3 cm into the vagina.

- After delivery of the head, the mouth and nose should be suctioned and the neck palpated for evidence of a nuchal cord. If present, this should be reduced by looping it over the fetal head, or by clamping twice and cutting if it will not reduce.

- Next, the operator’s hands are placed along the parietal bones and the patient is asked to push again to allow delivery of the anterior shoulder. Gentle downward traction should allow the shoulder to clear the pubis, and the fetus should be directed anteriorly to allow delivery of the posterior shoulder. The remainder of the body will normally follow rapidly. Wrap infant in dry towels.

- Once the fetus delivers, the cord should be doubly clamped and cut. The placenta usually delivers within 15 minutes of delivery, but may take up to 60 minutes. Delivery of the placenta is heralded by uterine fundal elevation, lengthening of the cord, and a gush of blood. While waiting, gentle pressure may be placed on the cord, however, vigorous uterine massage and excessive traction can lead to complications.

- Following delivery of the placenta, the patient should be started on an infusion of lactated Ringer’s with 20 units of oxytocin (Pitocin). Oxytocin can also be given IM if there is no IV access. If there is no oxytocin available, alternatives are methylergonovine maleate (Methergine) 0.2 mg intramuscular (IM) or allowing the patient to breastfeed. **The placenta should be inspected for evidence of fragmentation that can indicate retained products of conception.**

- **Inspection and repair.**

  - Following delivery of the placenta, the vagina and cervix should be inspected for lacerations. Downward digital pressure on the posterior vagina and fundal pressure (by
Gynecologic Trauma and Emergencies

an assistant, if available) will facilitate visualization of the cervix. A ring forceps is then used to grasp and visualize the entire cervix.

- The vagina should be inspected with special attention to the posterior fornix. The perineum and periurethral areas should also be inspected. Vaginal and cervical lacerations may be repaired with 3-0 vicryl or an equivalent suture in running or interrupted layers.

- If the anal sphincter is lacerated, it should be reapproximated with 2-0 absorbable interrupted single or figure-of-eight sutures.

- If the patient has torn into the rectum, the rectal-vaginal septum should be repaired with interrupted sutures of 3-0 vicryl. A second layer imbricating the underlying tissue will decrease the risk of breakdown. Care should be taken to preserve aseptic technique. If a large tear is noted, a saddle block or spinal anesthetic may be necessary.

- Patients with a periurethral tear may require urethral catheterization. In addition to lacerations, hematoma in the vulva, vagina, or retroperitoneum may occur. See above gynecologic trauma for management.

Emergency Cesarean Section

- Indications.
  - Fetal heart rate drops below 100 and stays down for more than 2 minutes.
  - Acute uterine hemorrhage persisting for more than a few minutes (suggestive of placental abruption or previa).
  - Breech or transverse fetal presentation.

- The patient should be placed in the left tilt position with an IV bag or towel displacing the uterus to the left. She should undergo a quick prep from just below the breasts to the mid thigh. A major abdominal equipment set should have most of the instruments that you will need.

- Basic steps to performing an emergency C-section (Fig. 19-4 a,b,c,d).
  - Enter the abdomen through lower midline.
Fig. 19-4. Emergency C-Section.
Identify and incise the peritoneal reflection of the bladder transversely, and create a bladder flap to retract the bladder out of the field.

Using a scalpel, carefully incise the uterus transversely across the lower uterine segment (where the uterine wall thins).

Once the amniotic membranes are visible or opened, extend the incision laterally, either bluntly or by carefully using bandage scissors. Avoid the uterine vessels laterally. If necessary, the incision can be extended at one or both of its lateral margins in a J-fashion by vertical incision.

Elevate the presenting fetal part into the incision, with an assistant providing fundal pressure.

Upon delivery of the fetus, suction the nose and mouth and clamp and cut the cord. Hand the infant off for care (see below).

Direct anesthetist to administer 2 grams of cefazolin (Ancef) once the cord is clamped.

Allow the placenta to deliver by providing gentle traction on the cord and performing uterine massage.

Begin oxytocin, if available as above.

Using a sponge, clean the inside of the uterus, and vigorously massage the fundus to help the uterus contract.

Quickly close the incision with 0-vicryl. A single layer (running, locking) is adequate, if hemostatic, for transverse incisions. Take care to avoid the lateral vessels. If the incision has a vertical extension, close it in 2 or 3 layers.

Once hemostasis is assured, close the fascia and abdomen in the usual fashion.

In the rare case of continued uterine hemorrhage, evaluate and treat as outlined in the section below.

**Uterine Atony**

- The majority of postpartum hemorrhage is secondary to uterine atony (failure of uterine contracture).

When the uterus fails to contract following delivery of the placenta, bleeding may be torrential and fatal.
Emergency War Surgery

- Initial management should include manual uterine exploration for retained placenta. Without anesthesia, this procedure is painful. An opened sponge is placed around the examiner’s fingers. Place the opposite hand on the patient’s uterine fundus and apply downward pressure. Gently guide your fingers through the open cervix and palpate for retained placenta. The inside of the uterus should feel smooth, and retained placenta will feel like a soft mass of tissue. This may be removed manually or by using a large curette if available.
- If no tissue is encountered, use both hands to apply vigorous uterine massage to improve the uterine tone.
- Medications should also be used if available. Oxytocin may be given by IV bolus using 40 units in 1000 cc, or up to 10 units IM, but never by IV push. Although unlikely to be available, other medications that can be considered are Methergine, dinoprostone (Prostin), and misoprostol (Cytotec).
- If no medication is available, the patient should be encouraged to breast feed or do nipple stimulation to increase endogenous oxytocin release.

If conservative measures fail to arrest the postpartum hemorrhage, laparotomy (if the hemorrhage is occurring post vaginal delivery), should be performed.

- Intraoperative massage of the uterine fundus may be tried.
- If the massage fails to improve uterine tone, the uterine arteries should be ligated in a stepwise fashion. Begin with the ascending branch at the junction of the upper and lower uterine segment. Using 0 or No. 1 chromic, place a stitch through the myometrium medial to the artery from front to back. The stitch is then brought out through the adjacent broad ligament and tied. If bilateral ligation of the ascending branch does not control bleeding, the descending branch should be ligated at the level of the uterosacral ligament. If this fails, consider bilateral hypogastric artery ligation (see above). If this fails, proceed to hysterectomy as outlined in the gynecologic portion of this chapter.
Neonatal Resuscitation

- **Immediately following delivery, every infant should be assessed for need for resuscitation.** Equipment that may be needed includes warm towels, bulb syringe, stethoscope, flow-inflating or self-inflating bag with oxygen source, laryngoscope and blade, suction catheter, and endotracheal tube. The two medications that may be needed are epinephrine 1:10,000 and naloxone (Narcan) 0.4 mg/ml.

- Nearly 90% of term babies are delivered without risk factors and with clear fluid, requiring only to be dried, suctioned and observed. **If the baby is less than 36 weeks, or if there is meconium in the fluid at delivery, the baby will need to be observed more closely.**
  
  - In the first 30 seconds after delivery, dry and stimulate the baby, position it in order to open the airway, and give free flow oxygen if the color is poor.
  
  - At 30 seconds, evaluate the heart rate. **If it is < 100 begin to provide positive pressure ventilation.** After 30 seconds of ventilation, recheck the heart rate. **If it is < 60, then chest compressions should be started.** After 30 seconds of chest compressions, again re-evaluate. If the heart rate remains < 60 you should administer epinephrine. Epinephrine can be given either through the umbilical vein or the endotracheal tube. The level of experience of the team present should dictate which route should be used. The dose is 0.1–0.3 ml/kg of the 1:10,000 solution.
  
  - If heart rate rises over 100, stop the positive pressure ventilations, but continue to provide free flow oxygen. If the mother has been given a dose of narcotics in the 4 hours prior to delivery, and positive pressure ventilation has resulted in a normal heart rate and color but poor respiratory effort, then naloxene is indicated. Administer naloxene by IV, IM, or endotracheal route at a dosage of 0.1 mg/kg.

- **If at any time during resuscitation the heart rate goes above 100, with good respiratory effort, tone and color, the baby may be moved to an observation status.**
Emergency War Surgery
Chapter 20

Wounds and Injuries of the Spinal Column and Cord

Introduction
Combat injuries of the spinal column, with or without associated spinal cord injury, differ from those encountered in civilian practice. These injuries are often open, contaminated, and usually associated with other organ injuries.

Following the ABCs of advanced trauma life support (ATLS), management principles include:
- Initial spine stabilization to prevent neurologic deterioration.
- Diagnosis.
- Definitive spinal stabilization.
- Functional recovery.

In complete injuries, the likelihood of neurological recovery is minimal and is not influenced by emergent surgical intervention. However, incomplete injuries with neurological deterioration may benefit from emergent surgical decompression. Emergent, life-saving, soft tissue exploration, and debridement may still be required, particularly with colorectal involvement.

Classification
Four discriminators must be considered in the classification and treatment of spinal injuries.
- Is injury open or closed?
- Neurologic status: complete vs incomplete vs intact.
  - Complete injury demonstrates no neurologic function below the level of injury after the period of spinal shock
Emergency War Surgery

(usually 24–48 h, evidenced by return of the bulbocavernosus reflex).

- Location of the injury: cervical, thoracic, lumbar, or sacral.
- Degree of bony and ligamentous disruption: stable vs unstable.

Pathophysiology of the Injury to the Spinal Cord

- Injury to the spinal cord is the result of both primary and secondary mechanisms.
  - Primary: the initial mechanical injury due to local deformation and energy transmission.
    - High-velocity missile wounds in the paravertebral area can cause injuries even without direct trauma. Stretching of the tissue around the missile’s path during formation of the temporary cavity, or fragmentation of the projectile and bone resulting in secondary missiles, cause injury without any direct destruction of the spinal column.

The destructive nature of high-velocity wounds explains the futility of decompressive laminectomy in the management of these wounds.

- Secondary: the cascade of biochemical and cellular processes initiated by the primary process that causes cellular damage and even cell death.

The critical care of spinal cord injury patients includes attempts to minimize secondary injury from hypoxia, hypotension, hyperthermia, and edema.

Mechanical integrity of the vertebral column

The vertebral column is composed of three structural columns (Table 20-1).
Table 20-1. Support of the Spinal Column.

<table>
<thead>
<tr>
<th>Column</th>
<th>Bony Elements</th>
<th>Soft-Tissue Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior</td>
<td>Anterior two-thirds of vertebral body</td>
<td>Anterior longitudinal ligament</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anterior annulus fibrosus</td>
</tr>
<tr>
<td>Middle</td>
<td>Posterior one-third of vertebral body</td>
<td>Posterior longitudinal ligament</td>
</tr>
<tr>
<td></td>
<td>Pedicles</td>
<td>Posterior annulus fibrosus</td>
</tr>
<tr>
<td>Posterior</td>
<td>Lamina</td>
<td>Ligamentum flavum</td>
</tr>
<tr>
<td></td>
<td>Spinous processes</td>
<td>Interspinous ligaments</td>
</tr>
<tr>
<td></td>
<td>Facet joints</td>
<td></td>
</tr>
</tbody>
</table>

- Injuries occur by either direct penetrating forces or a combination of flexion, axial loading, rotation, and distraction forces.
- Loss of integrity of two of the three columns results in instability of the spine.
- **Instability is common following blunt injury of the vertebral column, but is not usually the case with gunshot or fragment wounds of the vertebral column.**
- Cervical instability by lateral radiograph (must include C-7/T-1 junction) is defined by:
  - 3.5 mm or greater sagittal displacement or translation.
  - Angulation of 11° or more on the lateral view.
  - Should questions exist regarding cervical stability, flexion and extension lateral radiographs can be obtained in the awake, cooperative patient.
- Thoracic and lumbar spine instability:
  - 5 mm of sagittal translation.
  - 20°–30° of sagittal angulation.
  - 50% loss of vertebral body height.
  - Widened pedicles on anterior-posterior (AP) radiographs. Computed tomography (CT) is very effective in demonstrating spinal instability and has become available in some field environments.
Instability must be presumed (and the spine stabilized) in any patient with:
- Complaints of a sense of instability (holds his head in his hands).
- Vertebral column pain.
- Tenderness in the midline over the spinous processes.
- Neurologic deficit.
- Altered mental status.
- SUSPECTED, but NOT PROVEN injury.

Patient Transport

On the battlefield, preservation of the life of the casualty and medic are of paramount importance. In these circumstances, EVACUATION TO A MORE SECURE AREA TAKES PRECEDENCE OVER SPINE IMMOBILIZATION. Data do not support the use of cervical collars and spine boards for PENETRATING spine injuries on the battlefield.

Extrication

- Cervical spine.
  - The neck should never be hyperextended.
  - If an airway is needed.
    - If appropriate, attempt endotracheal intubation with in-line neck stabilization.
    - Cricothyroidotomy is necessary if intubation fails.
  - The head should be maintained in alignment with the body.
    - Requires several people, including one just to stabilize the neck.
    - Log roll with the most experienced person stabilizing the neck.
  - A stiff cervical collar and sandbags provide stabilization of the neck during the transport. The head and body should be secured to the extrication device.
- Thoracic and lumbar spine.
- Use log roll or two-man carry as demonstrated in Fig. 20-1.
  - The two-man carry alone does not protect the cervical spine.
  - The cradle-drop drag may also be used.
- In the absence of a spine board, makeshift litters can be fashioned from local materials.

Fig. 20-1. (a) Log roll (b) two-man carry.

Anatomical Considerations
Cervical Spine
All potentially unstable cervical spine injuries should be immobilized in a rigid collar, unless halo immobilization is required.
- Indications for halo use:
The role of halo immobilization in the acute combat setting is quite limited. In nonpenetrating trauma to the cervical spine, immobilization with a cervical hard collar or sand bags is preferable until arrival at a definitive treatment site.

Should traction be indicated for cervical spine injuries (eg, facet joint dislocations or burst fractures with a tenuous neurologic status), the Gardner-Wells tongs should be applied and sufficient weight (generally 2–10 kg) placed in line of the spine (Fig. 20-2, Table 20-2). It is paramount to remember that injuries to occipitocervical articulation should not be treated with traction-in effect, putting these injuries in traction “pulls the head off”. If traction is applied, radiographs must be obtained to be certain that no undiagnosed ligamentous injury has been exacerbated by the weight.

The role of collar immobilization in penetrating injuries to the cervical spine is less well established. Soft-tissue care is compromised by the collar’s position and, in general, penetrating injuries coupled with osseous instability should be managed in Gardner-Wells traction.

Fig. 20-2. Gardner-Wells tongs.
Table 20-2. Application of Gardner-Wells Tongs.

<table>
<thead>
<tr>
<th>Step</th>
<th>Procedure</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Inspect Insertion Site:</strong> Select a point just above apex of each ear.</td>
<td>Rule out depressed skull fracture in this area.</td>
</tr>
<tr>
<td>2</td>
<td><strong>Shave and Prep Pin Insertion Site.</strong></td>
<td></td>
</tr>
</tbody>
</table>
Turn Patient Appropriately: Use Stryker, Foster, or similar frame and turn patient every 4 h. When initially proned, obtain radiographs to ensure that the reduction is maintained. If reduction is not maintained when the patient is proned, rotate the patient only between the 30° right and left quarter positions. The use of a circle electric bed is contraindicated with injuries of the spinal cord or column.

If Satisfactory Alignment Cannot Be Obtained, Further Workup Is Necessary. Consider myelogram, CT scan, tomograms, and neurosurgical/orthopedic consultations.

Thoracic and Lumbar Spine
- Although the thoracic rib cage contributes considerable rotatory stability, it does not protect completely against injuries.
- The vascular supply of the spinal cord is most vulnerable between T-4 and T-6 where the canal is most narrow. Even minor deformity may result in cord injury.
- The most common place for compression injuries is at the thoracolumbar junction between T-10 and L-2.
- Most burst fractures result from an axial load, and occur at the thoracolumbar junction. These fractures are associated with compromise of the spinal canal and progressive angular deformity. They are often associated with significant neurologic injury.
- Evaluation for surgical stabilization and spinal cord decompression should be done with advanced imaging such as CT and/or magnetic resonance imaging (MRI).

When complex wounds involving the head, thorax, abdomen, or extremities coexist with vertebral column injuries, lifesaving measures take precedence over the definitive diagnosis and management of spinal column and cord problems. During these interventions, further injury to the unstable spine must be prevented by appropriate protective measures.
Emergent Surgery

Emergent spine surgery for penetrating or closed injuries of the spinal cord is indicated only in the presence of neurological deterioration.

- Penetrating Spine Injuries.
  - Injuries associated with a hollow-viscus should undergo appropriate treatment of the viscus injury without extensive debridement of the spinal injury, followed by appropriate broad-spectrum antibiotics for 1–2 weeks. Inadequate debridement and irrigation may lead to meningitis.
  - Removal of a fragment from the spinal canal is indicated for patients with neurological deterioration.
  - In neurologically stable patients with fragments in the cervical canal, delaying surgery for 7–10 days reduces problems with dural leak and makes dural repair considerably easier.
  - Casualties not requiring immediate surgery may be observed with spine immobilization and treated with 3 days of IV antibiotics. Surgical stabilization can be performed following evacuation.

Pharmacologic Treatment

- Penetrating injuries of the spine should NOT receive corticosteroid treatment.
- Closed spinal cord injuries may be treated with an IV corticosteroid if started within 8 hours of injury.
  - 30 mg/kg bolus of methylprednisolone initially.
  - 5.4 mg/kg/h of methylprednisolone for the next 24–48 hours.
    - If therapy is started within 3 hours of injury, continue treatment for 24 hours.
    - If therapy is started within 3–8 hours after injury, then treat for 48 hours.
General Management Considerations

Neurogenic shock
- Traumatically induced sympathectomy with spinal cord injury.
- Symptoms include bradycardia and hypotension.
- Treatment:
  - Volume resuscitation to maintain systolic BP > 90 mm Hg.
  - May use phenylephrine (50–300 µg/min) or dopamine (2–10 µg/kg/min) to maintain BP.

Gastrointestinal tract
- Ileus is common and requires use of a nasogastric tube.
- Stress ulcer prevention using medical prophylaxis.
- Bowel training includes a schedule of suppositories and may be initiated within one week of injury.

Deep vein thrombosis
- Start mechanical prophylaxis immediately.
- Initiate chemical prophylaxis after acute bleeding has stopped (See Chapter 11, ICU Care).

Bladder Dysfunction
- Failure to decompress the bladder may lead to autonomic dysreflexia and a hypertensive crisis.
- The bladder is emptied by intermittent or indwelling catheterization.
- Antibiotic prophylaxis for the urinary tract is not advised.

Decubitus ulcers
- Skin breakdown begins within 30 minutes in the immobilized hypotensive patient.
  - For prolonged transport, the casualty should be removed from the hard spine board and placed on a litter.
- Frequent turning and padding of prominences and diligence on the part of caretakers are essential to protect the insensate limbs.
- All bony prominences are inspected daily.
- Physical therapy is started early to maintain range of motion in all joints to make seating and perineal care easier.