EMRA

Trauma Guide

Beginner's Approach to the Trauma Bay

1st Edition

Kaushal H. Shah, MD, FACEP, Editor-in-Chief

Christina S. Hajicharalambous, DO, MSEd, Associate Editor

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ATLS

Chapter 1

TRAUMA OVERVIEW

S. Selesny, M. Jones

Trauma is one of the leading causes of mortality worldwide, and the ED must rapidly identify and treat life- and limb-threatening injuries. As hemorrhage is the leading cause of death in trauma, the main focus is to identify the source of bleeding in conjunction with stabilization.

Preparation

- When possible, EMS notifies the hospital when significant trauma is en route; ensure adequate preparedness before the patient arrives
- Trauma team
  - Key players: emergency physician, trauma surgeon, anesthesiologist, nurses, technicians, respiratory therapists, security
  - Full team allows maximum coordinated response, but can create loud, hectic environment if not carefully monitored
    - When possible, assign roles before patient arrives
- Proper equipment
  - Check supplies and equipment in the treatment area prior to the patient's arrival, taking into account EMS field reports. For example:
    - Patient unconscious: prepare equipment for intubation and airway maintenance
    - Penetrating chest wound: chest tube tray, pleura vac, and cordis central line for rapid vascular access to facilitate rapid transfusion if needed
- Trauma team safety
  - Personal protective equipment should be worn by all staff. This typically includes gloves, gowns, and face shields.
  - If the patient is agitated and could pose a physical threat to staff, alert security, behavioral health, and/or law enforcement for assistance.
- Review steps of initial assessment
  - Should be a systematic process
  - Team leader should adequately communicate critical findings and interventions that are performed.
  - ATLS Use clear, closed-loop communication
    - Task is assigned to a specific individual with explicit instruction
    - That individual repeats the task and specifics of what needs to be completed
  - Good communication not only prevents errors (eg, the wrong dose or medication), but also allows the full team to clearly understand next steps.

Arrival of the Patient

- EMS should hand off the patient to the team leader. Brief history should include mechanism of injury (blunt vs penetrating), basic patient information (age, gender), vitals in the field, and any interventions performed in the field (medications given, procedures performed).
- EMS may have information that can help direct management (eg, estimated blood loss on scene, severity of injury of others involved or damage to any structures or vehicles.
- A systematic review of the patient begins with a rapid primary survey, followed by adjunct testing and a more detailed secondary exam.
- Reassessment is critical. If at any point the patient appears to decompensate, reevaluation should begin from the primary survey to ensure there hasn't been a critical change.

Primary Survey

- Rapid, thorough evaluation that immediately identifies threats to life and limb
- ABCDE
  - **A**irway
  - **B**reathing
  - **C**irculation
  - **D**isability
  - **E**nvironment/exposure
- Can be performed in tandem (eg, airway can be assessed while another team member holds pressure on a bleeding wound)

Airway

- Determine if the airway is intact
  - Can the patient speak clearly? If so, airway is intact.
  - Gurgling sounds, gasping, and/or hoarseness can indicate potentially compromised airway
  - Unconscious patient: inspect for foreign bodies or maxillofacial fractures that may result in airway obstruction
- Inadequate airway
  - May require definitive airway protection to secure the airway, including orotracheal intubation or surgical airway (cricothyrotomy)
  - Upper airway obstruction: initially attempt to maintain airway with chin lift/jaw thrust, suctioning, and oral/nasopharyngeal airway adjuncts
  - Most common cause of airway obstruction in an unconscious patient is the tongue
- Cervical spine
  - Assume c-spine injury in any patient with injury above the chest or with a significant mechanism of injury
  - Ensure in-line c-spine precautions throughout the survey, particularly during airway step

Breathing

- Ventilation
  - Assess for bilateral breath sounds
  - Tension pneumothorax: immediate needle decompression
  - Significant hemothorax or pneumothorax: chest tube
  - If the patient is ventilated via endotracheal tube, decreased breath sounds on the left side may be indicative of a right mainstem bronchus intubation. Adjust the endotracheal tube by pulling it back so that it lies above the carina.
- Oxygenation
  - Measured by pulse oximeter
  - Low oxygen saturation: provide oxygen supplementation and assess for underlying cause

Circulation

- Survey for signs of bleeding and apply direct pressure to the site of hemorrhage.
- Assess vital signs and compare them to vitals obtained by EMS in the field. Large changes could indicate deterioration and should be immediately addressed.
- Place patients on a cardiac/blood pressure monitor to consistently monitor for signs of shock.
- Assess for adequate pulses in all extremities. A weak pulse in an injured limb can indicate vascular compromise — address immediately.
- In a significant trauma, 2 large bore IVs (at least an 18 gauge) should be obtained. If peripheral access is unattainable, consider intraosseous (IO) cannulation or other central access.
- Fluid resuscitation
  - Avoid administering large amounts of crystalloids during trauma resuscitation as it causes deleterious physiological effects (eg, ↓ body temperature, ↑ hemodilution, and worsening acidosis) leading to increased mortality.
  - Known or suspected hemorrhage: blood products preferred to help achieve hemodynamic stability
  - Vasopressors do not have a role in patients with hemorrhagic shock from trauma.
  - In some instances of severe hemorrhage, a massive transfusion protocol (MTP) can ensure the patient receives enough blood products as quickly as possible. MTP aims for a balance of blood components to provide repletion of not just red blood cells but also coagulation factors and platelets.
- Near death or loss of vitals
  - Bleeding is uncontrolled with conventional methods: consider other hemostasis options

- Resuscitative thoracotomy
- Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA)
- These methods are very invasive and should only be considered in patients nearing death.

Disability

- Neurologic function typically assessed using the Glasgow Coma Score (GCS). Eye movement, verbal, and motor functions are scored to assess overall neurologic status
- See revised GCS table from 10th edition of ATLS; includes "non-testable" as an option
- Assess pupil symmetry and reaction to light; can indicate brain trauma
- Extremity motor exam is necessary to detect potential spinal damage, particularly before intubation
- GCS $\leq$ 8 generally requires intubation
- Immediately intubate unconscious patient arriving with GCS $\leq$ 8; do not wait until the disability portion of the survey

Glasgow Coma Scale (GCS): 10th edition ATLS

Original Scale	Revised Scale	Score
Eye opening (E)	**Eye opening (E)**	
Spontaneous	Spontaneous	4
To speech	To sound	3
To pain	To pressure	2
None	None	1
	Non-testable	NT
Verbal Response (V)	**Verbal Response (V)**	
Oriented	Oriented	5
Confused conversation	Confused	4
Inappropriate words	Words	3
Incomprehensible sounds	Sounds	2
None	None	1
	Non-testable	NT
Best Motor Response (M)	**Best Motor Response (M)**	
Obeys commands	Obeys commands	6
Localizes pain	Localizing	5
Flexion withdrawal to pain	Normal flexion	4
Abnormal flexion (decorticate)	Abnormal flexion	3
Extension (decerebrate)	Extension	2
None (flaccid)	None	1
	Non-testable	NT

Exposure/Environmental

- Remove or cut off all garments from patient to avoid missing any potentially devastating injury.
- Scan entire body surface for injuries
  - Log-roll the patient (providing c-spine stability) and assess posterior aspect for injuries, as this is 50% of the body surface
  - Assess perineum and both axilla for injuries
- Palpate the full length of the spine to assess for spinal step-offs or point tenderness; check rectal tone during this step to assess for spinal cord injury
- Check body temperature
  - Particularly in winter, hypothermia may be present; if discovered, immediately begin rewarming
  - Hyperthermia could help indicate the cause of trauma (eg, an older patient may have syncope from underlying infection and dehydration)
- Avoid unnecessary heat loss in trauma patients
  - After completely disrobing a patient and assessing for injuries, cover the patient with warm sheets and blankets
  - Use environmental controls to ensure appropriately warm climate in the resuscitation bay.

Adjuncts to Primary Survey

- eFAST (Extended Focused Assessment with Sonography in Trauma): use to quickly assess for intraperitoneal free fluid, pericardial free fluid, and pneumothorax
- Portable AP chest x-ray: evaluate for hemo/pneumothorax, widened mediastinum indicating an aortic dissection, and misplacement of central line or endotracheal tube
- Portable pelvic x-ray: assess for pelvic and hip fractures, which can be a significant source of hemorrhage
- Foley insertion: monitor urine output and fluid status
- EKG: identify life-threatening dysrhythmias, STEMI, cardiac tamponade

Secondary Survey

- Complete the history: "AMPLE"
  - **A**llergies
  - **M**edications (with particular attention to anticoagulation or cardiac medications)
  - **P**ast medical and surgical history
  - **L**ast meal time (particularly helpful if the patient goes to the OR)
  - **E**vents of the incident (exact mechanism, location of injuries, loss of consciousness, blood loss on scene)
- Comprehensive head-to-toe physical exam
  - Identify specific injuries that may have been missed during the primary survey, as well as old scars that could indicate prior surgeries, etc.

Management Principles

- Medication administration
  - Analgesia
  - Tetanus prophylaxis (especially if last immunization unknown)
  - Antibiotics in significant soft-tissue and penetrating injuries
- CT imaging (in stable patients only)
  - Follow validated decision rules when possible
  - Whole body CT
    - Consider strongly in severely injured polytrauma patients
    - Consider in patients with altered mental status or unable to obtain reliable exam
- Transfer patient to an outside facility if:
  - Inadequate resources to treat particular injuries (eg, subdural hematoma needs a neurosurgical procedure)
  - Injuries requiring ongoing higher level of care (eg, burn center)
- In a trauma center, management and disposition should be a joint decision between trauma and emergency medical teams.

Summary

- Adequate preparation and team communication are essential in the assessment and care of a trauma patient
- Primary survey consists of continually assessing ABCDEs
- Adjunctive tools to the primary survey can help identify and treat underlying pathology
- Perform secondary survey using an AMPLE history and head-to-toe exam once the patient is stabilized
- If there is any change in airway or hemodynamic status, repeat primary survey
- First of the trauma ABCs and usually top priority in trauma
  - One exception: exsanguination from a wound
- Delayed intubation can lead to increased mortality, even among those initially stable
  - Airway management is an essential skill for all EM physicians

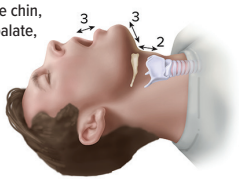
Chapter 2

AIRWAY

N. Bhatt, M. Jones

General Principles

- Assessment of airway: multitude of contributors to potential airway compromise
  - Level of consciousness
  - Vomiting and/or aspiration risk
  - Maxillofacial trauma
  - Neck trauma
  - Respiratory distress
  - Signs of cyanosis
  - Pulse oximetry and end tidal CO_2
- Common indications for intubation
  - Airway obstruction
  - Hypoventilation
  - Persistent hypoxemia despite oxygen supplementation
  - Severe cognitive impairment (GCS ≤ 8)
  - Severe hemorrhagic shock
  - Cardiac arrest
  - Other considerations
    - Facial/neck injuries with potential for airway obstruction
    - Persistent combativeness refractory to pharmacological intervention
    - Respiratory distress w/o hypoxia or hyperventilation
    - Preoperative management
    - Early intubation for cervical spine injury with evidence of respiratory compromise
    - Burns: determination of airway compromise can be tricky as the signs may not be obvious visually. Consider intubation if: severe cognitive impairment (GCS ≤ 8), > 40% burns, major burns/inhalation with prolonged transportation to definitive care facility, moderate-to-severe facial burns, oropharyngeal burns, airway injury seen on endoscopy
- Before intubation, assess the difficulty of the airway
  - Physical features: obesity, small/large chin, short neck, buckteeth, high arched palate, oral-maxillofacial trauma
  - LEMON mnemonic
    - **L**ook for external features predictive of difficult airway
    - **E**valuate neck geometry with 3-3-2 (fingerbreadths) rule (see image)



ATLS TIP

    - ♦ oral opening [3]
    - ♦ mentum-hyoid distance [3]
    - ♦ mandible-thyroid cartilage distance [2]
  - **M**allampati score: range from 1 (complete visualization of posterior pharynx) to 4 (limited/no visualization)
  - **O**bstruction/obesity
  - **N**eck mobility
- — Bag-valve-mask (BVM) for ventilation
  - Factors that make proper use difficult: facial hair, obesity, edentulous patient, advanced age, snoring, oral-maxillofacial trauma
  - If BVM can adequately ventilate and oxygenate a patient, then you have time to strategize an appropriate and safe plan for the patient
- A potentially difficult airway will require more pre-planning and use of other devices
  - — Alternative devices (direct vs. video, bougie, LMA, etc.)
    - ☛ Video laryngoscopy offers increased first pass success in providers familiar with use
    - ☛ Direct laryngoscopy may be better if there is a bloody airway
  - — Anesthesia service at bedside
  - — Advanced airway equipment (cric kit, fiberoptic intubation scope, etc.)

Rapid Sequence Intubation (RSI): The 6 P's

- Preparation
  - — SOAP ME — **S**uction, **O**xygen, **A**irways (BVM, scalpel, Glidescope, LMA, DL blades), **P**harmacology, **M**onitor, **E**scape plan (anticipate worst-case scenarios)
- Preoxygenate (replaces nitrogen with oxygen)
  - — NC + NRB for spontaneously breathing patients
  - — NC + BVM for hypoventilatory and apneic patients
- Position
  - — Bed at intubator's beltline
  - — C-collar removed and stabilized manually by an assistant
  - — If no concern for c-spine injury, position patient's head parallel to ceiling, neck and head elevated > 45° starting from the shoulders, neck slightly extended
- Pre-treatment
  - — Resuscitate by correcting volume and other physiologic abnormalities as best as able (can affect patient's response to RSI)
- Paralytics and induction (RSI)
  - — Induction agents
    - Etomidate (0.1–0.3 mg/kg)
      - ♦ Rapid onset
      - ♦ Risk of adrenal insufficiency, ARDS and lowering seizure threshold

- Ketamine (1–2 mg/kg)
  - ♦ Increased sympathetic drive, increases BP and HR
  - ♦ Theoretical increase in CPP and ICP (controversial)
- Propofol (1–2 mg/kg)
  - ♦ Can cause hypotension
  - ♦ Can stop seizure activity

— Paralytics (perform neuro exam before administration)
- Succinylcholine (1.5 mg/kg)
  - ♦ Rapid onset, rapid off (8–10 min)
  - ♦ Contraindications: crush injury, burns > 24 hours, prolonged immobilization, skeletal myopathies, ESRD
- Rocuronium (1.2 mg/kg)
  - ♦ Rapid onset, long lasting (45 min) which can be beneficial
  - ♦ Prolonged paralysis can be problematic if unable to intubate/secure airway

■ Placement with proof
— Confidently seeing the endotracheal tube go between the vocal cords
— End-tidal CO_2 capnography or colorimeter CO_2 detector (may be negative in some cardiac arrest patients)
— Symmetrical chest rise with BVM breaths
— Equal, bilateral breath sounds on auscultation
— CXR demonstrating placement of endotracheal tube in trachea

■ Postintubation management
— Analgesia
— Sedation
— OG tube

IMAGES COURTESY OF RICHARD LEVITAN, MD | AIRWAY•CAM

Failed Airway

■ If there is failure to intubate and failure to oxygenate adequately, or the patient is unable to undergo orotracheal/awake intubation, then cricothyrotomy is definitive airway management.

TIP

- See failed trauma airway algorithm
- Identify cricothyroid membrane (ideally marked with pen before initiation)
  - ☛ Consider identifying cricothyroid membrane before every intubation to practice finding it and to know in case the intubation fails
- Use 10-blade to make a 4 cm vertical incision through the skin
- Find membrane with palpation again and make horizontal incision through membrane
- Dilate hole with gloved finger
- Pass bougie through incision site
- Pass ET tube over bougie until balloon just passes the skin
- Confirm placement

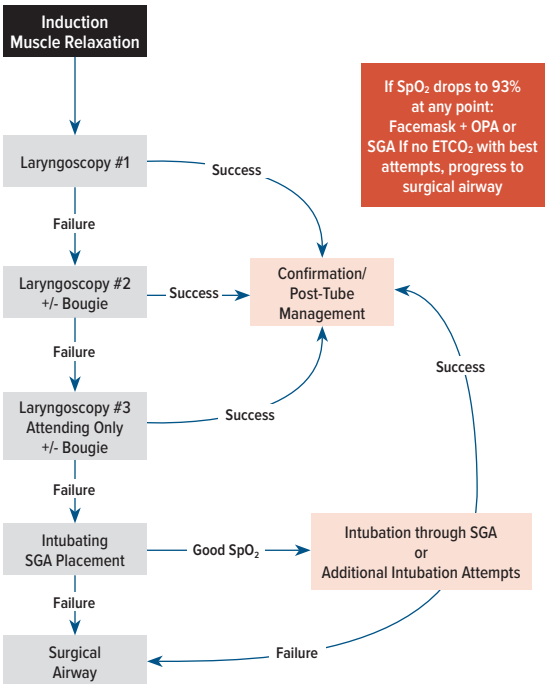
PEARLS AND PITFALLS

- Tachypnea can be a subtle/early sign of airway compromise
- When patients are on high supplemental oxygen, pulse oximetry oxygen saturation can be normal even with compromised breathing (end tidal CO_2 is more reliable)
- Have proper rescue airway equipment prior to paralyzation to allow for adequate oxygenation and ventilation in the case of a difficult or failed airway
- Follow failed airway algorithm to guide decision to perform cricothyrotomy, as delayed decision often result in poor outcomes

Summary

- Airway is top priority in ABCs
- If BVM can adequately ventilate and oxygenation a patient, you have time to strategize the best course of action
- Make the decision to intubate early
- Anticipate the difficult airway and prepare to go down the failed airway algorithm.
- 6 P's: **P**repare, **P**reoxygenate, **P**osition, **P**retreat, **P**aralyze/induce, **P**lacement/confirm, **P**ost-intubation care
- Do not hesitate to perform cricothyrotomy early in the failed airway algorithm

Shock Trauma Center Failed Airway Algorithm



OPA: oropharyngeal airway
SGA: supraglottic airway

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Chapter 3

FLUID RESUSCITATION

K. Khambhati, M. Jones

ATLS TIP

General Principles

- While hemorrhagic shock is the most common etiology of shock in trauma patients, it is important to consider the alternatives, including cardiogenic, obstructive, distributive, and hypovolemic.
- In managing patients with suspected hemorrhagic shock, the treatment goal is definitive control of bleeding and repletion of circulating volume.
- Initial administration of crystalloid fluid serves a dual purpose of bolstering lost intravascular volume (serving to improve organ perfusion) and evaluating fluid-responsiveness of patients. However, excessive fluid administration may both dilute blood hemoglobin concentration and cause hypertension, leading to further bleeding.
- Adults should initially receive 1 liter of warmed isotonic fluid, including pre-hospital administered fluid. The decision for further fluid administration should be based on fluid-responsiveness. ATLS recommends classifying responsiveness to initial fluid administration into 3 categories:
  - Rapid responders: generally have normalization of vital signs, indicating < 15% blood volume loss; may not require blood emergently
  - Transient responders: improved vitals followed by relative decrease or increase in BP or HR, respectively; estimated 15–40% blood volume loss. Typically require blood upon subsequent clinical deterioration after initial fluid administration
  - Minimal or non-responders: no normalization of vitals with initial fluid administration; estimated > 40% blood volume loss. Require blood products and initiation of massive transfusion protocol (MTP)
- Many academic trauma centers have advocated for immediate resuscitation with blood products, entirely skipping crystalloid when patients exhibit initial evidence of hemorrhagic shock.
- Give type and cross-matched blood when possible, but in emergent situations use readily available type O and Rh-negative packed red blood cells (pRBCs).
- Changes in BP and HR may be more useful than absolute values. Other relevant clinical findings: capillary refill, urine output (0.5–1 cc/kg/hr in adults and 1–2 cc/kg/hr in pediatric patients), serial lactate and base deficit

Permissive Hypotension

- To minimize dilution of intravascular contents and risk of rebleeding through "popping the clot," target systolic blood pressure (SBP) can be lower in hemorrhagic shock resuscitation as compared to that of other forms of shock.

ATLS
TIP

- Target SBP is variable in practice, with recommendations ranging from 50–70 mmHg SBP and some recommending 80 mmHg SBP
- Typically practiced in penetrating trauma
- Never implement for patients with head trauma

Damage Control Resuscitation

- MTP: > 4 units of pRBCs transfused in first hour of resuscitation or > 10 units of pRBCs within a 24-hr period
- Most common recommendation: administer fresh frozen plasma (FFP), platelets, and pRBCs in a 1:1:1 or 1:1:2 ratio, respectively. Note: no significant benefit in 24-hr or 30-day mortality has been shown in 1:1:1 versus 1:1:2 administration
- Rationale behind MTP is multifactorial but the goal is to match whole blood resuscitation as much as possible. Administration of whole blood (as opposed to packed RBCs alone) prevents dilution of coagulation factors and platelets, replenishes lost factors and platelets to hemorrhage, and assists in combating hypothermia- and consumption-induced platelet and factor dysfunction.

Crystalloid vs Colloid

- Colloidal fluids contain high molecular weight matter and are associated with intravascular volume expansion.
- The evidence does not demonstrate a benefit in trauma populations; the CRISTAL trial serves to show no benefit in 28-day mortality in colloids over crystalloid for initial resuscitation in ICU patients presenting in hypovolemic shock. Among critically ill patients needing acute resuscitation, the use of hydroxyethyl starch, which is used in certain colloidal solutions, increased risk of acute kidney injury.

Pediatrics

- Pediatric patients compensate for greater volumes of blood loss than adult patients. Children may not exhibit signs of hypovolemia until ~25% decrease in blood volume.
- Initial fluid resuscitation: warm isotonic crystalloid at 20 cc/kg; may be repeated based on response.
- If suspected bleeding after 2 boluses: packed RBCs at 10 cc/kg.
- Pediatric MTP: replacing half of the estimated blood volume in 3 hrs or the whole estimated blood volume in 24 hrs
- Pediatric MTP is predominantly institution-specific; however, the Pediatric Trauma Society has a suggested protocol.

Calculating Blood Volume

Estimated weight by age = 2 x age (years) + 10
Estimated blood volume by age

Age	Estimated Blood Volume
< 1 year	80 cc/kg
1–3 years	75 cc/kg
>3 years	70 cc/kg

Summary

- If the blood pressure and heart rate do not respond to an initial fluid bolus, consider blood products early.
- Packed RBCs cannot be stored warm but can be given warm through a rapid infuser to combat hypothermia.
- Large bore intravenous (IV) access allows for high flow rates; aim for two 16 gauge IVs.
- Particularly for penetrating trauma, target lower SBP than otherwise indicated in non-hemorrhagic forms of shock.
- Children may not exhibit clinical signs of hypovolemia despite significant blood loss.

ATLS
TIP

eFAST

N.J. Leonard, M. Jones

Extended Focused Assessment with Sonography in Trauma (eFAST)

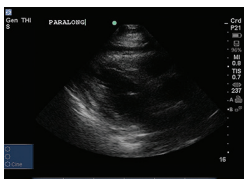
The extended Focused Assessment with Sonography in Trauma (eFAST) is an important adjunct to the primary survey. The goal of this sonographic evaluation is to identify intra-abdominal and intrathoracic free fluid, pericardial tamponade and pneumothorax. In the setting of trauma, this free fluid is assumed to be blood. Ultrasound is a non-invasive, non-radiating and inexpensive tool with the considerable advantages of bedside availability compared to other imaging techniques.

General Principles

- The eFAST exam should be performed as an adjunct in unstable blunt trauma patients after the initial primary survey has been completed.
- No absolute contraindications in a trauma patient
- Do not delay resuscitative measures or patient transfer to wait for imaging
- Areas of scanning: pericardial view, right upper quadrant (RUQ) view, left upper quadrant (LUQ) view, pelvic view, bilateral anterior thoracic.

Pericardial

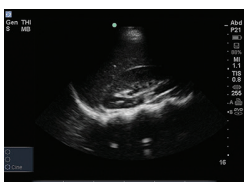
- Evaluate for pericardial tamponade (life-threatening diagnosis; some recommend that it should be the first view obtained): subcostal or parasternal long views
- Pericardial effusion identified when anechoic fluid is visualized between the heart and the pericardium. Along with vital signs, the presence of right ventricular collapse indicates tamponade.
- For more, see Pericardial Tamponade chapter in Chest Trauma section.



Pericardial Effusion (Abnormal)

Right Upper Quadrant

- Conventionally, the second view to be obtained is the RUQ view as it is the most sensitive view for detecting intra-abdominal fluid.
- The RUQ view detects free fluid surrounding the liver and right kidney. It is important to visualize the entire hepatorenal recess (Morrison's pouch) as well as the caudal liver edge.



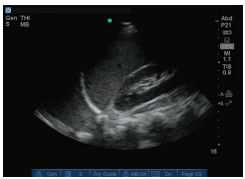
Normal FAST RUQ

TIP

Visualizing the space above and below the diaphragm is necessary for a complete RUQ view. Hypoechoic fluid above the diaphragm indicates pleural effusion, which is presumed to be hemothorax in the setting of trauma.

LUQ

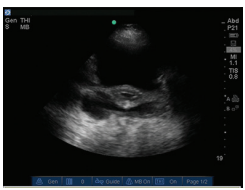
- The LUQ view evaluates the space between the spleen and the left kidney. In order to obtain this view, the operator will likely need to position their probe more posteriorly compared to the RUQ view.
- The area below and above the diaphragm (for intra-abdominal and intra-thoracic free fluid respectively) must also be visualized for a complete LUQ scan.



Normal LUQ

Pelvic

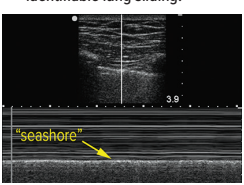
- The pelvic view identifies all borders of the bladder in both the transverse and longitudinal views.
- While scanning through the entirety of the bladder, the provider should search for hypoechoic fluid lateral or inferior to the bladder.



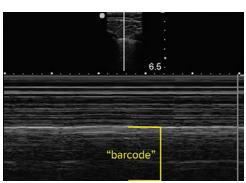
Bladder

Anterior Thoracic

- The anterior thoracic view assesses for the presence or absence of pleural sliding between rib spaces.
- A pneumothorax is identified on 2D mode if no lung sliding is identified, or by using M-mode and looking for the classic "barcode sign."
- The presence of a lung point is highly suggestive of a pneumothorax and is identified as an abrupt transition point between lung sliding and no identifiable lung sliding.



Normal seashore sign



Barcode sign

IMAGES CONTRIBUTED BY SOPHIA LIN, WEILL CORNELL MEDICINE

TIP

PEARLS AND PITFALLS

- The purpose of the eFAST exam is not to identify the specific source of hemorrhage, but only the presence or absence of intraabdominal free fluid (presumed hemorrhage) in order to guide further management.
- A minimum of 150–200 cc intraperitoneal fluid to be detected by US.
- CT scan remains the gold standard for diagnosing intra-abdominal injuries. However, CT scan requires more time and involves transportation of the patient out of the emergency department, which poses a concern when treating the hemodynamically unstable patient.
- Negative FAST does not exclude the possibility of significant intra-abdominal injury. Therefore, abdominal exams and FAST scans should be repeated, especially if there is a change in patient's symptoms or hemodynamics.

TIP Unlike CT, the FAST exam cannot identify retroperitoneal bleeds.

Summary

- The eFAST exam has a high specificity and sensitivity and is quick and non-invasive.
- ATLS states that it should be performed as an adjunct to the primary survey and gives emergency physicians and surgeons insight into the potential site of hemorrhage.
- Hemodynamically unstable patients can potentially forgo additional imaging such as X-ray or CT prior to chest tube placement or transfer to the OR.
- In stable patients with low suspicion for intraabdominal or intrathoracic injuries, serial FAST and abdominal exams can be used to potentially forgo CT.

Chapter 5

IMAGING

A. Lee, M. Jones

General Principles

Radiographs, ultrasound, and CT scans can provide quick and valuable information, including the ability to rule out life-threatening conditions.

- Trauma bay imaging
  - Portable chest x-ray
    - Identifies life threats such as tension pneumothorax, free air under the diaphragm, wide mediastinum
    - Identifies hemothorax, a potential cause of hypotension
    - Useful to evaluate for proper placement of the endotracheal tube, chest tube(s), central venous catheter(s), and naso- or orogastric tube
  - Portable pelvis x-ray
    - Identifies significant pelvic fractures, a potential source of hemorrhage leading to hypotension
    - Patients who are alert, awake, walk at the scene, and without pelvic pain or tenderness do not need a pelvic x-ray
  - eFAST exam
    - Identifies blood in retroperitoneal spaces of abdomen, thorax, and pericardial space, all potential causes of hypotension
- For potentially significant trauma, diagnostic x-rays should be obtained even in pregnant patients.

CT (Computed Tomography)

- High sensitivity and specificity in detecting injuries that are not apparent on physical exam.
- CT scan is performed once the patient is stabilized, and the decision to obtain scans of specific body regions is made based on the patient's history, mechanism of injury, and findings from the primary survey, secondary survey, or adjunctive tests.
- Head CT
  - The decision to obtain a CT scan of the head is often based on one of several clinical decision-making instruments
  - The Canadian Head CT Rule has a sensitivity of 83–100% for all intracranial traumatic findings and a sensitivity of 100% for identifying neurosurgical interventions.
  - See Head Trauma section for more details on imaging and management of injuries.
- Spine
  - For cervical spine injuries, validated clinical decision tools such as the Canadian C-spine rule or NEXUS can be used to determine need for radiographic evaluation.

  - CT of the thoracic, lumbar or sacral spine should be obtained in patients who have spine pain or tenderness to palpation, neurological deficits, or noted to be obtunded with significant concerning mechanism of injury.
  - CT is the primary screening modality for the spine and is superior to x-rays.
  - See Spinal Trauma section for more details on imaging and management of specific injuries.
- Abdomen/Pelvis
  - CT scan with IV contrast is the definitive imaging of the abdomen and pelvis.
  - Indications for abdominal CT scan in hemodynamically normal patients include suspicion for retroperitoneal or pelvic injuries difficult to assess with physical examination or FAST, the presence of abdominal pain and/or tenderness, or potentially deep flank or back stab wounds.
- Whole Body CT or "Pan Scan"
  - Non-contrast head and spine, and contrast-enhanced chest, abdomen, and pelvis CTs
  - Typically performed in patients with major blunt trauma and/or multiple injuries suspected but evaluation is limited
  - Whole body CT can allow for rapid diagnosis and potentially clear a patient for discharge.
  - Whole body CT has been shown to shorten ED and hospital length of stay, minimize the rate of missed injuries, and decrease mortality.
  - Whole body CT also may increase time to treatment for dangerous injuries, increase radiation exposure, and increase incidental findings on CT.
  - There remains debate whether selective CT scanning or whole body CT approach is superior.

Other Specific Contrast Studies

- Urethrography
  - Perform before inserting urinary catheter when urethral injury is suspected (ie, blood at the urethral meatus and bruising in the perineum)
  - Note: "high-riding prostate" is no longer an indication
  - Secure a urinary catheter in the meatus and instill a small amount of contrast. An AP radiograph should show reflux of contrast into the bladder without extravasation.
  - See Urethral Trauma chapter in the GU Trauma section for more
- CT cystography
  - Used to diagnose intra- or extraperitoneal bladder rupture
  - Clamp the Foley before obtaining CT scan to allow contrast to fill the bladder.

NEW

- CT cystography is the best study to visualize urinary tract injuries
- Remember to unclamp Foley after imaging.
- See Bladder Trauma chapter in the GU Trauma section for more

Extremity radiographs

- Used to assess for fractures based on physical exam findings.
- Depending on a patient's hemodynamic status, extremity x-rays may need to be delayed until the patient is stabilized.
- If there is a suspected fracture based on the physical exam (pain, swelling, deformity, tenderness, crepitus, abnormal motion), x-rays should be obtained.
- For patients with altered mental status, consider x-rays of the joints above and below the suspected fracture site to exclude dislocation and concomitant injury.
- Open fracture: give IV antibiotics ASAP
  - CT scan can assess for open joint injury (intra-articular gas)
- Suspected vascular injury: obtain CT angiography, but do not delay reestablishing arterial blood flow.

PEARLS AND PITFALLS

- Imaging studies should not delay patient resuscitation.
- CT is time-consuming outside of the trauma bay and should only be obtained in hemodynamically stable patients and when there is no emergent indication for an emergency intervention or disposition (ie, OR).
- If hemodynamic abnormalities (unstable): patient needs to be either resuscitated in the ED or taken to OR for hemorrhage control.
- If the patient needs to be transferred to a facility with a higher level of care: do not delay transfer to obtain CT imaging. CT scans should only be performed if it will alter care at the referring facility or facilitate stabilization for transfer.

Summary

- Portable chest and pelvic radiographs, and FAST are useful adjuncts to the primary survey that can be performed in the resuscitation bay and can identify a source of bleeding or shock.
- CT scan is useful in identifying injuries that are not evident on physical exam or primary survey, but should not delay resuscitation of the patient or transfer to a level 1 trauma center.
- Use validated clinical decision tools to guide the need for CT imaging of head and c-spine.

Chapter 6

REVERSING ANTICOAGULATION

M. Sachet, M. Jones

NEW
TIP

Introduction

- As the number of patients on anticoagulation grows, its impact on the management of trauma patients cannot be overstated. Pre-injury warfarin treatment has been identified as an independent risk factor for mortality, with up to a three-fold increase in mortality in trauma patients taking warfarin.
- While protocols are in place for managing warfarin use in trauma patients, the advent of multiple direct oral anticoagulation (DOAC) agents has made reversing anticoagulation challenging.
- Most of the DOACs and antiplatelet drugs do not reliably cause laboratory abnormalities, making their use difficult to identify and treat.
- Given an aging population with many comorbid conditions, the importance of considering anticoagulant use in traumatic injury has increased substantially.

General Principles

- The general principles of anticoagulation reversal in trauma can be categorized based on severity of bleeding and type of agent.
- In the patient with life-threatening bleeding, hemodynamic instability, or traumatic brain injury (TBI), rapid reversal of anticoagulation is required. The reversal method depends upon the type of agent used, see table below.
- Specific guidelines for warfarin reversal also apply to patients without life-threatening bleeding (see flow diagram).
- Identify coagulopathy early
  - Obtain PT/INR, PTT, and blood count including platelets within the first hour of arrival
  - TIP Thromboelastography (TEG) and rotational thromboelastometry (ROTEM) can be useful adjuncts and are available in some emergency departments
- Consider initiation of massive transfusion protocol (MTP) as per institutional guidelines
- TIP Weigh benefit of reversing anticoagulation with potential for complications
  - Thrombotic complications
  - Vitamin K, especially when given intravenously, can cause anaphylaxis. Protamine also has a risk for anaphylaxis.
  - Fresh frozen plasma (FFP) — one unit is 250 cc, and multiple units are required to achieve the same effect as a single vial of 4-factor prothrombin complex concentrate (PCC). There is potential for volume overload, as well as potential for transfusion reactions (keep in mind that FFP is type-specific, and the universal donor is AB+)

TABLE. Reversal of anticoagulation in life-threatening bleeding, hemodynamic instability, or brain injury due to traumatic injury

Life-threatening bleeding, hemodynamic instability, TBI		
Type of agent	**Therapy**	**Additional information**
Warfarin	• Vitamin K 10 mg IV and PCC 25-50 mg/kg IV (not to exceed 5,000 units) will reverse effects within 30 min • 3-Factor PCC, FFP, and rFVIIa are alternatives, see chart 1	• PCC • INR 2 to <4: 25 units/kg; not to exceed 2500 units • INR 4–6: 35 units/kg; not to exceed 3500 units • INR >6: 50 units/kg; not to exceed 5000 units
Direct thrombin inhibitors (dabigatran)	• Idracuzimab 5 g IV • If not available, PCC 25–50 mg/kg IV (not to exceed 5,000 units) • Consider hemodialysis (HD)	• Idarucizumab: monoclonal antibody fragment specifically for use in dabigatran reversal
Factor Xa inhibitors (rivaroxaban, apixaban)	• PCC 25–50 mg/kg IV (not to exceed 5,000 units) • If available, andexanet alfa (dose varies, see additional info)	• Andexanet alfa: recombinant modified FXa. If dose/timing unknown, administer 800 mg IV bolus @30 mg/min, followed by IV infusion of 8 mg/min for up to 120 min • Give half dose for apixaban 5 mg or less or rivaroxaban 10 mg or less, or for any dose if > 8 hrs since last taken • Heavily protein-bound, so HD is ineffective
Heparin products (unfractionated heparin (UFH), low molecular weight heparin (LMWH))	• Protamine 1 mg IV per 100 units of UFH administered within past 3 hrs; 1 mg IV per 1mg of enoxaparin given in previous 8 hrs; 0.5 mg IV per every 1 mg enoxaparin if 8–12 hrs since last dose	• Protamine does not completely reverse enoxaparin

TIP

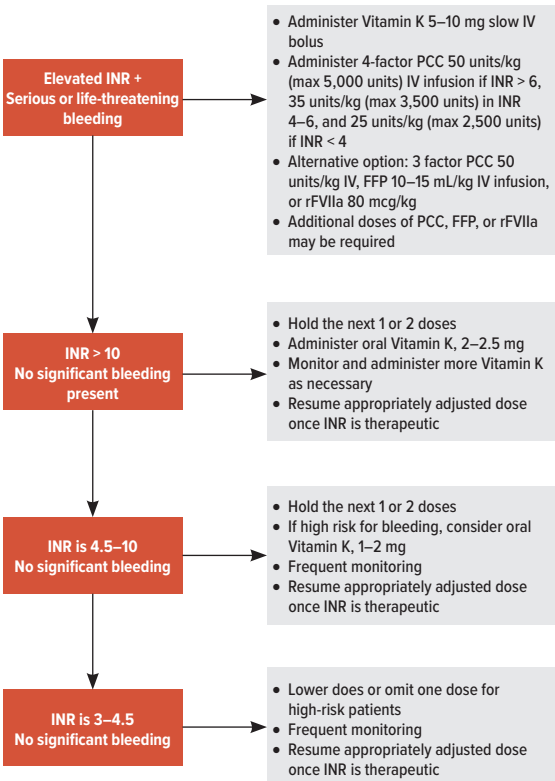
Life-threatening bleeding, hemodynamic instability, TBI (cont.)		
Type of agent	**Therapy**	**Additional information**
Aspirin	• Platelet transfusion to increase platelet count by 50,000/mm^3 • Desmopressin 0.3–0.4 mcg/kg IV over 30 min	• Platelet inhibition can last up to 7 days, repeat transfusion may be required • Increase in count by 50,000 typically requires one single-donor apheresis-collected platelet concentrate, or 6 units of random donor platelets
Other antiplatelet agents (clopidogrel, ticagrelor, prasugrel)	• Platelet transfusion to increase platelet count by 50,000/mm^3 • Desmopressin 0.3–0.4 mcg/kg IV over 30 min	• NSAID-induced platelet inhibition lasts < 1 day • ADP receptor inhibitor-induced platelet dysfunction may last 5–7 days

PEARLS AND PITFALLS

- Use caution with tranexamic acid (TXA) administration in this patient population. Co-administration of TXA in anticoagulated patients requiring reversal can lead to more thrombotic complications. Confirm with EMS that TXA was not already given in the field.
- Establish an accurate timeline of drug administration. Activated charcoal may reduce intestinal absorption of many oral anticoagulants if given within 1–2 hrs of drug ingestion.
- In general, avoid FFP unless it is given as part of massive transfusion protocol, or PCC is unavailable.

TIP FFP requires longer preparation time due to thawing, takes longer to correct coagulopathy (1–2 hours, as opposed to minutes for PCC), and requires a much larger volume compared to PCCs. This results in delay in administration, delay in action, and potential for volume overload.

Guidelines for Correction of Warfarin-induced Coagulopathy



RESUSCITATIVE THORACOTOMY

A. Rodrigues, N. Caputo

TIP

Airway/Breathing

- If not already intubated, attempts can continue but should not delay thoracic incision
- Some experts recommend right mainstem intubation to facilitate left lung collapse during procedure

Circulation

- Trauma victims often become pulseless because they've lost their circulating blood volume. If exsanguination is the cause of cardiac arrest, compressions are unlikely to be beneficial; initiate massive transfusion protocol.
- Some experts do not perform closed-chest compressions during traumatic cardiac arrest

Indications

- Victims of penetrating trauma who are with or without signs of life
- Victims of blunt trauma WITH signs of life:
  - Gag reflex
  - Pupillary reflex
  - Echocardiographic motion
  - PEA rhythm
  - Spontaneous breathing
  - Pulse or BP
- NOT eligible: blunt trauma victims without signs of life (unless they become pulseless in the ED)
  - ☛ In a study of 187 patients who underwent resuscitative thoracotomy, those without pericardial fluid or cardiac motion on FAST ultrasound had 0% survival
  - Surgery must be readily available

Goals of Resuscitative Thoracotomy

- Relief of tamponade (intervention of most benefit)
- Hemorrhage control
- CPR augmentation

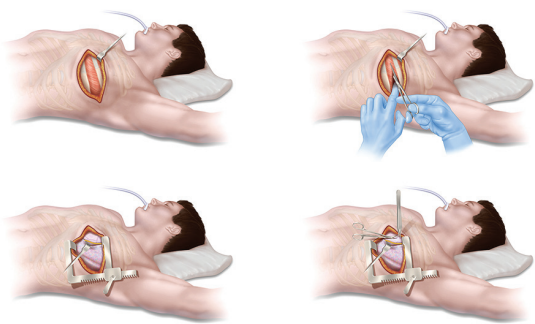
Procedure

- Positioning and setup
  - Stand to patient's left chest, with patient's left arm restrained up and out of the way
  - After applying PPE (mask with eye shield, gown, gloves), cleanse the left chest with antiseptic solution
  - Consider a right mainstem intubation to facilitate left lung collapse

- Make an incision to the left anterolateral chest, following the natural course of the 4th–5th intercostal space, cutting through skin, subcutaneous tissue and fat in 3–4 strokes, exposing the ribs and intercostals
- Insert one large blade or mayo-type scissors above superior border of lowermost rib and cut medially along the rib to the incision's anterior apex, and then back downward/posteriorly along rib to incision's lateral apex
- Insert Finochietto retractor, preferably with crossbar down toward the bed, and crank open to spread ribs until adequate window attained
- Gently compress left lung and push it upwards to expose heart

Goal 1. Relieve Tamponade

- AVOID PHRENIC NERVE, which runs along left lateral heart border, by lifting fibrous pericardium away from myocardium with forceps, and making a small vertical incision through pericardium as it lies over the anterior surface of the heart
  - — No blood expressed: proceed to goal 2
  - — Blood is expressed: Extend pericardial incision from top to bottom of heart and remove heart from pericardium
- Check the heart carefully, front and back, for a through-and-through penetrating injury
  - — If a defect is identified, cover it with a finger(s) to prevent additional hemorrhage, and proceed to OR



TIP

☛ Insertion of a Foley may significantly enlarge the defect! Use Foley balloon tamponade only for large lacerations

Goal 2. Hemorrhage Control

- Any gross hemorrhage in chest: hold direct pressure with gloved hands, 4" x 4" gauze, or lap pads
- Hemorrhage to the right side of the chest is identified via right-sided finger thoracostomy or chest tube placed by another team member. Alternatively, run your flat hand between the heart and sternum into the right hemithorax to identify additional sources of hemorrhage

Goal 3. CPR Augmentation

- Use 2 flat hands to compress the heart at a rate of 100–120 beats per minute while resuscitative efforts continue (augments coronary perfusion pressure, compression-phase pressure gradients and cardiac output compared to closed-chest CPR)
- Compressions with a single hand is less effective and can lead to puncturing of the heart with the thumb

Additional Considerations

- Aortic cross-clamp: last-ditch effort unlikely to be successful
  - To cross clamp the aorta (a blind procedure) once goals 1–3 have been achieved, run the back of your flat hand, palm up, down around the posterior L rib cage. The first tubular structure you encounter is the aorta
  - Use blunt dissection to loop a finger around the aorta, then use your finger to guide a large hemostat clamp around the aorta, which is closed to complete the cross-clamp
  - Alternatively, consider compression of the aorta manually; if ROSC occurs, take patient to OR with continued compression of the aorta.
  - An aorta cross-clamped for > 30 mins will likely result in irreversible, deadly organ ischemia
- Consider discussing clamshell (bilateral) thoracotomy with surgical colleagues in accordance with local practice guidelines

NEW
TIP

TUBE THORACOSTOMY (CHEST TUBE)

T. O'Connell, N. Caputo

Definition: Procedure in which any tube or small catheter is placed through the chest wall into the pleural cavity; used primarily to drain air or fluid

Indications

- Traumatic cause of pneumothorax (except asymptomatic, apical pneumothorax)
- Moderate to large pneumothorax
- ANY pneumothorax with respiratory symptoms
- Increasing pneumothorax after initial conservative management
- Hemothorax
- Bilateral pneumothorax regardless of size
- Tension pneumothorax

Contraindications

- *Relative:* Anticoagulation, coagulopathy, overlying infection, or a bleeding diathesis
- Consider conservative management in both penetrating and blunt trauma when the PTX is < 35 mm from parietal and visceral pleura/mediastinum in a line perpendicular to the chest wall on imaging

Airway: Usual airway assessment/management

- Positive pressure ventilation may worsen pathology from pneumothorax; be prepared for chest tube placement
- Look for signs of airway obstruction: blood, hematoma, edema, vomitus, facial or neck trauma, foreign bodies

Breathing: Usual breathing assessment/management

- The mechanisms of injury, such as penetrating chest trauma or blunt force trauma to the chest, may signal impending respiratory failure
- Bedside US is reliable to assess for pneumothorax (eg, lung sliding) and hemothorax
- If unequal breath sounds, and you identify pneumothorax, hemothorax, or hemopneumothorax, perform a tube thoracostomy

Circulation: Usual circulation and hemorrhage control management

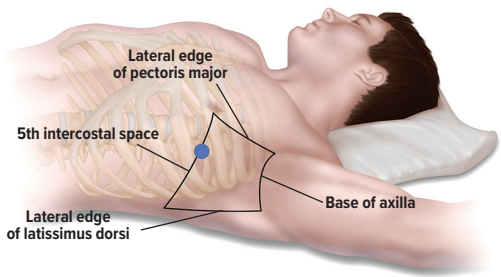
- Consider autotransfusion of blood loss from hemothorax
- In non-hemorrhagic shock, consider tension pneumothorax as an etiology

Procedure

- **Basic equipment** (often in prepared "chest tube kits")

■ Povidone-iodine or chlorhexidine	■ Needle driver
■ 10–20 mL syringes	■ Mayo scissors, large curved
■ Local anesthetic with epinephrine	■ Size 0 or 1-0 silk or nylon
■ 25–27 gauge needle	■ Petroleum gauze
■ #10 scalpel blade and handle	■ 4" x 4" gauze
■ Kelly clamps — large and med	■ Adhesive tape
■ Chest tubes	■ Sterile drape
■ Chest tube drainage setup with water seal	■ Sterile gown and gloves
■ Suction source and tubing	■ Face mask with shield/goggles

- **Location for insertion**
  - 4th–5th intercostal space, anterior axillary line
  - Use "safe triangle" as a guide for insertion (see figure)



- **Positioning and preparation**
  - Provide supplemental oxygen via NRB
  - Position the patient's arm restrained above their head and out of the way
  - Prep and drape the skin using sterile technique (time permitting)
  - Prep your chest tube:
    - Place curved Kelly clamp on the end entering chest cavity
    - Place straight clamp across the back end of the tube to prevent blood drainage on the floor

- **Anesthesia**
  - Anesthetize *entire* tract of incision (skin to parietal pleura)
  - Consider IV pain control (fentanyl, ketamine, etc.)
- **Placing tube**
  - After confirming your location, make a 3–5 cm incision along the upper border of the lower rib of your desired intercostal space
  - Bluntly dissect the tract using Kelly clamps along the upper border of the rib (**avoiding** the neurovascular bundle resting under the inferior border of the upper rib)
  - Briskly push the closed tip of the clap through the parietal pleura into the pleural cavity (you should feel loss of resistance and/or "rush" of air when you penetrate the pleural cavity)
  - Spread the jaws of the clamp to enlarge the tract
  - Insert your finger into the pleural cavity (feeling re-expanded lung)
  - Gently break any adhesions of lung and thoracic cage
  - Place 28–30F chest tube into cavity along tract of your finger (large chest tubes are not necessary, even for hemothorax)
  - Once confirmed in the pleural cavity, advance the tube until the last drainage hole is at least 2 cm beyond the rib margin
  - Connect chest tube to suction device under water seal
- **Securing the tube**
  - There are multiple methods to secure the tube
  - Important to close the skin incision and have a firm grasp on the tube to prevent removal
  - Apply occlusive dressing (petroleum gauze) around the tube to create a seal, then cover with 4" x 4" gauze
  - Tape the gauze and chest tube to the torso
  - Secure the drain and connection to water sealed suction device
- **Post-chest tube care**
  - Obtain chest x-ray to confirm placement
  - Monitor output from chest tube

Other considerations

- **Post-thoracostomy indications for OR thoracotomy**
  - Initial chest tube drainage >20 mL/kg (approx. 1.5L)
  - Persistent bleeding at rate > 200 mL/hr
  - Increasing hemothorax on x- ray
  - Persistent hypotension despite resuscitation and other sites of blood loss ruled out
- **Chest tube size**
  - Conventionally, ATLS recommended use of a large tube (36–40F) but this has been amended
  - Recent evidence supports equal outcomes in smaller size chest tube (28–30F)

- **Use of autotransfusion**
  - Blood output from a hemothorax is an excellent source of *whole blood* that is identical match for the patient
- **Needle decompression**
  - Allows for rapid decompression of suspected tension pneumothorax
  - 2nd intercostal space in midclavicular line is no longer recommended due to high failure rates (up to 65%)[3–8]
  - Insert needle in same location as chest tube: anterior axillary line 4–5th intercostal space
- **Antibiotics**
  - Limited evidence for or against the use to prevent empyema or pneumonia

TIP

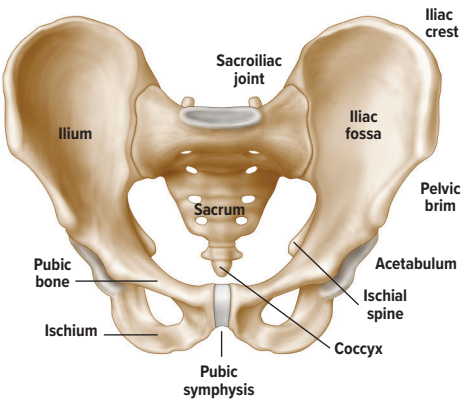
PELVIC FRACTURES/PELVIC BINDER

J. Yee, N. Caputo

Pelvis Anatomy

- Composed of ilium, ischium, pubis, sacrum, and coccyx
- Multiple ligaments hold the pelvis together
  - Strongest ligamentous connections in the body
  - If disrupted, have high suspicion for high-energy mechanism injury

Physical Examination



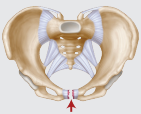
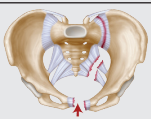
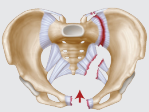
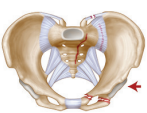
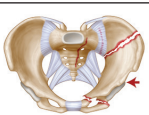
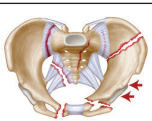
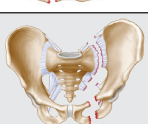
- Perform pelvic manual compression (grab iliac crests and push in) to check for bony instability. This should only be performed once as to avoid disrupting any clot formation and tamponade.

TIP Do NOT rock the pelvis! This can cause further bleeding and exsanguination.

Pelvic X-ray

- Check pelvic ring and pubic rami
- Check if the bones, SI joint, and pubic symphysis are intact

TIP If a fracture line is identified within the pelvic ring, look for another because a ring has to break at more than one point.

Young-Burgess Classification			
Anterior-Posterior Compression (eg, "open book" pelvic fracture pattern)		APC I (stable)	Pubic symphysis diastasis < 2.5 cm
		APC II (rotationally unstable, vertically stable)	Diastasis > 2.5 cm, anterior sacral ligaments torn
		APC III (unstable)	Hemipelvic separation with complete symphysis and posterior ligament disruption
Lateral Compression (transverse fracture of the pubic rami)		LC I (stable)	Posterior compression of the sacroiliac (SI) joint without disruption of the ligaments
		LC II (rotationally unstable, vertically stable)	Posterior SI ligament disruption, sacral crush injuries, or iliac wing fracture
		LC III (unstable)	LC II with open book fracture, APC, to contralateral pelvis
Vertical Shear (Malgaigne fracture)		VS (unstable)	Vertical displacement of symphysis and sacroiliac joint

CRITICAL INTERVENTIONS

TIP

Approch to Pelvic Trauma

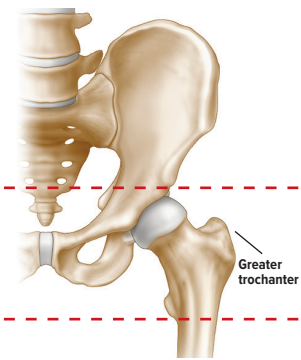
- Start with ABCs, IV, O_2 monitor
- Concern for hemorrhagic shock
- Majority of pelvic bleeds are venous in origin and benefit from a pelvic binder

Pelvic Binder

- **Goal**: Decrease available space in pelvis for hemorrhage to accumulate and potentially tamponade active bleeding
- **Indication**: Patients with suspected pelvic injuries on exam (movement noted when applying inward pressure to lateral pelvis) or confirmed significant pelvic injuries on imaging
- **Equipment**: Commercial pelvic binder or bed sheet folded approximately to 18" height with 2 or 4 hemostats

Bed Sheet Binder

- Undress the patient
- Check for distal pulses
- Fold the sheet to approximately 18" in height
- Place binder under patient, centered at level of the greater trochanters (see image)
- Bring both ends to front of patient
  - Optional: Cross the ends and turn them 180°
- Apply pressure to the pelvis until the pelvic ring has closed
  - Avoid over-reduction and internal rotation by checking if legs, greater trochanters, and patellae are in a neutral position. (Check feet! If they are pointing away from each other, hips likely are not in an internally rotated position)
- Secure binder with hemostats
- Check again for distal pulses
- Place legs in internal rotation and tape them together to further limit space in the pelvis
  - Obtain an X-ray to confirm reduction



☛ TIP

Additional

- Steps may vary with commercial device; consult device manual
- Vertical shear pelvic ring fractures may be displaced superiorly; lower extremity should be reduced inferiorly before applying the pelvic binder
- Pelvic binder is a temporizing measure; definitive management is trauma or orthopedic surgery

Special Considerations

- Patients with significant pelvic trauma requiring a pelvic binder are often in hemorrhagic shock (tachycardic, hypotensive, poor perfusion)
  - — Ensure 2 large bore IVs are in place and consider massive transfusion and TXA early
  - ☛ Avoid fluid resuscitation through the lower limbs as it can drain into the pelvis/retroperitoneal space
- Consider interventional radiology for persistent instability despite pelvic binder or blush on CT imaging indicating an ongoing arterial bleed
- Pelvic fractures require a high mechanism of energy transfer and can lead to high morbidity and mortality
- 10% mortality for pelvic fractures
- Up to 50% mortality for pelvic fractures in the unstable patient

TIP

TOURNIQUETS

J.E. Drouet, N. Caputo

Hemorrhage control is paramount in an actively bleeding trauma patient. Though not well-utilized in the prehospital/civilian environment, tourniquets can help the exsanguinating patient.

Remember the C-ABCs in trauma!

- **C**ontrol active bleeding (direct pressure, tourniquets, suture ligatures)
- **A**irway
- **B**reathing
- **C**irculation

Indication

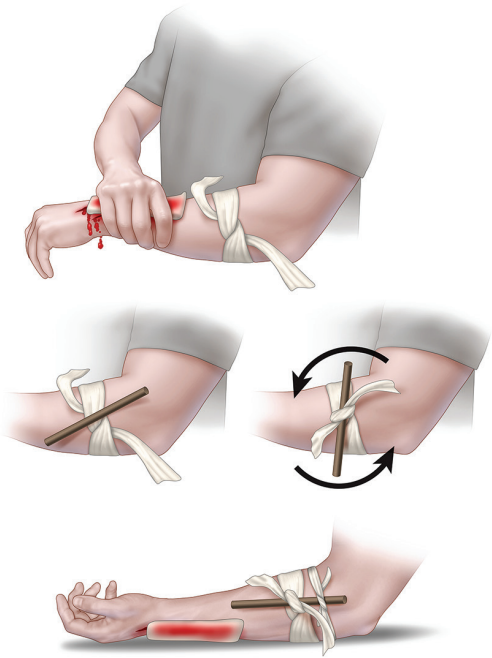
- Consider tourniquet when direct pressure does not control bleeding
- If you can control hemorrhage by less invasive means, you should

Combat-Application-Tourniquet (CAT)

- Ideal for quick application and removal
- Can be applied with one hand (if applying CAT to your own injury)
  - Check distal pulses
  - Place tourniquet between injured vessel and the heart, about 2" from closest wound edge
  - Place tourniquet over a bone, not at joint (NEVER place it over the wound itself!)
  - Tighten tourniquet until loss of distal pulse
  - Note time of placement (tourniquet should not be in place > 2 hrs)

Improvised "Windlass" Tourniquet

- Used when formal tourniquet is not available
- Best chance for successful application
  - Tie a 2–3" wide strip of material about 2" from edge of wound, over a long bone between wound and heart
  - Insert a stick or other strong, straight item into the knot
  - Turn stick to tighten tourniquet until pulse below the tourniquet cannot be felt
  - Secure in place with second piece of material
  - Note time of placement
  - Monitor the wound for bleeding
  - Monitor for swelling below tourniquet



Removal of Tourniquet

- Place patient on a cardiac monitor
  - Patients can suffer from crush syndrome if tourniquet that is left on for too long is removed quickly
  - Surge of potassium and inflammatory mediator release from lysed cells causes arrhythmias
- Slowly release pressure until you feel distal pulse return
- Watch for re-bleeding. If no active bleeding, leave tourniquet on loosely
- If re-bleeding occurs, try direct pressure; if not successful, re-tighten tourniquet

TIP

PERIMORTEM CESAREAN SECTION

B. O'Keefe, N. Caputo

Definition

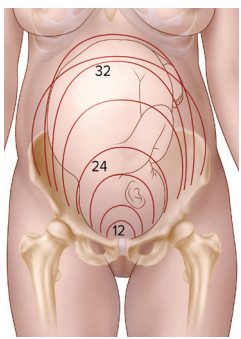
- C-section performed during maternal cardiac arrest or peri-arrest
- Goal: improve maternal resuscitation efforts in order to boost maternal survival and concomitant fetal survival

Perform within 5 min of maternal arrest for best neurological outcome for a viable fetus

Approach to Traumatic Pregnant Patient

- ABCs, IV, O_2, monitor, advanced airway equipment
- To resuscitate the fetus, you must resuscitate the mother
- Contact obstetrics, pediatrics, and neonatology (if available)
- Notable physiological changes:
  - By 28 weeks of pregnancy, blood volume increases 30–40% from non-pregnancy state
  - As fetus and uterus grow, the pregnant patient is susceptible to hypotension secondary to direct pressure on the IVC by the uterus
  - Functional Residual Capacity is decreased due to uterus elevating the diaphragm

  Resuscitative efforts should be aimed at ***maternal survival***
- **Airway**
  - In 3rd trimester, there is narrowing of the airway and possible need for one size smaller endotracheal tube
- **Breathing**
  - Pregnant patients are predisposed to desaturation; apply supplemental oxygen in all resuscitative efforts
  - Use RSI in all pregnant patients to decrease risk of aspiration, as lower esophageal tone is decreased during pregnancy
- **Circulation**
  - Pregnant patients are hypervolemic and hemodilute, thus signs of hypovolemia may be masked; have a high index of suspicion for hypovolemia
  - Displace uterus to the left to decompress the IVC and increase preload and cardiac output
  - During CPR, a team member should displace uterus to the side



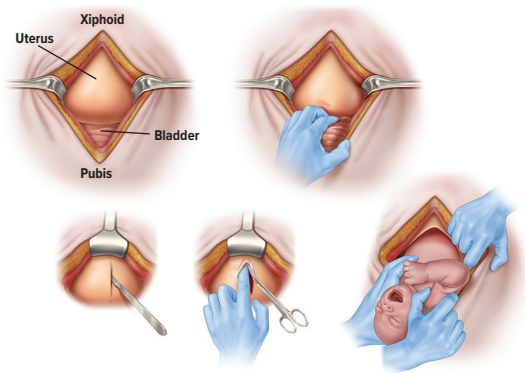
Height of fundus correlates with age of fetus

Indications

- If the fetus is small, uterus is unlikely causing hemodynamic instability
- Perform in any pregnant patient who is peri-arrest or arresting and at least 24 weeks pregnant (fundal height 4 cm above umbilicus)
  - Assessing 24 weeks via fundal height may be difficult; use ultrasound
  - Height of fundus correlates with age of fetus (see image)

Procedure

- Single midline vertical incision from xiphoid process to pubis
- Cut through subcutaneous tissue to expose peritoneal wall
- Using scissors or scalpel, dissect through peritoneal wall and bluntly dissect to reach uterus
- Use retractors to retract abdominal wall and expose uterus (see image)
- Deliver uterus and make a single vertical incision (sparing the placenta)
- Deliver neonate, clamp and cut umbilical cord
- Pack uterus with sterile packing
- Continue to resuscitate mother and neonate



ED MANAGEMENT AND ALGORITHM OF HEAD TRAUMA

J. Marks, C. He, E. Legome

Primary Survey and Initial Interventions

- Place patient on monitor, establish 2 large bore IVs
- Ensure ABCs intact
- Determine initial GCS, and call out all three components of the scale
- Intubate if GCS $\leq$ 8 or patient is not protecting airway (eg, gurgling secretion)
- Bolus 1 L IVF or give blood products if hypotension secondary to blood loss
- Avoid permissive hypotension in patients with head trauma.
- EMS handoff information is an integral part of assessing interval changes in GCS and vital signs

TIP

- Remember hypotension does not occur from traumatic intracranial hemorrhage; consider other sources of bleeding if hypotensive

Secondary Survey Unique to Head Trauma

- Head
  - Depressed skull fractures and lacerations
  - CSF leak from ears or nares
  - Signs of basilar skull fractures as evidenced by hemotympanum, Battle's Sign, and raccoon eyes
- Neck
  - Consider cervical spine immobilization if unable to clear with NEXUS or Canadian c-spine rules
- Neurologic
  - Assess for pupillary abnormalities, size and reactivity, this may be the first sign of impending herniation
  - Babinski's sign, posturing, focal neurologic deficits, and dynamic changes in GCS
  - This exam should be repeated over time
- General
  - Obtain collateral information from EMS, family members, medical records, etc.
  - Determine if patient on anticoagulation

Optimizing Cerebral Perfusion

- ICP is increased in head trauma
- Cerebral Perfusion Pressure = MAP minus ICP
- Maintain MAP > 80 throughout ED course to overcome increases in ICP
- Initially use normal saline if no signs of internal or external hemorrhage
- Remember to restrict crystalloids to less than 500 cc if any suspicion of bleeding and resuscitate with blood products to maintain MAP

NEW
ATLS

- Consider vasopressors as second line therapy
- Maintain pulse oximetry of 95%
- If patient is intubated, maintain $PaCO_2$ of 35 by adjusting respiratory rate on ventilator
- Avoid hypotension and hypoxia — a single episode of either increases mortality

Imaging

- *Canadian CT Head Trauma Rule* and PECARN (Pediatric Emergency Care Applied Research Network) can help determine need for brain imaging
- *NEXUS Criteria* and the *Canadian Cervical Spine Rule* can help determine need for cervical spine imaging
- If exam is suspicious for basilar skull fracture, obtain dedicated CT cuts of temporal bone and consider prophylactic antibiotics
- Clinical presentation and physical examination determine need for facial bone and other imaging
- Anticoagulation is increasingly prevalent, particularly among the elderly. Ask specifically about coumadin or DOACs. Remember, most decision rules do not apply to the elderly or those on anticoagulation!

Treatment of Severe Head Injury (GCS 3-8)

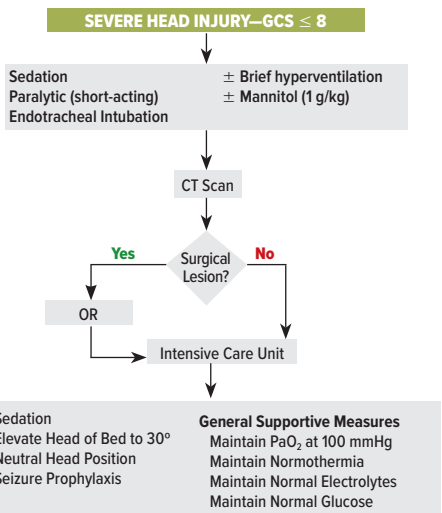
- Immediate neurosurgical consultation
- Airway management
- Reversal of anticoagulation
- Seizure prophylaxis with levetiracetam, phenytoin, or fosphenytoin
- Clinical signs of herniation: bradycardia, hypertension, abnormal respirations
- For patients with clinical or radiographic signs of herniation:
  - Head-of-bed elevated to 30°
  - Mannitol 1 g/kg IV or hypertonic saline 3% 100 mL IV
  - Definitive care: emergent operative intervention
  - Hyperventilate briefly to aim for pCO_2 to 30–35 mmHg in patients with elevated end tidal CO_2

Airway Management

- **Indications for intubation**
  - GCS $\leq$ 8
  - Lack of airway protection (depressed mental status, persistent hypoxia, etc.)
  - Anticipated hospital course requiring intubation
    If a hospital transfer is required, carefully consider the need for intubation prior to transport
- **RSI premedication**
  - Consider fentanyl 3–5 mcg/kg IV bolus for neuroprotection if patient is not hypotensive

- **Induction medications**
  - Propofol
    - Pros: Anti-epileptic properties, easily titratable afterwards
    - Cons: Hypotension, particularly in the elderly
  - Etomidate
    - Commonly used in head trauma because of minimal hemodynamic effects
  - Ketamine
    - No longer thought to decrease cerebral perfusion
    - Consider if patient hypotensive
- Paralytic medications
  - Succinylcholine: short duration of action allowing for prompt repeat neuro exam
  - Rocuronium: often chosen when succinylcholine is contraindicated

Algorithm for Initial Treatment of Severe Head Injury

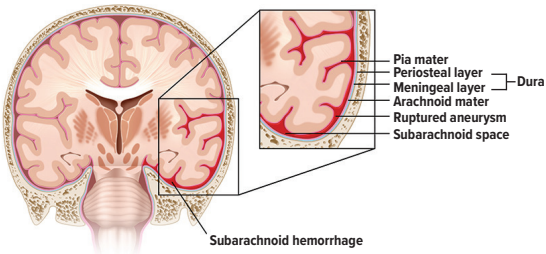


SUBARACHNOID HEMORRHAGE

F. Rusnack, C. He, E. Legome

Definition

- Traumatic subarachnoid hemorrhage (tSAH) is blood accumulation within the CSF and meningeal intima from tearing of small subarachnoid vessels or rupture of hemorrhagic contusions/hematomas into the subarachnoid space.
- Distinguished from non-traumatic SAH, which is usually due to aneurysm or AVM rupture



ED Presentation

- May present after trauma with headache, vomiting, altered mental status, and meningeal signs (neck rigidity, Kernig's sign, Brudzinski's sign)
- Other intra or extracranial injuries may be present; common associated findings include skull fractures, brain contusions, subdural hemorrhage, epidural hematoma

Diagnosis

- On non-contrast CT imaging, subarachnoid hemorrhages appear as increased curvilinear densities within interhemispheric fissures, sulci, and basilar cistern

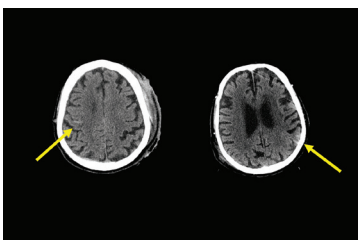


IMAGE COURTESY OF DR. ANDREW SCHWEITZER, WEILL CORNELL DEPARTMENT OF RADIOLOGY

Evaluation

- Rapid non-contrast CTH for patients with high clinical suspicion or who are unable to be excluded using validated guidelines
  - Elderly patients, intoxicated patients and those on anticoagulants generally do not fit into validated guidelines
- Unlike non-traumatic SAH, a negative CT is appropriate to exclude the diagnosis and, due to the underlying etiology, an LP is never required to rule out SAH
- Immediate concerns to address:
  - Hypotension and hypoxia: alone or in combination, associated with significantly worse outcomes secondary to adequate brain perfusion
  - Intubate if patient unable to protect airway, hypoxia, or hypercarbia
  - Give reversal agents if patient is anticoagulated
  - Signs of herniation require alleviation of increased ICP and prompt neurosurgical consultation

Critical Interventions

- Brain Trauma Foundation guidelines commonly accepted as best practices in managing traumatic intracranial injury
- ED management is directed at early diagnosis, preventing hypotension and hypoxia, reversing anticoagulation, and facilitating rapid consultation and OR intervention
- There is no proven medication or specific ED intervention for decreasing mortality; however, in the appropriate patient, certain neurosurgical interventions such as an external ventricular drain to monitor and remove CSF may be useful
- Decompressive craniotomy may be used in certain select circumstances
- Protect the brain from secondary injury
- **Airway**
  - Secure airway early if indicated to avoid aspiration and hypoxia/hypercarbia that can cause secondary brain injury
  - Complete a rapid, detailed neuro exam before sedating or paralyzing
  - Avoid excessive BVM ventilation in the peri or post intubation period
- **Blood Pressure Control**
  - Systemic hypotension can cause significant secondary brain injury and increase mortality. Below targets are considered to decrease mortality and improve outcomes
    - **Target BP for patients 50–69 years old ≥ 100 mmHg**
    - **Target BP for patients 15–49 years old or > 70 years: ≥ 110 mmHg or above**
  - Consider vasopressors if the blood pressure is borderline, especially when intubating

- **Coagulopathy**
  - Provide appropriate reversal agents (see appendix)
  - Consider TXA for moderate injury with intracranial bleeding
- **Seizure Prophylaxis**
  - Post traumatic seizures may lead to worsening hypoxia, hypercarbia, and elevated ICP
  - Administer benzodiazepines for active seizures
  - With phenytoin, fosphenytoin, or levetiracetam: balance with potential adverse effects; no definite indications but more likely to be useful with moderate to severe injury
  - No benefit in preventing long-term seizures, only early post traumatic seizures
- **Elevated Intracranial Pressure**
  - Elevate head of bed to 30° with neck in neutral position
  - Consider administration of osmotic agents such as mannitol or hypertonic saline in discussion with neurosurgery for acute neurological deterioration
    - Mannitol can worsen hypotension and is not as effective in volume depletion; for hypotensive patients, use hypertonic saline instead
  - Hyperventilation generally contraindicated and no longer recommended as a short-term bridging intervention
  - Normocarbia ($PaCO_2 \sim 35$) is preferred to avoid cerebral ischemia
- **Cerebral Vasospasm**
  - Most serious complication of tSAH; can occur 48 hrs to 2 weeks after injury
  - Vasospasm in tSAH has a different time course, duration, and risk factors than aneurysmal SAH and is generally not an immediate concern

Additional Considerations

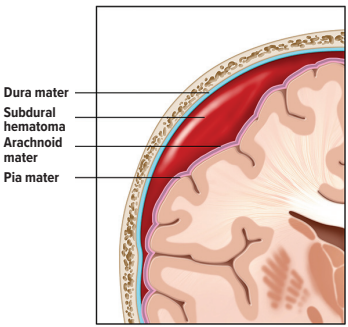
- tSAH is the most common CT scan finding in patients with head trauma
- Patients with minor TBI and isolated subarachnoid generally have good outcomes and may be candidates for short-term observation; all others usually require ICU admission
- Amount of blood within the tSAH directly correlates with patient outcome and is inversely related to presenting GCS

SUBDURAL HEMATOMA

S. Huang, C. He, E. Legome

Definition

- Blood accumulation between dura and arachnoid membranes
- Traumatic subdural hematomas may present after an acute trauma or in a delayed fashion as a chronic collection of blood
- Most commonly caused by tearing of bridging veins, which drain blood from surface of brain to dural sinuses

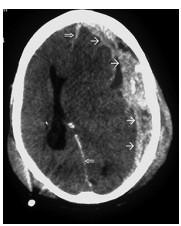


ED Presentation

- Head trauma is most common cause
- Chronic subdural hematomas can present with multiple vague neurological symptoms such as altered mental status, personality changes, nausea and vomiting, seizure, headache, lightheadedness, dizziness
- Chronic subdural hematomas may be precipitated by minor trauma that initially appears insignificant to the patient
- Patients with cerebral atrophy are at higher risk for subdural hematomas (ie, elderly, alcoholics, history of prior head trauma) as are patients using anticoagulants or antiplatelet agents

Diagnosis

- Non-contrast CT head is preferred imaging modality
- Acute subdural hematomas will present as a high density (bright) crescent or contact-lens shaped collection accumulated in the subdural space
- Subacute and chronic subdural hematomas will appear hypodense (dark) as the accumulated blood forms into a clot and degrades
- In contrast to epidural hematomas, subdural hematomas can cross suture lines



LUCIEN MONFILS

TIP

Evaluation

- ABCDEs
- Emergent CT head without contrast for patients with severe head trauma and suspected intracranial hemorrhage/subdural hematoma
- Hold low threshold for CT in high-risk patients such as the elderly or those on anticoagulants; LOC or severe trauma not required
- Use a validated clinical decision instrument, such as Canadian CT Head Rule, to risk stratify the need for imaging in non-high risk patients
- Lab tests including BMP, CBC, T&S, PT/PTT can help guide management; correct electrolyte abnormalities such as hyponatremia
- Monitor for signs of elevated intracranial pressure and herniation and manage appropriately:
  - Cushing's Triad: irregular breathing, hypertension, bradycardia
  - Signs of herniation: Pupil changes ("blown pupil"), focal weakness, posturing, coma
- Drug and alcohol screening may be helpful in correlating clinical exam findings

Critical Interventions

- Early diagnosis with rapid CT imaging
- Prevention of hypotension and hypoxia to avoid secondary injury to the brain
- Reversal of anticoagulation
- Emergent Neurosurgical consultation.
  - Neurosurgical treatment depends on the size of the subdural hematoma and level of neurological impairment
  - Symptomatic subdural hematomas often require neurosurgical drainage either by craniotomy or burr hole.
  - Asymptomatic subdural hematomas may be monitored with serial CT scans.
- Manage elevated intracranial pressure
  - Elevate the head of the bed to 30°
  - Avoid fluid overload
  - Consider mannitol or 3% hypertonic saline may lower ICP

Additional Considerations

- Repeat CT imaging if neurological status changes
- Consider seizure prophylaxis in consultation with neurosurgery/neurology for patients at risk for early post-traumatic seizures with levetiracetam, phenytoin, or fosphenytoin. However early post-traumatic seizures have not been associated with worse outcomes.
- Brain Trauma Foundation guidelines commonly accepted as best practice

EPIDURAL HEMATOMA

R. Renacci, C. He, E. Legome

TIP

Definition

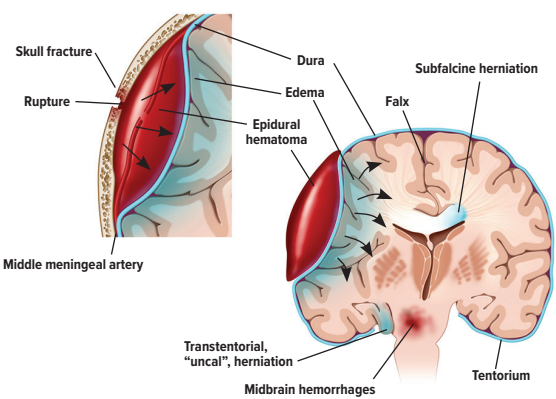
- Blood accumulation in epidural space between calvaria of the skull and outer (periosteal) layer of the dura mater
- Most commonly from a tear of the middle meningeal artery

ED Presentation

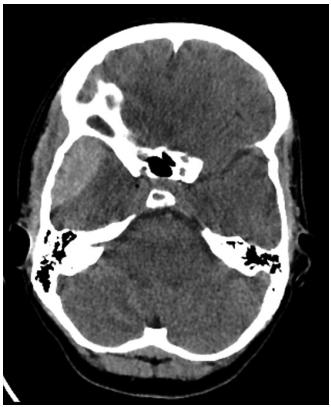
- Common etiology: assault, fall, sports injury, motor vehicle collision
- Patients are more commonly adolescents and young adults
- Classic mechanism is acute blunt trauma to temporal or temporoparietal region of the head adjacent to the middle meningeal artery
  - Presents with brief LOC followed by "lucid interval" as mental status declines
- Can lead to brain herniation and death; treat as true emergency
- Clinical presentation may be variable due to size and progression of lesion and can range from brief loss of consciousness to coma
- A fixed and dilated pupil on the side of the lesion with contralateral hemiparesis is a classic late finding indicating herniation

Diagnosis

- All moderate to severe presentation (GCS < 13) after trauma require urgent head CT



- Use validated decision rules such as the Canadian CT Head Injury/Trauma Rule or New Orleans Criteria to determine need for imaging in minor head trauma
- On non-contrast CT imaging, acute epidural hematomas appear hyperdense and convex or lens shaped because their expansion is limited by the skull's sutures (where the dura mater attaches to the skull).



Epidural hematoma

IMAGE COURTESY OF DR. ANDREW SCHWEITZER/WEILL CORNELL DEPARTMENT OF RADIOLOGY

Evaluation

- Expedite non-contrast CT imaging; neurological outcomes significantly improved with expeditious neurosurgical intervention
- Maintain cervical collar until c-spine injury excluded
- Signs or symptoms of elevated intracranial pressure should prompt rapid neurosurgical evaluation for evacuation
- Symptoms of elevated ICP:
  - TIP Cushing's Triad (decreased respiration, decreased pulse, elevated blood pressure, opposite of what is seen in shock)
  - Worsening headache
  - Nausea/vomiting
  - Lateralizing neurological signs
- Clinical signs of herniation:
  - Ipsilateral third nerve palsy
  - Ipsilateral fixed and dilated pupil
  - Contralateral hemiparesis
  - Contralateral increased deep tendon reflexes
  - Contralateral upgoing Babinski reflexes

Critical Interventions

- Intubate all patients in coma (GCS $\leq$ 8) or if unable to maintain airway
- Maintain oxygenation and avoid hypo- or hyperventilation: aim for pCO_2 of 35–40 mm
- Maintain systolic blood pressure above 100-110 mmHg in patients with severe injury
- Consult neurosurgery expeditiously. Morbidity and mortality significantly increases if treatment delayed > 2 hrs
  - ED burr hole procedure: extremely rare in ED; consider in the herniating patient when no neurosurgeon and rapid transfer is unavailable
- Reverse anticoagulation as soon as feasible and consider treatment of increased intracranial pressure for signs of herniation.
- Manage elevated intracranial pressure
  - Elevate the head of the bed to 30°
  - Avoid fluid overload
  - Consider mannitol or 3% hypertonic saline; may lower ICP

Additional Considerations

- In consultation with neurosurgery, consider antiepileptic drugs for short-term prophylaxis of seizures in the more seriously injured
- Non-operative management is occasionally an option
  - Adult patients with small (< 30 cm^3) hematoma with clot thickness < 15 mm and midline shift <5 mm may be observed
  - Close observation in ICU setting with hourly neuro exams and serial brain imaging given the risk of hematoma enlargement and neurologic deterioration
  - First follow-up head CT at no later than 6–8 hrs after head injury

INTRAPARENCHYMAL HEMATOMA

C. Margus, C. He, E. Legome

Definition

- Hemorrhagic lesion in brain parenchyma; also called IPH
- Intra-axial (or intracerebral) bleed that is distinct from the extra-axial (ie, epidural, subdural, and subarachnoid) hemorrhages that occur within the skull but outside the brain tissue itself

ED Presentation

- Most IPH cases are not due to trauma; trauma may be secondary to spontaneous bleed
  - IPH most commonly occurs spontaneously (78–88% of time), often as a result of uncontrolled hypertension or cerebral amyloid angiopathy
  - Secondary causes include coagulopathy, arteriovenous malformation, aneurysm, cerebral venous thrombosis, vasculitis, tumor, and hemorrhagic conversion of stroke
- Half of IPH patients present with mild head injury (GCS 13–15), 25% with moderate head injury (GCS 9–12, 27%), and remaining 25% with severe head injury (GCS 3–8)
- Include in DDx for all patients suffering TBI, especially with traumatic headache, nausea/vomiting, seizure, altered mental status, or neurological deficit such as arm or leg paralysis, dysphagia, or fixed or anisocoric pupils

Diagnosis

- Main imaging modality is CT brain without contrast, while MRI can be used later in the course to better characterize non traumatic etiologies of bleed
- Can present as solid-type hematomas (30%) or petechial-type contusions (70%)

TIP

IPH type (solid v. petechial) does not correlate with lesion size or progression

Evaluation

- Obtain neurological exam, including GCS and pupillary exam, prior to paralysis and intubation if possible
- Early CT imaging and neurosurgical consultation are paramount, as worsening mental status, hematoma expansion on reimaging, and cistern effacement significantly increase the likelihood of needing surgery
- Indications to involve neurosurgery:
  - Loss of consciousness > 5 min
  - > 30 min of retrograde amnesia
  - GCS < 15 2 hrs after injury
  - Suspected open or depressed skull fracture
  - Basilar skull fracture

- ≥ 2 episodes of vomiting
- ≥ 65 years old
- Anticoagulant use

Critical Interventions

- Avoid hypotension and hypoxia
- Reverse anticoagulation
- Tranexamic acid (TXA) is thought to prevent clot breakdown and hematoma expansion; although controversial, consider in patients with moderate head injury
- Consider seizure prophylaxis in consultation with neurosurgery/neurology for patients at risk for early post-traumatic seizures with levetiracetam, phenytoin, or fosphenytoin. However early post-traumatic seizures have not been associated with worse outcomes
- In the setting of herniation due to mass effect, consider hyperosmolar agents such as IV mannitol (0.5–1 g/kg bolus) or 3% hypertonic saline, while monitoring for evidence of fluid overload or metabolic acidosis
- Manage in ICU, given the need for hourly neurological assessments, close glucose monitoring to avoid both hypoglycemia and hyperglycemia, and blood pressure targeting for those with SBP between 150–200 on presentation to an SBP of 140

Additional Considerations

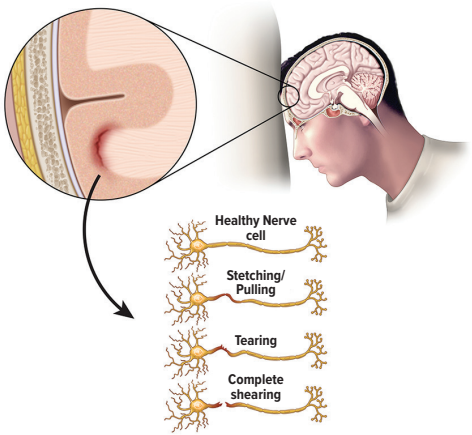
- Likelihood of hematoma expansion has been independently associated with co-existent subarachnoid or subdural hemorrhage and with initial IPH size (odds of progression increase by 11% for each initial cm^3)
- Frequent monitoring of glucose and tight glucose control is of benefit, as both hyperglycemia and hypoglycemia are harmful
  - Previously recommended range of 80–110 mg/dL is in question
- Patients should be kept NPO until formally screened for dysphagia, so as to prevent aspiration

DIFFUSE AXONAL INJURY

D. Weinick, C. He, E. Legome

Definition

- Extensive shearing of white matter axonal tracts, leading to damage at the gray and white matter junction



ED Presentation

- Most common secondary to blunt head injuries, resulting in rapid acceleration and deceleration of the brain
- MVCs are most common cause of DAI, but cases have been documented from falls, assault, and non-accidental trauma (shaken baby syndrome)
- Symptoms can range from mild headache, amnesia and dizziness (mild DAI) to more severe alterations in mental status and low GCS scores (severe DAI)
- Presentation can be complicated by nausea, vomiting, and seizure activity
- It is estimated that DAI occurs in 50% of all comatose patients who have suffered a severe head injury
- DAI affects wide areas of the brain, including cerebral white matter, grey-white matter junction, corpus callosum, dorsal upper brainstem, and cerebellum

TIP

Diagnosis

- Non-contrast head CT
- CT imaging may demonstrate small punctate areas of high density that should increase clinical suspicion for DAI
- MRI is much more sensitive and manifests as scattered small white matter lesions that are often multifocal, in multiple lobes of the brain, and may have a hemorrhagic component
- Can be diagnosed clinically with significantly altered mental status after trauma and normal CT
- Adams Diffuse Axonal Injury Classification helps to differentiate 3 classes

Adams Diffuse Axonal Classifications	
Grade 1 (mild)	Microscopic white matter changes in cerebral cortex, corpus callosum, brainstem
Grade 2 (moderate)	Gross focal lesions in corpus callosum
Grade 3 (severe)	Findings as Grade 2 plus additional focal lesions in brainstem

Evaluation

- Avoid hypotension and hypoxia
- Have a high suspicion for c-spine involvement; DAI occurs with traumatic shearing from rapid changes in acceleration/deceleration
- If CT is normal in head trauma patients with severe altered mental status, assume high-grade DAI, but also consider potential confounders that can decrease mental status (eg, drugs or alcohol).

TIP Repeat imaging may be indicated in 24–48 hrs, as structural changes may take up to 2 days to appear

Critical Interventions

- Early neurosurgical consultation recommended, even in absence of CT findings, in patients with moderate to severe traumatic brain injury (GCS < 13)
- Continuous monitoring may help prevent precipitous change in ICP, which may be difficult to recognize in an already obtunded patient
- Consider seizure prophylaxis in consultation with neurosurgery/neurology for patients at risk for early post-traumatic seizures with levetiracetam, phenytoin, or fosphenytoin

TIP

Additional Considerations

- Follow Brain Trauma Foundation Guidelines for the Management of Severe Traumatic Brain Injuries
- ☛ While associated with poor prognosis, it is difficult to prognosticate early in the ED and should be avoided
- Transient electrolyte derangements, including hyponatremia, may be present with severe DAI due to SIADH and cerebral salt wasting; thought to be caused by damage to the posterior pituitary gland, leading to increased release of vasopressin
- Patients suffering from severe DAI may develop dysautonomia, which may manifest as hyperthermia, tachycardia, diaphoresis, and increased muscle tone
- Patients presenting with headache, nausea, vomiting, and dizziness will likely be treated as concussion but may have subclinical DAI without evidence of severe neurologic dysfunction

mTBI AND CONCUSSION

J. Williams, C. He, E. Legome

TIP

Definition

- Concussions are the most common type of mild traumatic brain injury
  - Usually associated with direct head trauma
  - Any rapid and forceful impact anywhere on the body can potentially lead to a concussion
- Most recent guidelines define mild TBIs as GCS of 13–15 after head injury

ED Presentation

- Most patients commonly report a transient disturbance of baseline cognitive status; may include being in a daze, confusion, dizziness and/or brief LOC
- mTBI does not present with persistent vomiting, focal neuro deficit, or physical signs of skull fracture

Diagnosis

- Orientation questions are commonly asked and important for a general neurological exam but are insufficient in the assessment for concussion
- In addition to basic history and neurological examination, assess for:
  - Disorientation and/or confusion after the event
  - Impaired balance
  - Impaired cognitive function: the patient should be able to perform 3 words recall (after 5 min) or perform serial 7s
  - Slower reaction times often observed within 48 hrs

Evaluation

- CT imaging generally has little role in the evaluation of a concussion given the insult is at a cellular level, though there are clear indications for imaging
- CT imaging should be based on existing, validated decision instruments, such as Canadian Head CT and NEXUS Head CT Rule

Initial Treatment and Patient Education

- In acute concussion, treatment should be symptomatic
  - Pain medication for headache
  - Antiemetics for nausea should be provided
  - "Brain rest" with gradual increase in mental activity as symptoms resolve over time
  - Although the current research is mixed, it is still generally recommended that those affected by a concussion rest after injury
- Providers should make patients aware that post-concussive symptoms (intermittent headaches, dizziness, nausea and mental fog) may persist
- Second-impact Syndrome: brain is at an increased risk of further damage during recovery period, which is why physical and cognitive rest is recommended
- Length of recovery period is unique for each individual and history of previous concussion

ED MANAGEMENT OF SPINAL TRAUMA

R. Abualsaud, J. Truong

Initial management: ATLS primary survey, assess ABCDE

Airway

- Higher levels of c-spine injury are more likely to require early airway management
- Assume difficult airway in patients with neck trauma, prepare all adjuncts
- ☛ Substitute c-collar with manual in-line stabilization for intubation
- Indications for early airway management: stridor, acute respiratory distress, airway obstruction with blood/secretions, expanding neck hematoma, profound shock, subcutaneous emphysema, AMS, tracheal shift

Breathing

- Upper cervical injury and ascending spinal cord edema from caudal lesions can lead to diaphragm paralysis (phrenic nerve C3–5), abdominal breathing, eventually respiratory compromise
- Pneumo and hemothorax present in 20% of penetrating neck trauma; consider portable CXR

Circulation

- Substitute c-collar with manual in-line stabilization, assess penetrating neck traumas and other sources of bleeding, and apply direct pressure for hemostasis
- Shock in patients with spinal trauma is hemorrhagic shock until proven otherwise; treat with blood products. Consider other causes (cardiac injury, tension pneumothorax); consider neurogenic shock in patients refractory to fluid and blood resuscitation
- ☛ **Neurogenic shock** is a distributive shock caused by loss of sympathetic tone and unopposed vagal activity. Clinical triad:
  - Bradycardia: uncommon in trauma; early sign of c-spine injury
    - Treat with atropine, glycopyrrolate
    - Severe cases could require dopamine infusions
  - Hypotension: use fluids, vasopressors to decrease risk of secondary spinal cord ischemia
    - Start with norepinephrine (MAP goal 85–90)
    - Phenylephrine can cause reflex bradycardia; use as adjunct
    - Refractory cases may require epinephrine, vasopressin infusions
  - Peripheral vasodilatation
    - Corticosteroid use is controversial, do not administer without consulting neurosurgery or spine specialists.

☛ TIP

Disability and Exposure

- Assess level of alertness
- Check finger stick glucose
- Substitute c-collar with manual in-line stabilization and assess for penetrating injuries and neck trauma
- Consider checking for rectal tone and saddle anesthesia to evaluate for spinal injury

Evaluation

- Cervical Spine
  - Can be cleared using NEXUS criteria
  - Use NEXUS or Canadian c-spine Rule (CCR) to evaluate need for CT scan in alert patients
  - Obtain CT imaging to evaluate for c-spine fractures
  - Ensure patient is hemodynamically stable before CT
  - In obtunded, high-risk patients, consider MRI (more sensitive for ligamentous injury) and neurosurgical consult
  - Associated complications: increased ICP, pressure ulcers, difficult airway, trouble assessing other injuries, pain, agitation

NEXUS C-Spine Criteria
Absence of midline tenderness
Absence of focal neurologic deficits
Normal alertness and consciousness
No evidence of intoxication
Absence of painful or distracting injury

Canadian C-Spine Rule Risk Factors for Imaging	
High Risk	**Low Risk**
Age ≥ 65	Simple rear-end MVC
Paresthesia in extremities	Patient able to set up in ED
Dangerous mechanism: fall > 3 ft, axial loading, high-speed MVC, rollover, ejection, bicycle or motorized recreational vehicle collision	Ambulatory at any time
	Delayed-onset neck pain
	No midline cervical tenderness
	Can actively rotate neck 45° left and right

- TLS Spine
  - Use proper log rolling technique
    - One person stabilizes the neck
    - Two people cross arms at patient's hip to maintain spinal alignment as patient is rotated
  - Evaluate thoracolumbar and sacral spine with midline spinal palpation
  - CT image any midline tenderness, step-offs, or obvious deformities

Management

- Based on type of injury, consult with neuro or ortho surgery
- Maintain immobilization to avoid secondary injury
- Maintain hemodynamics to ensure perfusion

C1 (ATLAS) FRACTURE

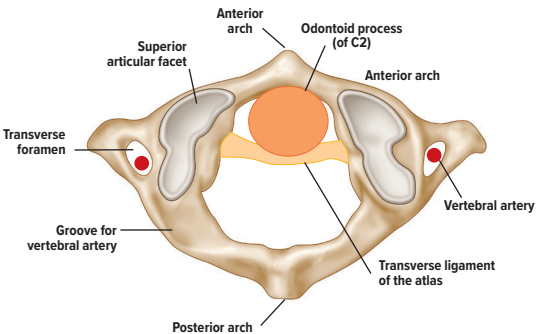
J. Alvelo, J. Truong

ED Presentation

Pain in upper cervical spine with history of trauma such as diving head-first into shallow water or MVC

Relevant Anatomy

- C1 lacks a vertebral body
- Consists of anterior and posterior arch surrounding spinal cord
- Vertebral arteries travel through transverse foramina of the atlas

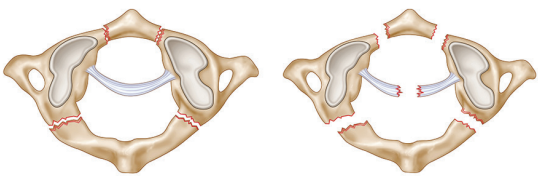


Classification of Unstable Fractures by Mechanism

- Flexion
  - — Atlanto-occipital or atlantoaxial joint dislocation with or without associated fracture
  - — Unstable because of the location and relative lack of muscle and ligament support
- Flexion-rotational
  - — Rotary atlanto-occipital dislocation
  - — Best visualized with open-mouth odontoid films
- Extension
  - — Posterior neural arch fracture
    - Potentially unstable because of location
    - Compression of posterior elements between occiput and C2 spinous process
  - — Hangman's Fracture

- Vertical Compression
  - — Jefferson (burst) fracture
  - — Vertical compression when occipital condyles are forced down into the lateral masses of C1⇢lateral masses are displaced outward⇢anterior and posterior arches are fractured and the transverse ligament is disrupted
  - ☛ Often associated with prevertebral hemorrhage and retropharyngeal swelling
  - — Identified on open-mouth odontoid film
  - — Sum of offset distance from displaced lateral masses of C1 to C2 is > 6.9 mm

☛ TIP



Jefferson Fracture

Imaging

- Plain films limited in evaluating c-spine, particularly at craniocervical junction
- Very high-risk patients require CT

Treatment

- No universally accepted treatment standards
- Majority of cases — maintain in hard collar until neurosurgical consult
- Surgical intervention rarely needed; indications for surgery are:
  - — Fracture associated with atlanto-occipital instability
  - — Transverse ligament rupture
  - — Unstable atlas fracture

Additional Considerations

- Concurrent cervical fractures are common; if identified on plain film, CT entire c-spine
- ☛ Per Denver Blunt Cerebrovascular Vascular Injury criteria, c-spine fractures, subluxation or ligamentous injury at any level are associated with vertebral artery injury, therefore CT angiography should be obtained
- C1 fractures less likely to cause neurological deficits

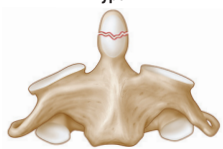
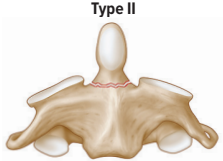
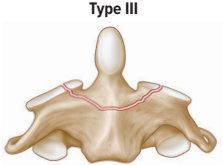
DENS/ODONTOID FRACTURE

J. Gallien, J. Truong

Relevant Anatomy

- C2, the axis, has an odontoid process, commonly referred to as the dens
- The dens allows C1 to articulate and pivot around the odontoid process

Classification of Fracture by Location
(Based on Anderson & D'Alonzo Classification)

Fracture Type	Description	Stable vs. Unstable
Type I 	Oblique fracture through the upper part/ tip of the dens	Stable
Type II 	Usually a transverse fracture through juncture of the base of the dens and axis body	Unstable
Type III 	Fracture through the body of the axis	Unstable

*Lower union rate (healing) with nonoperative management; thought to be secondary to bone surface area and healing time required.

Evaluation

- NEXUS Criteria and Canadian C-Spine Rule

Imaging

- Radiographs, CT scan, MRI
  - X-rays: quick screening but highest false-negative rate
    - AP, Lateral, and open-mouth odontoid views
  - CT scan: most common test for cervical injury and accurate for detecting bony abnormalities
  - MRI: Best diagnostic test, especially for ligamentous or spinal cord injury

Open-mouth odontoid view

IMAGE COURTESY OF DR. ANDREW SCHWEITZER/WEILL CORNELL DEPARTMENT OF RADIOLOGY

Treatment

- Type I: usually conservative management with rigid hard collar for 6–12 weeks; follow-up with spine specialist
- Type II: Halo vest immobilization vs surgical repair
- Type III: Usually halo immobilization, surgery if non-healing

Additional Considerations

- Prehospital management including assessment of ABC's, maintaining in line neutralization of head and cervical spine, with C-Collar if available, and monitoring of neurological status.
- Continuous monitoring of airway as injury of cervical spine particularly above level C3 can be life threatening
- Early consultation of neurosurgical service is advised
- Knowing which fractures are stable (Type I) vs. unstable (Types II & III)

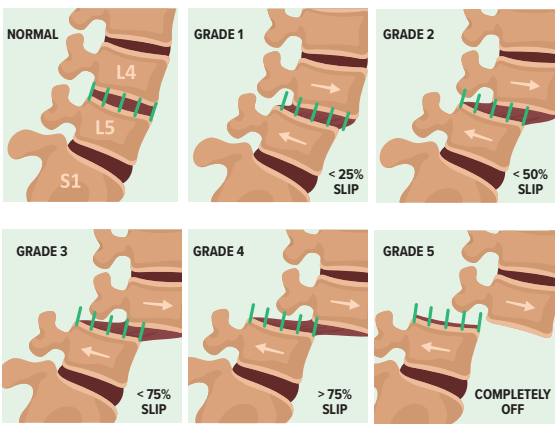
SPONDYLOLISTHESIS

D. Okeke, J. Truong

Definition

- Vertebral bodies slip forward or backward in relation to the vertebrae beneath
- Grade of displacement 1–4, Grade 4 most severe
- Most commonly seen with L5 slipping over S1
- Patients can be asymptomatic
- Symptoms include pain with exertion/walking, gait abnormalities, radiculopathic pain or urinary incontinence

SPONDYLOLISTHESIS GRADES



Etiology/Risk Factors

- Congenital malformations such as dysplasia or hypoplasia of spinal joints such as lumbosacral joints in L5/S1
- Repetitive hyperextension and rotation movements (gymnastics, swimming, weightlifting)
- Degenerative diseases such as osteoarthritis
- Disease processes (Paget's disease, osteogenesis imperfecta, malignancy/tumor)

Clinical Features

- Back pain at level of injury in > 80%
- 50% present with neurologic deficits
- Hangman's fracture is a type of spondylolisthesis
- Many patients have associated spinal fractures

Physical Exam

- Characteristic "step off sign:" palpable bony ligament at area of slippage
- Can present with lower extremity weakness and positive straight leg raise with reduced sensation and reflexes

Imaging

- X-ray
  - Useful in evaluating vertebral structures and degree/severity of slip/subluxation
  - Limited in evaluating for ligament and cord injury
- CT scan without contrast
  - Preferred modality in trauma patient with suspected injury
  - More likely to identify bony injury compared to plain film
  - Limited in evaluating for ligament or cord injury
- MRI
  - Gold standard for evaluation of ligaments, spinal cord and nerve roots
  - Can assess vascular integrity
- CT myelogram: option if MRI contraindicated

Treatment

- Conservative
  - Indicated if < 50% of slip/low grade spondylolisthesis (Grade 1 or 2) with no neurological deficits
  - Main goal: alleviate pain and increase mobility and function
  - Regimens include activity modification, physical therapy, lifestyle management, NSAIDS, epidural steroid injections
- Surgical
  - Indicated if > 50% of slippage (Grade 3 or 4), neurologic deficits, traumatic spondylolisthesis or if symptoms progress despite conservative treatment
  - Anterior/posterior/transforaminal lumbar interbody fusion
  - Spinal decompression

TEARDROP FRACTURE

V.K. Sharma, J. Truong

Definition

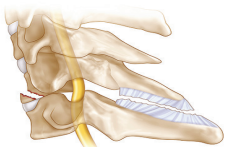
- Most commonly occurs with flexion of spine (but can occur with extension) along with vertical axial compression
- Fracture of anteroinferior aspect of the vertebral body
- Fragment is displaced anteriorly and resembles a teardrop

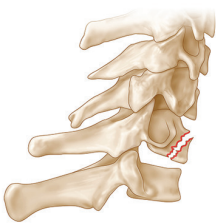
ED Presentation

- Cervical spine pain as a result of acute flexion or hyperextension.
- Patients are present after significant mechanism

Classification by Mechanism

- Flexion Teardrop
  - Unstable fracture
  - Severe flexion force and vertical axial compression like shallow pool diving and/or motor vehicle deceleration crashes
  - Disruption of anterior longitudinal ligament and posterior longitudinal ligament
  - Fracture fragment larger compared to extension injury
- Extension Teardrop
  - Unstable in extension, stable in flexion
  - Abrupt hyperextension leading to tension being placed on the anterior longitudinal ligament causing it to pull the anterior inferior fragment away from the vertebral body.
  - The height of the avulsed aspect usually exceeds its width





Imaging

- X-ray
  - Rarely performed; largely replaced with CT
- CT
  - Preferred initial imaging modality
  - Flexion teardrop fracture commonly at the level of C4–7 (C5–6 being the most common levels)
  - Extension teardrop more commonly seen in older patient with osteoporosis, typically occurring at the level of C2–3
- MRI
  - Given high association with ligamentous injury, MRI is warranted if teardrop identified on CT, especially if neurologic deficits are present

Management

- Cervical spine immobilization
- TIP Flexion injuries: more unstable and may have associated injuries, including anterior cord syndrome
- TIP Extension injuries: more stable but can be potentially unstable if injury occurs at lower levels (typically C5 to 7) as it may cause buckling of the ligamentum flavum into the cord resulting in *central cord syndrome*
- Definitive treatment may be surgical therefore consultation with spine specialist is recommended

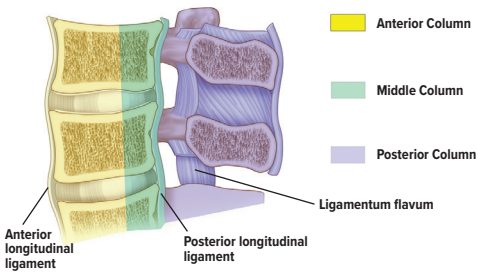
THORACIC/LUMBAR/SACRAL TRAUMA

D. Mishra, J. Truong

TIP

Background

- The human spine consists of 33 bony vertebrae — 7 cervical, 12 thoracic, 5 lumbar, 5 sacral (fused into one), and 4 coccygeal (usually fused into one)
- Spine is divided into three columns and contained within strong ligaments
  - — Usually stable when only one column involved
  - — Potentially unstable with 2 or 3 columns involved
  - ☛ Posterior ligament complex integrity is a critical predictor of spinal fracture stability



Injuries

Name	Mechanism	Description	Other
Wedge Fracture Stable 	Flexion	Force on anterior portion of the vertebral body leads to collapse	Stable unless posterior column is involved, multiple adjacent wedge fx, or loss of anterior vertebral height to > 50%
Teardrop Fracture Unstable 	Flexion	Get anterior displacement of a teardrop fragment of the anteroinferior portion of involved vertebra	Anterior and posterior ligaments are interrupted

Name	Mechanism	Description	Other
Bilateral facet Dislocation Unstable 	Flexion/ Rotation	Leads to anterior displacement of spine above level of injury	Anterior and posterior ligaments are usually interrupted — unstable fx
Unilateral facet Dislocation Stable	Flexion/ Rotation	Facet joint dislocates and the superior facet comes and rests within the intravertebral foramen — can lead to spinal injury	Rare. Typically see Bilateral Facet Dislocation in Thoracic and Lumbar region
Chance Fracture Unstable 	Flexion/ Distraction	Horizontal fx thru the vertebral	Can involve bones and/ or ligaments — called a bony chance fx when just involves bones 50% incidence of gastrointestinal injury/ileus Posterior only sometimes involved — if so, then see neurological issues
Burst Fracture Unstable 	Axial (Vertical Compression)	Comminuted fx of the vertebral body	
Transverse Process/Spinous Process Fractures Stable	Direct trauma to those areas		Always look for other injuries in surrounding areas Usually not associated with neurological injury

Imaging

- X-ray (rarely performed in major trauma)
  - AP view shows widening of pedicles as well as any coronal deformities
  - Lateral view shows retropulsion of bone into the canal and kyphotic deformity
  - Can see fracture type, pattern, and dislocation
  - Limitations: Subtle fractures are missed on x-ray and if suspicion is high based on mechanism, CT imaging preferred
- CT without contrast
  - Ideal imaging modality
  - Able to demonstrate fracture type and pattern as well as able to detect unilateral facet dislocations
  - Limitations: cannot identify soft tissue, ligamentous and spinal cord injuries as well as MRI
- MRI
  - Ideal for detection of ligamentous, soft tissue, and spinal cord injury
  - Important in assessing integrity of posterior ligaments
  - Gold standard in diagnosis of cauda equina or cord compression

Treatments

- Transverse process or spinal process injuries, as well as stable wedge fractures, are managed conservatively. Most all else will require spinal immobilization (especially when concerned for unstable fracture)
- Overall, most patients with TLS injuries are hospitalized given necessity to rule out other injuries, necessity to rule out other injuries, pain control and physical therapy
- Orthopedics uses the Thoracolumbar Injury Classification and Severity (TLICS) Score to determine conservative vs surgical management. Below findings typically necessitate surgical management:
- Focal neurological deficits (loss of sensation to extremities, weakness to extremities)
  - Saddle anesthesia
  - Urinary or fecal incontinence
  - Known/suspicion for unstable fracture
- Further treatment options in consultation with orthopedic or spine service.

Additional Considerations

- Reasons TLS injuries can be devastating
  - Precarious blood supply of anterior spinal artery creates a vascular watershed area resulting in cord ischemia when compromised
  - Narrowing of the canal in these areas
  - Instability at thoracolumbar junction: thoracic joints are limited in rotary range of motion while lumbar joints are mobile in flexion, extension, and rotational planes resulting in laxity at the interface
- Injuries below L2 have a better prognosis because spinal cord terminates at L1–L2 level; likely only nerve roots involved in these injuries

CORD SYNDROMES

L. Hartofilis, J. Truong

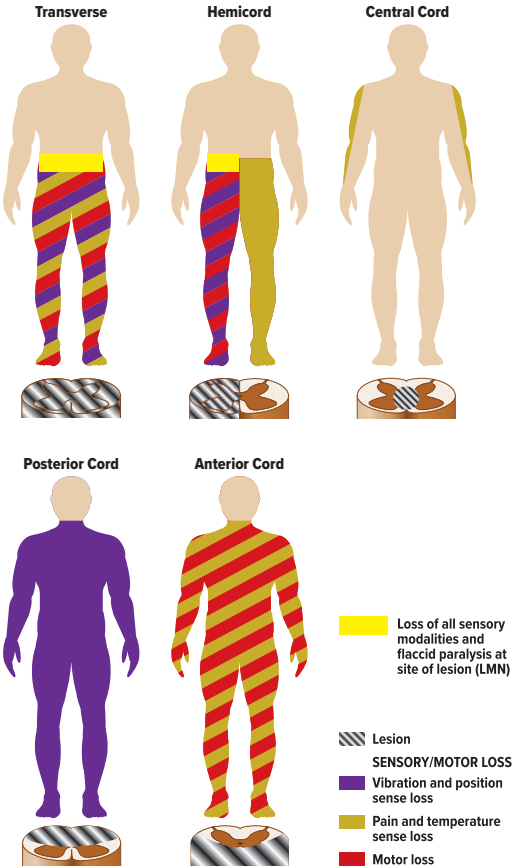
Definition

- *Complete spinal cord transection injury*: complete transection of spinal cord, below which all neurologic function ceases
- *Incomplete spinal cord injury*
  - Central cord syndrome
    - Central spinal cord injury secondary to *hyperextension* injuries
    - Most often in patients with degenerative arthritis, stenosis or spondylosis
  - Anterior cord syndrome
    - Direct anterior cord or anterior spinal artery compression secondary to *hyperflexion*, laceration of spinal artery, compression of the anterior cord from burst fracture fragments
    - Non traumatic causes: thrombosis of anterior spinal artery
  - Brown-Sequard syndrome
    - *Hemisection* of the cord
    - Most often in penetrating trauma or compression from a lateral fracture
  - Spinal cord injury without radiographic abnormality (SCIWRA)
    - Spinal cord injury seen on MRI but not on CT or xray
    - There is no associated fracture or subluxation
    - Typically seen in the pediatric population
- Shock Associated with Spinal Cord Injury
  - Spinal shock
    - Transient total neurologic dysfunction below the injured spinal level
    - Typically due to edema around the cord that persists days to weeks
  - Neurogenic shock
    - Distributive shock from disruption of autonomic pathways
    - Characterized by low blood pressure and bradycardia

ED Presentation

- Patients may present in shock
  - Spinal shock
    - Areflexia with flaccid paralysis
    - Loss of sensation distal to the injury site
    - Can last days to weeks
  - Neurogenic shock: A type of distributive shock, causing hypotension, bradycardia and hypothermia
- Detailed exam will help identify the type of incomplete cord syndrome
  - Complete spinal cord transection injury
    - Complete loss of sensory, motor and autonomic function distal to a certain spinal level.
    - Can only be assessed after resolution of spinal shock
    - The higher the transection, the worse the dysregulation

Cord Syndromes



- Central cord syndrome
  - Loss of motor strength: upper extremities weaker than lower extremities(spinothalamic tract), distal weaker than proximal (spinothalamic tract)
  - Varying degrees of sensory loss (spinothalamic tract and dorsal columns)
- Anterior cord syndrome
  - Paraplegia (spinothalamic tract)
  - Loss of pain and temperature (spinothalamic tract)
  - Preservation of position and vibration sense (dorsal columns)
- Brown-Sequard syndrome
  - Ipsilateral spastic paralysis (corticospinal tract)
  - Loss of position sense (dorsal column)
  - Contralateral loss of pain and temperature 1–2 levels below the level of the injury (spinothalamic tract)

Evaluation & Critical Interventions

- Maintain c-spine immobilization
- Ensure airway protection
  - The phrenic nerve roots, C3–C5, keep the diaphragm alive, injury at this level can severe compromise respiratory drive
  - Intubate if GCS $\leq$ 8
  - The number one cause of mortality and morbidity in these injuries is respiratory insufficiency.
- Hemodynamic support
  - IV fluid resuscitation to attain euvolemia
  - Consider blood products in the setting of hemorrhagic shock
  - Hypotension despite fluid resuscitation
    - Utilize vasopressors (dopamine, norepinephrine and phenylephrine are all options to consider with trauma surgery and neurosurgery)
    - MAP goal in cervical spine injuries is 85–90 mmHg
  - Hypotension leads to worse outcomes and causes secondary hypoperfusion injuries.
- Imaging
  - CT
    - Obtain expeditiously to assess for fracture or subluxation (captures 97% of fractures)
    - If c-spine fracture identified at any level obtain CTA as associated vascular injuries are common (per Denver Blunt Cerebrovascular Injury criteria)
  - MRI
    - Consider this if CT is negative but the neurologic exam remains abnormal
    - Can identify ligamentous injury, incomplete cord injury or SCIWRA

- Consultations
  - Neurosurgery (or transfer to spine specialist if unavailable)
  - Neurology in addition to neurosurgery, particularly if surgery is not warranted based on radiologic findings

Additional Considerations

- Spinal cord injury without radiographic abnormality (SCIWRA) can present with any constellation of neurologic symptoms caused by an injury to the spinal cord other than by an osseous or ligamentous injury
- Steroids as an intervention in cord injuries remains controversial and is not recommended by the Congress of Neurological Surgeons and Trauma Societies.

ED MANAGEMENT OF NECK TRAUMA

M. Robak, A. Tse Tanzillo

Overview

- ED management of neck trauma can be subdivided by mechanism of injury, area of injury (zones), or structures damaged
- Regardless of the complexities, the primary tenets of managing the ABCs and classifying patients as stable or unstable predominate

Initial Management

- **Airway**
  - Must be controlled early as anatomic distortion or blood can lead to rapid deterioration and inability to intubate
  - Concerning features in patients with airway compromise
    - Shock
    - Obvious airway obstruction
    - Stridor, respiratory distress
    - Impending loss of the airway including hard and soft signs of injury (see table below)
    - Altered mental status
    - GCS $\leq$ 8
  - Assume difficult airway
    - Assess ability to perform bag-valve mask ventilation prior to RSI and consider awake intubation if unable to bag
      - ♦ BVM may be hazardous as it can force air into tissue planes distorting anatomy or possibly cause an air embolism
    - Consider 1 attempt at orotracheal intubation by the most experienced provider with low threshold to transition to cricothyrotomy if failed attempt
      - ♦ Videolaryngoscopy (eg, Glidescope, CMAC) may have higher first pass success than direct laryngoscopy
      - ♦ Relative contraindications to cricothyrotomy: tracheal transection, laryngeal fracture, retraction of trachea into mediastinum
    - Awake fiberoptic intubation when possible with a sedative but no paralytic
- **Breathing**
  - Lung apices lie above the clavicles therefore pneumothorax and hemothorax are very possible with penetrating neck trauma
  - Evaluate for pneumo- or hemothorax in patients with unilateral breath sounds, hypotension, or respiratory distress
- **Circulation**
  - Hemorrhage control
    - Direct pressure +/- hemostatic gauze (avoid pressure on bilateral carotids)

        - Consider tamponading bleeding vessel with inflated foley balloon in neck laceration; avoid blindly clamping vessels due to risk of cerebral ischemia or nerve injury
    - Neck wounds should never be explored in the ED
- **Disability**
    - Calculate GCS
    - Consider removal of cervical collar as it may obscure injuries and impede airway control; Eastern Association for the Surgery of Trauma (EAST) Guidelines (supported by meta-analysis) recommend no cervical collar placement if alert with no neurologic deficits
    - Only place c-collar on patients with neurological deficits or altered mental status among patients with concerning mechanism (blunt trauma or polytrauma)
    - Always check for wounds, vascular thrills or bruits, and/or hematomas

Anatomy

- Sternocleidomastoid muscle separates neck into triangles
    - Posterior triangle: anterior edge of trapezius muscle, posterior surface of sternocleidomastoid muscle, and middle third of clavicle
    - Anterior triangle: borders of sternocleidomastoid, inferior mandible, midline of neck
- Can also be described by zones
    - Zone I: from clavicles to cricoid cartilage
    - Zone II: from cricoid cartilage to angle of mandible (most commonly injured)
    - Zone III: from the angle of mandible to base of skull
- Platysma: thin muscle extending from upper chest to lower facial muscles; lies just below skin and superficial fascia. Penetration of platysma raises concern for involvement of deep structures.

Mechanisms of Injury (see following sections for further detail)

- **Penetrating**
    - Penetrating neck trauma comprises only 1% of overall trauma presentations but accounts for 5–10% of mortality
    - Vascular injury is the leading cause of death from penetrating neck trauma
    - ~25% penetrating injuries require operative intervention
    - Penetrating neck injuries presenting to medical centers where surgical consultation is not available should be transferred after stabilization
- **Blunt**
    - Blunt neck trauma comprises 5% of all neck trauma
    - Vascular injury is rare but should be considered with cervical hyperextension and rotation mechanisms, or hyperextension during rapid deceleration. Types of vascular injury include: intimal dissections, thrombosis, pseudoaneurysms, fistulas, transections

- Mortality due to loss of airway more so than hemorrhage
- CTA has low sensitivity but high specificity for blunt cerebrovascular injury (BCVI)
  - First line treatment for BCVI is often anticoagulation to prevent thrombosis

- **Strangulation/Hanging**
  - Death typically occurs from cerebral anoxia/ischemia
  - Venous return obstruction leads to vascular congestion, edema and loss of consciousness
  - Difficult to predict future neurologic function: some have poor initial neuro exam and recover, others appear stable then decompensate
  - Consider intimate partner violence

Types of Injuries (see following sections for further detail)

- **Laryngotracheal**
  - Presentation: massive subcutaneous air and crepitus over the larynx is a sign of laryngotracheal injury until proven otherwise
  - Hard signs of laryngotracheal injury: stridor, hemoptysis, dysphonia, air or bubbling in wound, airway obstruction
  - Soft signs of laryngotracheal injury: hoarseness, neck tenderness, subcutaneous emphysema, cervical ecchymosis or hematoma, tracheal deviation or cartilaginous step-off, laryngeal edema or hematoma, restricted vocal cord mobility
  - Diagnosis: CTA, laryngoscopy
  - Priority: airway control
- **Vascular**
  - Hard signs for vascular injury: shock unresponsive to initial fluid therapy, active arterial/pulsatile bleeding, pulse deficit, expanding hematoma, thrill or bruit
  - Soft signs for vascular injury: undifferentiated hypotension, nonpulsatile or nonexpanding hematoma, injury with close proximity to major vessels
  - Diagnosis: CTA
  - Penetrating injury: management commonly surgical
  - Blunt injury: anticoagulation (see above), surgical, observation
  - Carotid artery injury leads to stroke in 15% of patients, death in 22%
- **Pharyngoesophageal**
  - Most missed injury!
  - Presentation is more subtle, leading to possible diagnostic delays
  - Soft signs: odynophagia, subcutaneous emphysema, dysphagia, hematemesis, oral blood, saliva draining from wound, severe neck tenderness, prevertebral air, transmidline trajectory
  - Death from mediastinitis/sepsis secondary to anatomic connection to mediastinum

- Diagnosis: CT (prevertebral air suggests pharyngoesophageal injury but can be missed), Esophagoscopy/esophagram
- Treatment: early IV antibiotics, parenteral/enteral nutrition
  - Pharyngeal perforations > 2 cm and esophageal perforations require surgical repair

- **Nervous system**
  - Brachial plexus injury
  - Spinal cord injury
  - Phrenic nerve injury (leading to diaphragmatic paralysis)
  - Recurrent laryngeal nerve injury (leading to vocal cord paralysis and hoarseness)

Physical Examination

Hard Signs	Soft Signs
Rapidly expanding or pulsatile hematoma	Minor hemoptysis
Massive hemoptysis	Hematemesis
Air bubbling from wound	Dysphonia, dysphagia
Severe hemorrhage	Subcutaneous or mediastinal air
Shock not responsive to fluids	Non-expanding hematoma
Decreased or absent radial pulse	Oropharyngeal bleeding
Vascular bruit or thrill	Neurologic findings
Stridor/hoarseness or airway compromise	Proximity wound
Cerebral ischemia	
+/- Massive subcutaneous emphysema	

- Ask patient to:
  - Cough: checks for hemoptysis
  - Swallow saliva: checks for dysphagia/esophageal injury
  - Speak: checks for laryngeal injury

Zone vs. No-Zone Approach

- Approach is institution and provider specific; however, prevailing protocol is the no-zone approach to penetrating neck trauma
  - Presence of hard signs or hemodynamic instability requires OR exploration
  - All other patients (regardless of zone) are evaluated with CTA
    - Zone approach challenging because of unpredictable trajectory of penetrating object

ED Workflow No-Zone Strategy

- ABCs
- Hemodynamics
  - Unstable: resuscitate as is feasible, then straight to OR
  - Stable: check for hard/soft signs
    - Hard signs → OR
    - Soft signs → CTA followed by scopes, esophagram, etc as appropriate
    - Asymptomatic: imaging vs. observation based on physician judgment

☛ CTA 100% sensitive and 97.5% specific in detecting all clinically significant injuries

ED Workflow Zone-Based Strategy

- ABCs
- Hemodynamics
  - Unstable: resuscitate as is feasible, then straight to OR
  - Stable: identify zone of injury
    - Zones I and III: angiography and/ or endoscopy
    - Zone II: historically, all zone II injuries violating platysma were surgically explored, now selective based on symptoms and imaging

☛ TIP

Special Considerations

- Pediatrics
  - Larynx is higher, more protected, and more flexible, so less likely to be injured
  - Smaller diameter trachea and mucosa is looser therefore edema/ hematoma progresses to airway compromise more rapidly

Disposition

- Most patients admitted to monitored setting; asymptomatic patients monitored before discharge
- Social work and/or psychiatry for patients in whom you suspect suicide risk or domestic violence

PENETRATING NECK TRAUMA

M. Castro, A. Tse Tanzillo

NEW

General

- Only 1% of overall trauma presentations but accounts for 5–10% of mortality
- Presentations include airway obstruction, hemorrhagic shock, vascular, or neurologic injury due to the number of important structures in the neck
- Physical exam is vital for diagnosis and management
- Serious injuries may not be initially obvious making diagnosis and management challenging
- Vascular injuries are the most common cause of death (80%) from penetrating neck trauma

Ask EMS if there was significant blood loss in the field

Anatomic Considerations

- See ED Management of Neck Trauma
- Platysma: thin muscle extending from lower mandible to upper chest; lies between skin/ superficial fascia and deep cervical fascia
  - Penetration of platysma raises concern for involvement of deep structures
  - Penetrating wounds that do not pierce through the platysma are not life threatening
- Fascial planes of the neck
  - Deep vs. superficial wounds: demarcated by penetration of the platysma (though this is rarely obvious on gross examination in the ED)
  - Fascial layers keep neck structures compartmentalized and aid to enclose hematomas
  - Fascial layers can also endure pressure from expanding edema/ hematoma compromising surrounding structures such as the airway

Clinical Features of Specific Injuries

Hard Signs	Soft Signs
Rapidly expanding or pulsatile hematoma	Minor hemoptysis
Massive hemoptysis	Hematemesis
Air bubbling from wound	Dysphonia, dysphagia
Severe hemorrhage	Subcutaneous or mediastinal air
Shock not responsive to fluids	Non-expanding hematoma
Decreased or absent radial pulse	Oropharyngeal bleeding
Vascular bruit or thrill	Neurologic findings
Stridor/hoarseness or airway compromise	Proximity wound
Cerebral ischemia	
+/- Massive subcutaneous emphysema	

ADAPTED FROM ROSEN'S 2018

- **Vascular Injury**
  - Most common cervical injury in penetrating trauma
  - Types of injuries: extravasation, occlusion, dissection, AV fistula, and pseudoaneurysm formation
  - Signs of injury: shock, severe hemorrhage, global or focal neurologic deficits, expanding hematoma, bruits/thrills, and decreased or absent peripheral pulses
  - Progressive or delayed-onset neurologic deficits should prompt evaluation for carotid artery dissection
- **Laryngotracheal Injury**
  - Signs of injury: airway compromise, stridor or hoarseness, dysphonia or odynophagia, anterior neck tenderness, subcutaneous air, hemoptysis
- **Pharyngoesophageal Injury**
  - Esophageal injuries are rare; diagnosis is vital due to high morbidity and mortality
  - Signs of injury: hematemesis, dysphagia, subcutaneous emphysema, hoarseness
  - Orogastric tracking into mediastinum can lead to inflammation, abscess and mediastinitis from bacterial contamination
  - 50% of patients will have concurrent laryngotracheal injury

Evaluation

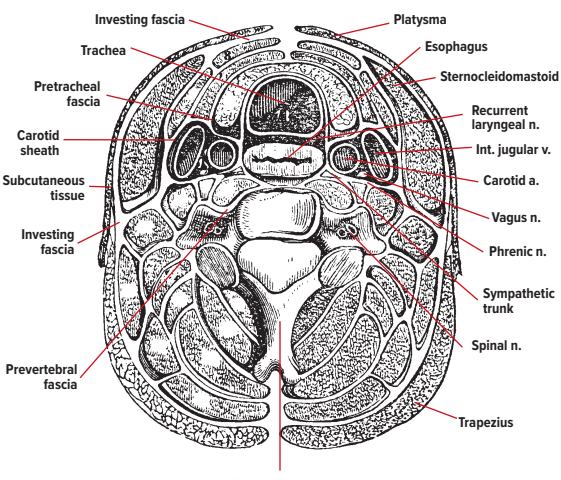
- **Airway**
  - Immediate airway control is prudent if patient presents in shock, with signs of airway obstruction, impending airway collapse, or with altered mental status
  - Preferred modality to secure airway is orotracheal intubation with RSI; however, if anatomy is distorted, consider fiberoptic laryngoscopy
  - Minimize bag-mask ventilation as it can cause airway distortion and massive subcutaneous emphysema
  - If endotracheal intubation is not possible, prepare for cricothyrotomy
  - Blind nasotracheal intubation is contraindicated
- **Breathing**
  - Zone I injury: assess for pneumothorax or hemothorax with chest x-ray and/or sonography
  - Continuous pulse oximetry and supplemental oxygen
- **Circulation**
  - Apply sufficient direct pressure to control hemorrhage
  - Avoid probing wounds as it could dislodge a clot or create new injury resulting in massive hemorrhage
  - Do not blindly clamp vessels to avoid inadvertently causing nerve injury or cerebral ischemia as the anatomy of the anterior neck is very complex
  - If direct pressure fails, insert 16- or 18-French foley catheter into wound tract; inflate balloon until bleeding stops or until there is resistance

- **Disability**
  - Cervical collar/immobilization is not necessary in patients with isolated penetrating injury without neurologic deficit
  - Prioritize airway control, monitoring and visualization of injury and life-saving procedures
  - Place cervical collar on patients neurologic deficits or significant mechanisms
- **Vascular Injury**
  - First line imaging modality: multidetector CTA
    - Also images aerodigestive tracts and C-spine (unlike angiography)
  - Previous gold standard: catheter angiography (diagnostic and therapeutic)
    - Angiography is invasive, expensive, resource-intensive, and carries a high contrast load
- **Laryngotracheal Injury**
  - Multidetector CTA
    - Obtain 1-mm cuts of larynx and perform multiplanar reconstructions
  - Flexible Fiberoptic Laryngoscopy
    - Assesses airway patency and extent of intraluminal injury
  - Plain films of neck and chest
    - Poor sensitivity for penetrating neck trauma injuries
    - Can show extraluminal air, fracture or disruption of cartilaginous (eg, larynx) structures
- **Pharyngoesophageal Injury**
  - Contrast esophagography (90% sensitivity) with water soluble contrast (eg, Gastrografin)
  - If negative contrast esophagography, obtain flexible endoscopy (most sensitive)
    - Combination of contrast esophagography + esophagoscopy has sensitivity close to 100%
  - Plain films of neck and chest
    - Findings such as pneumomediastinum, hydrothorax, or retropharyngeal air may suggest perforation but are not sensitive

Management

- **No Zone Approach (see algorithm)**
  - If hemodynamically unstable or with hard signs of injury
    - Immediate OR for exploration
    - Inappropriate for CT imaging
  - If hemodynamically stable with suspicion for neck injury or soft signs
    - CTA for further evaluation
    - Management based on imaging results
  - No suspicion for internal injury, brief observation is reasonable

- **Vascular Injury**
  - Treatment options vary and should be decided in consultation with trauma/vascular surgeon
    - Observation
    - Surgical repair
    - Angiographic embolization/stenting
- **Laryngotracheal Injury**
  - Airway management
    - If immediate airway compromise: consider awake, fiberoptic-guided oral intubation or video laryngoscope
    - If surgical airway required, tracheostomy in OR is preferred over cricothyrotomy to avoid further larynx damage
  - If no identifiable injury besides laryngeal tenderness, consider observation for 12–24 hrs
  - Small mucosal injuries, nondisplaced fractures, and hematomas can be managed conservatively (pain control, humidified air, elevation of head of bed, steroids, vocal rest, antireflux medications and clear diet)
- **Pharyngoesophageal Injury**
  - If esophageal injury suspected, start broad-spectrum IV antibiotics with anaerobic coverage

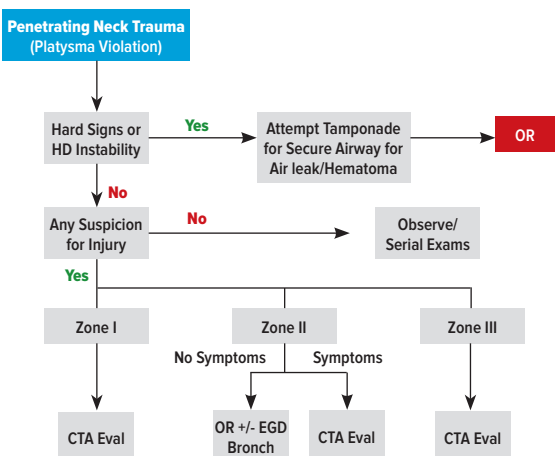


- — Patient should be made NPO
- — NGT should only be placed under endoscopic guidance to prevent further injury
- — Pharyngeal perforations > 2 cm and esophageal perforations require surgical repair

Disposition

- Admit symptomatic patients to a monitored setting
- Given delayed symptoms are common, consider monitoring patients who are asymptomatic on arrival
  - — Serial exams to assess for dyspnea, dysphonia, stridor, drooling, bruits, focal neuro deficits
  - — Only discharge after ruling out airway threat, neurological deficit, vascular injury, or suicidal/ homicidal ideation
- Social work and/or psychiatry for patients in whom you suspect suicide risk or domestic violence

Penetrating Neck Trauma Algorithm



SPERRY 2013

BLUNT NECK TRAUMA

S. Maheshwari, A. Tse Tanzillo

Overview

- 5% of all neck trauma
- Mortality due to loss of airway more so than hemorrhage

Mechanism

- MVCs with cervical hyperextension, flexion, rotation during rapid deceleration, direct impact
- Strangulation: hanging, choking, clothesline injury (see chapter on strangulation in this section)
- Direct blows: assault, sports, falls

Initial Management/Primary Survey

- **Airway**
  - Evaluate for airway distress (stridor, hoarseness, dysphonia, dyspnea) or impending airway compromise
  - Early aggressive airway control: low threshold for intubation in unconscious patient, evidence of airway compromise including voice change, dyspnea, neurological changes, or pulmonary edema
  - Assume a difficult airway
- **Breathing**
  - Supplemental oxygen
  - Assess for bilateral breath sounds
  - Can use bedside ultrasound to evaluate for pneumothorax or hemothorax
- **Circulation**
  - Assess for open wounds, bleeding, hemorrhage
  - IV access
- **Disability**
  - Maintain C-spine immobilization
  - Calculate GCS
  - Look for seatbelt sign

Secondary Survey

- Evaluate for specific signs of vascular, laryngotracheal, pharyngoesophageal, and cervical spinal injuries with inspection, palpation, and auscultation
- Perform extremely thorough exam to evaluate for any concomitant injuries (stab wounds, gunshot wounds, intoxications/ ingestions, etc.)

Types of Injuries

- **Vascular injury**
  - Overview
    - Carotid arteries (internal, external, common carotid) and vertebral arteries may be injured

TIP

- Mortality rate ~60% for symptomatic blunt cerebral vascular injury (BCVI)

— Mechanism
  - Hyperextension and lateral rotation of the neck, direct blunt force, strangulation, seat belt injuries, and chiropractic manipulation
  - Morbidity due to intimal dissections, thromboses, pseudoaneurysms, fistulas, and transections

— Clinical Features
  - Most patients are asymptomatic and do not develop focal neurological deficits for days
  - If Horner's syndrome present, suspect disruption of thoracic sympathetic chain (wraps around carotid artery)

☛ Specific screening criteria are used to detect blunt cerebrovascular injury in asymptomatic patients

DENVER BCVI SCREENING CRITERIA **Obtain CTA of neck vessels if any criteria are met**	
Signs & Symptoms	**Risk Factors: High-energy transfer mechanism**
Arterial hemorrhage	Le Fort fracture: Type 2 or 3
Cervical bruit in pts < 50 years	Base of skull fractures involving carotid canal
Expanding cervical hematoma	Cervical spine fracture patterns • Fractures involving C1, C2, or C3 • Fractures involving transverse foramen • Subluxation
Focal neurologic deficit	
Neurologic exam incongruous w/ head CT	
Stroke on secondary CT	
	Near-hanging with hypoxic-ischemic (anoxic) brain injury
	Diffuse axonal injury with GCS < 6

■ Diagnostic Testing
— Gold standard for evaluation of BCVI is MDCTA (multidetector four-vessel CT angiography)
  - <80% sensitive but 97% specific
  - Also images aerodigestive tracts and C-spine (unlike angiography)

— Digital Subtraction Angiography (DSA) is used to confirm positive results or for further evaluation in cases of high suspicion
  - Angiography is invasive, expensive, resource-intensive, and carries a high contrast load

■ Management
— Antithrombotics vs. interventional repair based on BCVI grading system
— Involve consultants early: trauma surgery, neurosurgery, vascular surgery, neurology
— All patients with blunt cerebral vascular injury will require admission

Blunt Carotid and Vertebral Artery Injury Grading Scale		
Grade	**Description**	**Treatment**
I	Luminal irregularity or dissection with < 25% luminal narrowing	Antithrombotic agent
II	Dissection or intramural hematoma with ≥ 25% luminal narrowing, intraluminal thrombus, or raised intimal flap	Antithrombotic agent or surgical repair if accessible
III	Pseudoaneurysm	Antithrombotic agent or surgical repair if accessible
IV	Occlusion	Antithrombotic agent or surgical repair if accessible
V	Transection with free extravasation	Surgical repair if accessible Balloon occlusion or embolization

- **Pharyngoesophageal injury**
  - Overview
    - Rare in blunt neck trauma
    - Includes hematomas and perforations of both pharynx and esophagus
  - Mechanism
    - Sudden acceleration or deceleration with hyperextension of the neck
    - Esophagus is thus forced against the spine
  - Clinical Features
    - Dysphagia, odynophagia, hematemesis, spitting up blood
    - Tenderness to palpation
    - Subcutaneous emphysema
    - Neurological deficits (delayed presentation)
    - Infectious symptoms (delayed presentation)
  - Diagnostic Testing
    - Esophagography with water-soluble contrast (eg, Gastrografin)
    - If negative contrast esophagography, obtain flexible endoscopy (most sensitive)
      - Combination of contrast esophagography + esophagoscopy has sensitivity close to 100%
    - Swallow studies with water-soluble agent
    - MDCTA — usually first line imaging test given accessibility in the ED
    - Plain films of neck and chest
      - Findings such as pneumomediastinum, hydrothorax, or retropharyngeal air may suggest perforation but are not sensitive

- Management
  - All pharyngoesophageal injuries receive IV antibiotics with anaerobic coverage
  - Parenteral/ enteral nutrition
  - NGT should only be placed under endoscopic guidance to avoid further injury
  - Medical management vs. surgical repair depending on extent of injury
    - Surgical repair for esophageal perforations or pharyngeal perforations > 2 cm
  - Involve consultants early: trauma surgery, vascular surgery, otolaryngology, gastroenterology
  - All patients with pharyngoesophageal injury will require admission

- **Laryngotracheal injury**
  - Overview
    - Occurs in > 0.5% of blunt neck trauma
    - Includes hyoid fractures, thyroid/ cricoid cartilage damage, cricotracheal separation, vocal cord disruption, tracheal hematoma or transection

Laryngeal Injury Grading Scale

Grade	Description
I	Minor endolaryngeal hematoma without detectable fracture
II	Edema, hematoma, minor mucosal disruption without exposed cartilage, nondisplaced fractures
III	Massive edema, mucosal disruption, exposed cartilage, vocal fold immobility, displaced fracture
IV	Grade III with 2 or more fracture lines or massive trauma to laryngeal mucosa
V	Complete laryngotracheal separation

  - Mechanism
    - Assault, clothesline injuries, direct blunt force from MVCs compressing the larynx between a fixed object and the spine
  - Clinical Features
    - Patients are often asymptomatic at first and then develop airway edema and/or hematoma resulting in airway obstruction
    - Children are at higher risk for airway compromise due to less cartilage calcifications

- Diagnostic Testing
  - Flexible fiberoptic laryngoscopy (FFL) to assess airway patency and extent of intraluminal injury
  - MDCTA
    - ♦ Obtain 1-mm cuts of larynx and perform multiplanar reconstructions
  - Consider sonography to detect laryngotracheal separation
- Plain films of neck and chest
  - Can show extraluminal air, fracture or disruption of cartilaginous (larynx) structures
- Management
  - ☛ When securing the airway, use an ETT that is one size smaller due to likelihood of airway edema
  - Conservative management (IV antibiotics, steroids, observation) vs. surgical repair
    - ♦ Grades III, IV, and V laryngotracheal injuries require OR
  - Involve consultants early: trauma surgery, neurosurgery, vascular surgery, neurology, otolaryngology

- **Cervical spine/spinal cord injury:** See Spinal Trauma section

Disposition

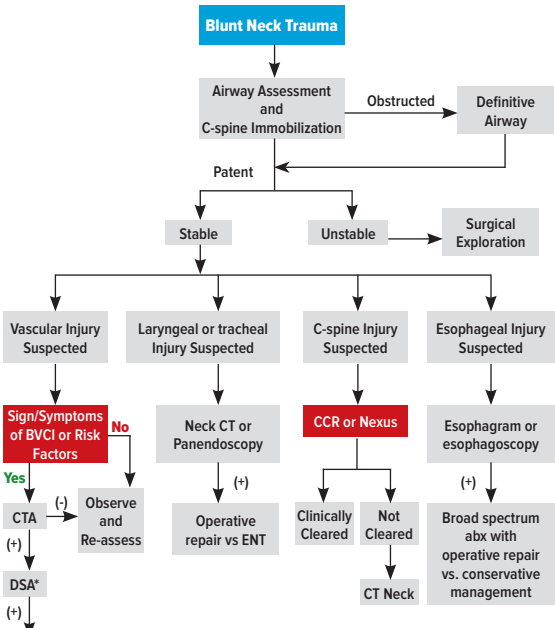
☛ TIP

- Admit and monitor
- Given delayed symptoms, consider monitoring patients who are asymptomatic on arrival
  - Serial exams to assess for dyspnea, dysphonia, stridor, drooling, bruits, focal neuro deficits
  - Only discharge after ruling out airway threat, neurological deficit, vascular injury, or suicidal/ homicidal ideation
  - Monitor asymptomatic patients on home anticoagulation in ED for at least 6 hrs from trauma to rule out delayed neck hematoma
- Social work and/or psychiatry for patients in whom you suspect suicide risk or domestic violence

PEARLS

- Aggressive early airway management for unconscious patient if signs of airway compromise (voice change, dyspnea, neurological changes, or pulmonary edema)
- Involve consultants early
- Blunt cerebral vascular injury may present completely asymptomatic but develop delayed neurological symptoms; monitor closely — especially those on home anticoagulation
- Evaluate for concomitant injuries
- Psychiatric evaluation for all attempted suicides

Blunt Neck Trauma Algorithm



*Digital Subtraction Angiography

Blunt Cerebral Vascular Injury Screening Criteria

Signs/ Symptoms	Arterial hemorrhage Cervical bruit Neurological deficit unexplained by head CT	Focal neurological deficit Cerebral Infarct on CT Expanding hematoma
Risk Factors High energy transfer mechanism	Midface fractures Upper rib fractures Fracture of C1 to C3 Basilar skull fracture Petrous bone fracture Hanging with anoxic brain injury	Diffuse axonal injury GCS ≤ 8 Scalp degloving Thoracic vascular injuries TBI with thoracic injury C spine fractures patterns Seat belt sign or soft tissue injury to the neck AND swelling or AMS

STRANGULATION

R. Sobolev, A. Tse Tanzillo

Background

- Strangulation includes hanging, manual strangulation, postural strangulation, ligature strangulation
- Most common type of completed suicide
- In domestic violence, strangulation is a strong predictor of future homicide

Mortality from strangulation

- Most common cause of death is secondary to vascular obstruction of brain from neck vessel occlusion
  - Cerebral congestion from obstruction of venous return (both internal and external jugular veins)
  - Cerebral ischemia secondary to arterial compression from loss of muscle tone
- It is less common to have death from airway compromise because more pressure is required to compress trachea than to compress jugular veins or carotid arteries
- A bradycardic arrest from carotid baroreceptor reflex is also possible
- Cardiac arrest at presentation is poor prognosticator; in-hospital mortality is often due to laryngeal/ pulmonary edema or cerebral anoxia

Other Notable Injuries from Strangulation

- Hangman's fracture (fracture of bilateral pedicles of C2)
  - An uncommon cervical spine injury from strangulation
  - Unstable fracture and can cause spinal compression
  - Refer to Dens/Odontoid chapter in Spinal Trauma section
- Spinal cord injury
  - Paraplegia/quadriplegia
  - Short term autonomic dysfunction
  - Central cord syndrome
  - Refer to Cord Syndromes chapter in Spinal Trauma section
- Carotid artery injuries/dissection
  - Suspect if lateralizing neurological exam or ecchymosis/ tenderness over carotid artery
- Pulmonary edema
  - Neurogenic: centrally mediated, due to sympathetic discharge
  - Post obstructive: negative intrapleural pressure due to inspiration against an external airway obstruction can lead to ARDS

Signs/Symptoms

- May see petechiae, neck contusions, subconjunctival hemorrhage, subcutaneous emphysema
- Complaints of neck pain, voice changes, difficulty swallowing

- Hypoxia associated with mental status changes and incontinence
- Brain ischemia secondary to carotid obstruction may show neurological deficits (vision changes, ptosis, facial droop, weakness)
- Many patients will show no physical signs of strangulation or will be asymptomatic at presentation which often results in under evaluation
  - Half of patients show no physical signs at presentation
  - Two thirds of patients with strangulation are asymptomatic at presentation
- Symptoms can be delayed or obscured by intoxication

TIP

Initial Stabilization

- There is a lack of evidence about evaluation and management of patients that have been strangled but IV access, cardiopulmonary monitoring, supplemental oxygen, aggressive airway management, and removing ligature are paramount
- Low threshold for intubation in unconscious patient, evidence of airway compromise including voice change, dyspnea, neurological changes, or pulmonary edema
- Consider emergent tracheostomy if hematoma over cricothyroid membrane or evidence of cricotracheal disruption
- Perform extremely thorough exam to evaluate for any concomitant injuries (eg, stab wounds, gunshot wounds, intoxications/ingestions, etc.)

ED Management

- Obtain imaging for symptomatic patients and have a low threshold for imaging asymptomatic patients
  - CTA neck is first line study for suspected internal injury
  - MRI cervical spine
    - High sensitivity for soft tissue injury, bone, and cartilaginous injury
    - May identify intramuscular hemorrhage or edema, platysma swelling, subcutaneous bleeding, hemorrhagic lymph nodes
  - Laryngobronchoscopy/ fiberoptic endoscopy (panendoscopy)
    - Consider if dyspnea, dysphonia, aphonia, odynophagia, aphonia, odynophagia
    - Can evaluate for edema and aero-digestive injury
  - Chest X-Ray
    - Pulmonary edema
    - Aspiration pneumonitis
    - Larynx or hyoid bone fractures
    - Tracheal deviation caused by edema or hematoma
  - CT of cervical spine through T1 to assess for fracture
  - CT brain
    - Cerebral hemorrhage
    - Subarachnoid hemorrhage
    - Hematoma

- Edema
- Evidence of hypoxic injury

- Management
  - Antithrombotics vs. interventional repair based on Blunt Carotid and Vertebral Artery Injury (BCVI) Grading Scale
  - All BCVI likely require admission
- Consultations
  - Trauma surgery
  - Otolaryngology/ ENT for soft tissue injuries
  - Vascular surgery for vascular injuries
  - Neurology for thrombosis, embolism, dissection
  - Neurosurgery and neurology for cerebral edema/ ICH

Blunt Carotid and Vertebral Artery Injury Grading Scale

Grade	Description	Treatment
I	Luminal irregularity or dissection with < 25% luminal narrowing	Antithrombotic agent
II	Dissection or intramural hematoma with ≥ 25% luminal narrowing, intraluminal thrombus, or raised intimal flap	Antithrombotic agent or surgical repair if accessible
III	Pseudoaneurysm	Antithrombotic agent or surgical repair if accessible
IV	Occlusion	Antithrombotic agent or surgical repair if accessible
V	Transection with free extravasation	Surgical repair if accessible Balloon occlusion or embolization

Disposition

- Admit symptomatic patients to monitored setting
- Given delayed symptoms, consider monitoring patients who are asymptomatic
  - Serial exams to assess for dyspnea, dysphonia, stridor, drooling, bruits, focal neuro deficits
  - Only discharge after ruling out airway threat, neurological deficit, vascular injury, or suicidal/ homicidal ideation
- Social work and/or psychiatry for patients in whom you suspect suicide risk or domestic violence

Special Populations

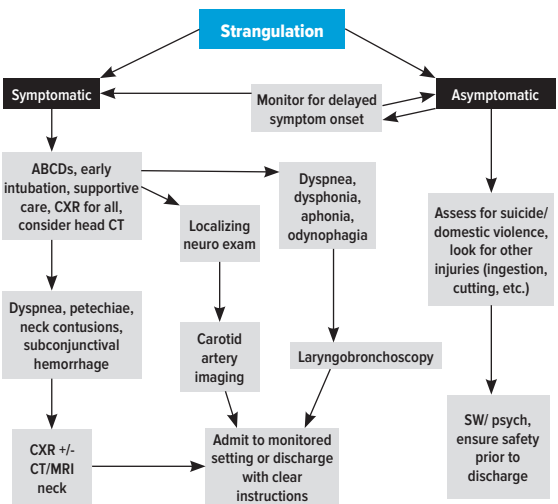
- Pediatric strangulation
  - Children are more predisposed to developing symptomatic airway edema due to the smaller diameter of the larynx and looser nature of the mucosa

- Anticoagulated Patients
  - Anticoagulated patients with neck trauma should have their anticoagulation reversed (when possible), except in blunt cerebral vascular trauma (where treatment is anticoagulation)

PEARLS

- Death from strangulation results from neck vessel occlusion more than airway failure
- Aggressive early airway management in unconscious patient or evidence of airway compromise including voice change, dyspnea, neurological changes, or pulmonary edema
- May present completely asymptomatic but develop delayed cerebral or pulmonary edema; monitor closely
- Remember to evaluate for concomitant injuries
- Psychiatric evaluation for all attempted suicides

Strangulation Algorithm



CHEST TRAUMA ED MANAGEMENT

B. Zhang, D. Egan

Primary Survey

- Airway
  - If unstable or patient unable to protect it, perform RSI
- Breathing
  - Assess for dyspnea, tachypnea, and bilateral breath sounds
  - Measure continuous pulse oximetry
  - Examine chest wall movement, looking for symmetric chest rise, crepitus, or paradoxical movement
- Circulation
  - Check for presence and symmetry of pulses in all extremities
  - Monitor hemodynamic status and identify any signs of shock

Secondary Survey

- Fully expose patient to identify injuries that may not have been visible externally
- Specific to chest trauma
  - Careful auscultation of lungs throughout all fields to identify asymmetry or abnormalities
  - Evaluate chest and axilla for penetrating injuries; location is important for specific thoracoabdominal injuries
  - Inspect and palpate entire chest region anteriorly and posteriorly, looking for deformities, ecchymosis, abrasions, lacerations, crepitus, areas of focal tenderness or abnormal chest wall movement
  - ☛ Pay specific attention to signs concerning for tension pneumothorax (tracheal deviation, distended neck veins, hypotension)

☛ TIP

Emergency Considerations

- Normal lung sounds do not exclude possibility of pneumothorax or hemothorax
- POCUS can identify pneumothorax (absence of lung sliding and/or lung point), pericardial effusion, hemothorax

Chest Trauma Emergencies
Airway obstruction
Aortic injury
Tension pneumothorax
Massive hemothorax
Flail chest
Cardiac tamponade

- Hemodynamically stable with blunt chest trauma: use **NEXUS Chest Decision Instrument** to determine need for chest imaging (CXR or CT)
- If all of the following criteria are negative, the decision rule excludes clinically significant thoracic injury with 99% sensitivity
  - Age > 60 years
  - Rapid deceleration mechanism (fall > 6', MVC > 40 mph)
  - Chest pain
  - Intoxication
  - Altered mental status
  - Distracting painful injury
  - Tenderness to chest wall palpation
- If CXR based on the above NEXUS criteria, proceed to NEXUS Chest CT Decision Instrument which has 99% sensitivity to rule out major injury and 90% sensitivity for major or minor injury
  - Abnormal chest X-ray
  - Distracting injury
  - Chest wall, sternum, thoracic spine, or scapular tenderness
  - Rapid deceleration mechanism (fall > 6', MVC > 40 mph)

ATLS

Emergency Interventions

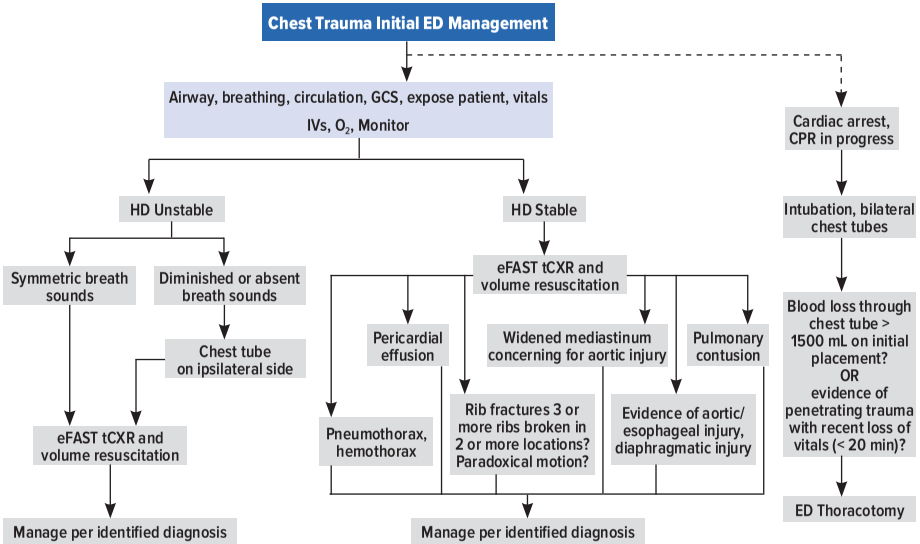
- Evidence of chest trauma: stat portable chest X-ray useful first test in resuscitation bay
- High clinical suspicion for tension pneumothorax necessitates needle decompression with a large bore angiocatheter in 5th intercostal space in midaxillary line (change from 2nd intercostal space in midaxillary line) followed by emergent tube thoracostomy
- Open pneumothorax (penetrating injury causing pneumothorax): apply 3-way occlusive dressing over wound and perform tube thoracostomy away from wound
- Hemothorax: perform tube thoracostomy and closely monitor output
- Flail chest: administer pain control and positive pressure ventilation via CPAP/BIPAP. Maintain low threshold for intubation if no improvement on non-invasive ventilation
- Cardiac tamponade identified by clinical exam (Beck's triad) or POCUS and signs of obstructive shock present: urgent surgical intervention. Pericardiocentesis at bedside can be bridge to surgery or if trauma surgery is not available

Additional Considerations

- CBCs may not immediately reflect significant blood loss; resuscitate with blood products. Chest cavity can hold large volumes of blood, so thoracic injury can lead to hemorrhagic shock
- ED thoracotomy (EDT) controversial; consider in all pulseless trauma patients
- Refer to Critical Interventions chapter for procedure
- Current EAST guidelines recommend:

Presentation	EAST recommendation for ED thoracotomy
Pulseless to ED with signs of life after penetrating thoracic injury	Strong recommendation for EDT
Pulseless to ED without signs of life after penetrating thoracic injury	Conditional recommendation for EDT
Pulseless to ED with signs of life after penetrating extrathoracic injury	Conditional recommendation for EDT (except in isolated cranial injuries)
Pulseless to ED without signs of life after penetrating extrathoracic injury	Conditional recommendation for EDT (except in isolated cranial injuries)
Pulseless to ED with signs of life after blunt injury	Conditional recommendation for EDT
Pulseless to ED without signs of life after blunt injury	Conditional recommendation against EDT

CHEST TRAUMA



PNEUMOTHORAX

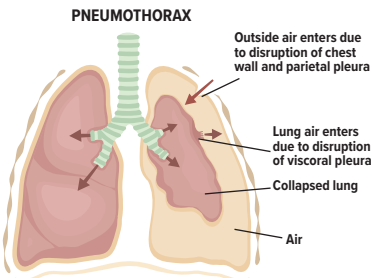
A. Wang, D. Egan

Definition

- Loss of negative pressure gradient between visceral and parietal pleural resulting in accumulation of air in potential space.
- Tension pneumothorax develops when air continues to accumulate and is unable to escape, leading to significant increase in intrathoracic pressure and hemodynamic instability

ED Presentation

- SOB, ipsilateral pain, hypoxia, tachycardia (most common early finding)
- Penetrating trauma to the chest wall is a common cause of traumatic pneumothorax
- Pneumothorax can occur with blunt trauma, particularly as a result of rib fractures



Diagnosis

- Typically made via CXR, CT, POCUS
  - Ultrasound
    - Use M-mode to evaluate for lung sliding. Evaluate multiple levels (at least 3) bilaterally in order to identify small pneumothoraces
    - Highly sensitive and specific in trauma
    - Findings
      - ♦ Absence of lung sliding. Normal movement of visceral and parietal pleura visualized in real time in normal lung
      - TIP In pneumothorax, using lung sliding, the absence of lung sliding is identified by the "Barcode" or "Stratosphere" sign
      - ♦ Lung point: transition point where lung sliding is normal adjacent to absent lung sliding

- ♦ Lack of B-lines: accumulation of air in pleural space does not allow this reverberation artifact to take place
- ♦ Presence of A-lines: horizontal lines, which are reverberation from the pleural, will remain present with pneumothorax

— Chest X-ray
- Upright inspiratory x-ray is the most sensitive method of identifying a pneumothorax on plain film as air rises to the apex. Unfortunately, acute trauma portable x-rays are often performed in the supine position.
- A supine film may not demonstrate typical pneumothorax appearance since air may accumulate anteriorly and at the base
- Findings:
  - ♦ Separation of the pleura with an area showing no interstitial or vascular lung markings and transradiancy
  - ☛ On a supine film, a deep sulcus sign may be present (a deeper costophrenic angle on the affected side)

— Chest CT
- Highest sensitivity for pneumothorax
- May identify small pneumothoraces not visible on regular CXR (occult pneumothorax)

☛ TIP
☛ ATLS

Evaluation

- Physical examination may reveal decreased or absent breath sounds on affected side; presence of breath sounds does not rule out diagnosis
- Though rarely performed, percussion of the chest may demonstrate hyperresonance and there may be asymmetric chest wall expansion during inspiration.
- Imaging studies are typically performed as above for definitive diagnosis

☛ For patients with tension pneumothorax, look for Beck's triad: Elevated jugular venous pressure/distended neck veins, hypotension and tracheal deviation.

Critical Interventions

- All patients with pneumothorax should receive supplemental oxygen with a nonrebreathing at 15L.
- Patients with tension pneumothorax require immediate decompression.
  — Needle decompression
  - ☛ Adults: was traditionally performed in the 2nd intercostal space of the anterior chest at the mid-clavicular line however given variable anterior chest wall depth, the new recommendation is to perform needle decompression in the 5th intercostal space in the anterior axillary line.
  - Children: recommendation remains 2nd intercostal space of anterior chest wall, midclavicular line

- Finger thoracostomy is another alternative and should be performed in 5th intercostal space at the anterior axillary line.
- An open pneumothorax requires the placement of an occlusive dressing over the wound. Tape the wound on 3 sides in order to prevent additional air from entering the thoracic cavity while simultaneously allowing air to exit.
- Treatment of the pneumothorax is dictated by its size assuming hemodynamic stability.
  - Occult and small pneumothoraces (< 3 cm apex to cupula): Oxygen therapy and repeat CXR in 6 hrs. If no progression and no other injuries, reliable patients may be candidates for outpatient management and follow-up.
  - Large pneumothoraces (> 3 cm apex to cupula): Oxygen therapy and tube thoracostomy.
- Patients who require positive pressure ventilation are at risk for expansion of their pneumothorax even in small cases. Tube thoracostomy is typically indicated for these patients to prevent decompensation and expansion of the pneumothorax.

Additional Considerations

- Pneumothorax and bullae of patients with chronic lung disease can look similar on CXR; consider clinical context when evaluating image. CT scan will differentiate the two.
- Placing a chest tube in a bullae can have significant negative consequences such as tension pneumothorax and bronchopulmonary fistulas.
- Iatrogenic pneumothorax is more common than spontaneous pneumothorax, so always remember to obtain your post-procedure plain films!
- Watch out for treatment complications of pneumothorax such as re-expansion injury, lung parenchymal damage, and intercostal vessel damage.

HEMOTHORAX

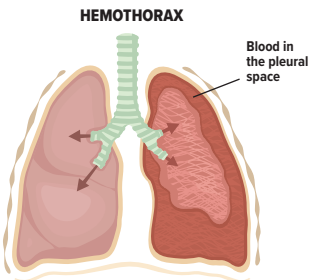
A. Shaikh, D. Egan

Definition

- Accumulation of blood in pleural space between visceral and parietal pleura

ED Presentation

- Consider in any patient with polytrauma or blunt or penetrating thoracic trauma
- Patients may complain of difficulty breathing and pain on ipsilateral side of chest



Diagnosis

- Physical examination may reveal diminished breath sounds on the side of the hemothorax
- Upright CXR preferred positioning but most acute trauma CXR performed supine
- Free fluid identified as an obliteration of costophrenic angle on upright x-ray and requires 400–500 cc of free fluid
- When x-rays are performed in supine position, the blood layers posteriorly and there will be a haziness unilaterally but no clear air-fluid level or blunting of the costophrenic angle.
- Ultrasound is more sensitive than x-ray in detecting intrathoracic fluid but does not offer information on the rest of the thoracic anatomy.
- CT chest with IV contrast can help localize injury in addition to being able to differentiate pleural fluid from blood.

Evaluation

- Assess lungs during primary survey. Decreased or absent breath sounds with hemodynamic instability is a hard stop and the patient must undergo an emergent tube thoracostomy.
- In hemodynamically stable patients not in shock or extremis, a secondary survey should be completed to identify other injuries and imaging should be obtained.
  - Portable CXR: pay attention to presence of rib fractures
  - Bedside ultrasound: may be the first modality to identify a hemothorax
  - CT chest: powerful tool to identify hemorrhage: amount, etiology and briskness of bleeding

TIP
ATLS

Critical Interventions

- Thoracic cavity is a common site of blood loss in hypotensive polytrauma patients; chest may accumulate > 4000 cc of blood
- Patients with a traumatic hemothorax should have tube thoracostomy performed in order to drain the collection and potentially identify ongoing bleeding.

☛ Large chest tubes are no longer recommended; 28–32F tubes will suffice.

- CBC may not immediately reflect significant blood loss; patients with large hemothorax or ongoing bleeding from the chest tube should be resuscitated with blood products.
- Indications for immediate OR transfer for emergent thoracotomy include shock, immediate large volume drainage of blood greater than 1500 cc (or 20 cc/kg) or persistent bleeding 300–500 cc/hr over 2–4 hrs from chest tube.

☛ TIP

RIB FRACTURES

C. Larsen, D. Egan

Definition

- Breaks in ≥ 1 pair of ribs
- Flail chest: multiple fractures on each of ≥ 3 adjacent ribs

ED Presentation

- Concern in any acute chest trauma
- Pain at site of injury worsens with inspiration
- Point tenderness typical over fractures
- Paradoxical inward movement of chest wall during inspiration may be sign of flail chest

Diagnosis

- X-rays are first line imaging but can miss up to half of all rib fractures
- Consider chest CT if suspicion is high and x-rays negative

Evaluation

- Consider in any patient with localized tenderness over ribs

TIP

- Portable chest x-ray assessing for pneumothorax is not adequate to fully rule out rib fractures; non-contrast CT is definitive
- Consider possible liver or spleen injuries with lower rib fractures

Critical Interventions

- Rule out life-threatening complications such as pneumothorax or hemothorax
- Provide adequate analgesia; pain can interfere with normal respiration and cause splinting. These patients may have difficulty coughing and taking a deep breath, which can lead to atelectasis, and ultimately pneumonia
- Consider lidocaine patches in combination with NSAIDs discharged patients; use opiates as needed but beware of respiratory depressive effects
- Consider intercostal nerve block for admitted patients
- Give patient an incentive spirometer and teach them how to use it to prevent atelectasis

TIP

- Patients (particularly elderly) with ≥ 3 rib fractures, displaced rib fractures, first rib fractures, or second rib fractures should be observed/admitted 24–48 hrs
- Flail chest requires surgical consult and admission

Additional Considerations

- About half of patients admitted with chest trauma have rib fractures.
- Most rib fractures heal well with conservative management.

PULMONARY CONTUSION

R. Abualsaud, D. Egan

Definition

- Alveolar capillary damage resulting in alveolar and interstitial hemorrhage and edema caused by blunt (85–90%) or penetrating (10–15%) trauma in the absence of pulmonary laceration.

ED Presentation

- Mild contusions are asymptomatic
- Moderate to severe contusions present with tachypnea, tachycardia and hypoxia
- Mechanisms of injury for blunt trauma include:
  - Compression: applied force overcomes the strength of the chest wall
    - Consider: rib fractures and costochondral disruption
  - Shearing: acceleration and deceleration injuries
    - Consider: soft tissue and vascular injury
  - Blast: indirect impact from pressure wave generated by an explosion.
    - Consider: contusion, edema and alveolar hemorrhage

Diagnosis

TIP

- Pulmonary contusion can take up to 6–48 hours to be visualized on X-ray, but can be visualized and quantified immediately on CT scan.
- Imaging of pulmonary contusion shows non-segmental, patchy or diffuse opacification of the lung parenchyma.
- In polytrauma, aspiration pneumonia and fat embolism can mimic pulmonary contusions. Both are visualized 12–24 hours later radiographically and have a segmental or lobar distribution.

Evaluation

- The physical exam will vary based on mechanism of injury but may show chest wall deformity (rib fractures), contusion, tenderness, and decreased or coarse breath sounds.
- Normal appearance of the chest wall does not exclude pulmonary contusion, particularly in children.
- Hypoxia, hypercapnia and respiratory acidosis in the setting of blunt chest trauma should raise suspicion for pulmonary contusion.

Critical Interventions

- Use caution with large volume fluid resuscitation in patients with large pulmonary contusions as this can precipitate cardiopulmonary decompensation and worsen VQ mismatch.
- Consider positive airway pressure through BiPAP or CPAP to overcome hypoxia and hypercapnia in alert patients.

- Non-invasive ventilation compared to invasive ventilation is associated with decreased risk of pneumonia, ICU and hospital stay and is preferred when possible for patients without contraindications.
- If the patient requires intubation, use lung-protective ventilation strategies with low tidal volumes (6–8 mL/kg ideal body weight).
- Adequate pain control is essential to prevent hypoventilation and atelectasis.
- Early chest physiotherapy including breathing exercises, suctioning and coughing improves clearing of secretions and oxygenation.

Additional Considerations

- Blunt trauma in pediatric patients with more compliant chest walls may result in severe, diffuse lung contusion without actual injury to the chest wall. Keep a high index of suspicion for pulmonary contusion based on clinical picture and mechanism of injury.
- Patients who have > 20% contusion of total lung volume have up to 80% risk of developing acute lung injury and ARDS.

PERICARDIAL TAMPONADE

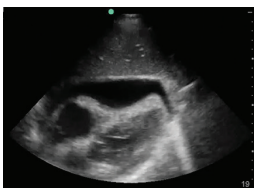
R.A. Giles, D. Egan

Definition

- Accumulation of fluid within pericardium
- Tamponade occurs when this fluid leads to decreased myocardial contractility and thus decreased cardiac output

ED Presentation

- Most commonly seen after penetrating thoracic trauma but can also occur as a result of blunt trauma or in atraumatic conditions that result in pathological pericardial effusion
- Consider in patients in shock that is not responsive to IV fluids
- Classically associated with Beck's Triad: hypotension, muffled heart sounds, jugular venous distension



Pericardial Tamponade

Diagnosis

- Can be diagnosed with POCUS, but largely a clinical diagnosis that shows signs of obstructive physiology
- ☛ Gold standard is bedside ultrasound/FAST examination showing hypoechoic fluid collection within pericardial sac. Typically with tamponade physiology, collapse of the right sided chambers is appreciated.
- CXR may show an enlarged "water bottle" shaped cardiac silhouette. However, this enlargement is not seen until there is > 200 mL of pericardial fluid and thus is generally not seen in acute tamponade
- EKG changes include electrical alternans (beat to beat alterations in the amplitude of the QRS complex), low amplitude EKG, and nonspecific ST segment changes

☛ TIP

Evaluation

- Cardiac ultrasound as part of the FAST examination is 90–95% accurate for the identification of pericardial fluid. Findings suggestive of tamponade include:
  - Collapse of cardiac chambers, most commonly the right sided chambers
  - Pericardial effusion
  - Plethoric IVC
- Obtain CXR, EKG, and labs to assist in diagnosis

Critical Interventions

- Immediate trauma surgery activation
- Tamponade without hemodynamic instability: manage conservatively with IV fluids, hemodynamic monitoring, and treatment of underlying cause; traumatic causes always need further investigation.
- Patients in extremis and hemodynamically unstable require emergent surgery; pericardiocentesis may be temporary measure as a bridge to definitive therapy
- Three approaches for pericardiocentesis: subxiphoid, parasternal, and apical. Whenever possible ultrasound guidance should be utilized
- Definitive management: pericardial window or thoracotomy in the OR; emergency thoracotomy indicated when pulses are lost in the ED

Additional Considerations

- Not strongly associated with any particular amount of effusion. Acute tamponade from trauma can occur with as little as 100–200 mL of pericardial fluid!

MYOCARDIAL CONTUSION

S. Zaidi, D. Egan

Definition

- Direct injury to cardiac muscle from blunt force trauma to chest wall, most commonly involving right ventricle because of its retrosternal and anterior position

ED Presentation

- Common mechanisms of injury include any force causing increased intrathoracic pressure or compression of heart between sternum and vertebrae, usually involving direct blow
- Often presents with signs of thoracic injury
- Chest pain, dysrhythmias, cardiac dysfunction, and rarely, hypotension

Diagnosis

- No consensus on strict diagnostic criteria as no single test can rule in or out
- Suspect with any of the following in context of blunt force to chest:
  - New abnormalities on EKG: dysrhythmias, conduction delays, ST-segment elevations or depressions
  - Elevated troponin
  - Echocardiogram showing cardiac dysfunction
- Definitive diagnosis can only be made through postmortem gross or histologic examination of cardiac tissue

Evaluation

- Look for "seat belt sign" or any chest wall injury/deformity that could indicate blunt chest trauma
- All patients with concerning mechanism of injury should have EKG and troponin testing

TIP

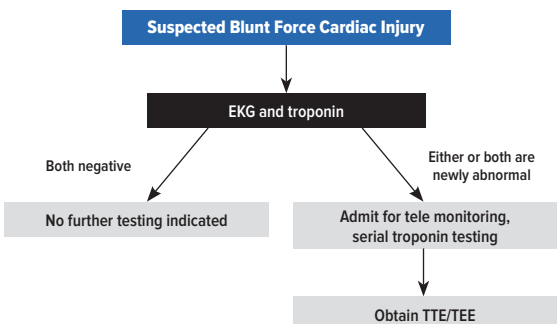
- If persistent dysrhythmias, hypotension, or shock are present, obtain TTE or TEE to evaluate for cardiac structural injury
- Rule out all other potential causes of shock (hypovolemia/hemorrhage, spinal injury, obstructive, etc.); cardiac contusion as etiology of shock is a diagnosis of exclusion.
- Troponin testing is generally advisable for patients with chest pain and may help guide admission, but it has not been shown to correlate with rate of complications with myocardial contusion

Critical Interventions

- Treat supportively
  - Oxygen for hypoxia
  - Hydration for pre-load support
  - Analgesia for pain
- If hypotension from cardiogenic shock is present despite fluid administration, consider dobutamine inotropic support
- Avoid aspirin or thrombolytics in trauma
- Treat dysrhythmias per ACLS protocol
- If new EKG changes are present, admit for continuous telemetry monitoring 24–48 hrs
- If EKG is at baseline and troponin is negative, no need for further testing

Additional Considerations

- Most patients recover without significant intervention. Dysrhythmias and EKG changes are usually transient.
- Prognosis depends on preexisting health of heart and coronary vessels along with location and extent of cardiac injury.



AORTIC INJURY

L. Hartofilis, D. Egan

Definition

- Broad spectrum of pathology ranging from small intimal tears to total transection of the aorta

Classification of Aortic Injuries

- **Grade I: Intimal tear**
  - Insult to the intima layer causing it to tear away from the media layer, creating an intimal flap and possible dissection with blood entering the intima-media space and propagating up or down the wall
- **Grade II: Intramural hematoma**
  - Blood collection within the aortic wall without intimal tear, which can also lead to dissection
- **Grade III: Pseudoaneurysm**
  - Aortic wall is damaged causing blood leakage into surrounding tissues that is walled off without aortic wall weakening/bulging
- **Grade IV: Rupture**
  - Complete transection of the aortic wall

ED Presentation

- Injuries may result from blunt trauma, penetrating chest trauma or deceleration injury (motor vehicle collisions or falls from high height)
- Among the most life-threatening, time-sensitive traumatic conditions seen in ED
  - Up to 30% morbidity and mortality rate in first 24 hrs
  - Patients often die in the field
- No fixed constellation of symptoms; have a high clinical suspicion if mechanism of injury is concerning
- Possible hypotension, external evidence of trauma (steering wheel or seatbelt marks, sternal ecchymosis), and altered mental status
- Chest pain, dyspnea, dysphagia, voice change, upper extremity blood pressure discrepancy, diminished femoral pulses, or cardiac murmur

Diagnosis

- Portable chest x-ray (low sensitivity)
  - Widened mediastinum
  - Loss of normal aortic knob contours
  - Left sided pleural effusion
  - Tracheal deviation to the right

- CT Angiogram preferred imaging modality
  - Abnormal soft tissue density in the mediastinum
  - Periaortic hematoma
  - Intraluminal filling defect
  - Abnormal aortic contour secondary to mural hematoma
  - Pseudoaneurysm
  - Extravasation of contrast
- TEE (transesophageal echo) in ED an option if too unstable for CT imaging

Evaluation

- Evaluate expeditiously
- CTA sensitive and specific for traumatic aortic injuries
- Bedside ultrasound (low sensitivity)
  - Hemopericardium
  - Hemothorax

Critical Interventions

- **Hemodynamic support**
  - ***Hypotensive*** despite direct pressure and tourniquets, initiate 1L crystalloids followed quickly by blood products (consider activation of massive transfusion protocol)
  - ***Hypertensive*** with an aortic injury, target a MAP of 60–70 and a HR < 80 with an esmolol drip to decrease the shearing effects of higher pressures
- **Chest tubes**
  - Unilateral or bilateral chest tubes may be indicated if bedside ultrasound demonstrates hemothoraces
  - A major vascular injury requiring operative management is likely if a chest tube drains 1500 cc (or 20 cc/kg) blood immediately, or ongoing drainage rate of 200 cc/hr
- **Consultations**
  - Consult cardiothoracic and/or vascular surgery ASAP
  - If unavailable, optimize hemodynamics for transfer to a trauma center/tertiary care center

DIAPHRAGM INJURY

M. Bhandari, D. Egan

Definition

- Defect in the diaphragmatic wall resulting from trauma
- Can result in herniation of abdominal contents into thoracic cavity

ED Presentation

- Clinical signs of diaphragmatic rupture are typically non-specific: chest pain, abdominal pain, referred shoulder pain, dyspnea, or respiratory distress
- Most cases of diaphragmatic rupture result from blunt thoracoabdominal trauma, but can result from penetrating trauma as well
- Significant force is required to rupture the diaphragm, and diaphragmatic injuries are almost always associated with other organ injuries, such as lung (77%), liver (52%), spleen (32%), and stomach (19%).
- Diaphragmatic defects may not be clinically apparent at presentation. As a result, over time, abdominal viscera may herniate through the unrepaired diaphragmatic defect and become strangulated or cause respiratory symptoms presenting after the initial injury.

Diagnosis

- Diagnosis may be difficult as even CT can miss small defects.
- Plain chest radiography is a low sensitivity screening modality for diagnosis of diaphragmatic injury. Common findings include elevated hemidiaphragm, herniation of abdominal contents in the chest cavity and pleural effusion.
- CT imaging of the abdomen and chest is more sensitive for the detection of diaphragmatic injury including diaphragmatic defects and intrathoracic herniation of abdominal contents. The classic "hourglass" or "collar sign" occurs with constriction of abdominal viscera in the defect.
- In patients with penetrating left thoracoabdominal trauma, the incidence of herniation of abdominal contents is high; thus, operative exploration is indicated to identify the injury and to repair the defect. 20% of these patients will have diaphragmatic injuries.

Evaluation

- Consider after trauma with abdominal pain, chest pain, or shortness of breath.
- Initial imaging will likely be with plain radiographs but consider CT imaging if suspicion arises based on CXR or mechanism.
- Ensure patients are stable prior to taking them to the CT scanner as cases of diaphragmatic injury may have respiratory instability requiring intervention.
- High risk patients with concerning signs and symptoms or imaging findings should undergo operative exploration
- Diaphragmatic injury should be suspected with any penetrating trauma in a region where you expect the diaphragm to traverse during inhalation and exhalation.

Critical Interventions

- Definitive treatment is surgery to repair the diaphragmatic defect.
- Penetrating left sided thoracoabdominal trauma often results in diaphragmatic injury, making nonoperative expectant management of these patients potentially unsafe.
- It is important to be vigilant in making this diagnosis and advocating for operative exploration in patients with suspicion of diaphragmatic injury, particularly penetrating trauma, as complications (herniation, strangulation) can arise over time and can be fatal to the patient.
- In blunt trauma, diaphragm injuries do not often occur in isolation therefore it is critical to identify associated injuries based on the mechanism of injury.

Additional Considerations

- Can present in a delayed fashion, sometimes months to years later.
- Get a detailed trauma history for patients with CP, shortness of breath and elevated hemidiaphragm or herniated abdominal contents in the chest on plain film.

PENETRATING ABDOMINAL TRAUMA

N. Volz, R. O'Halloran

Definition

- *Abdomen:* area between nipple line and the pubic symphysis, bound by the anterior axillary lines anteriorly; and between the posterior axillary lines, from the scapular tip to the iliac crest posteriorly
- *Flank:* area between the anterior and posterior axillary lines extending from the 6th intercostal rib to the iliac crest

ED Presentation

- Gather brief history from patient, EMS, and witnesses. Information about the size, range, and type of weapon are crucial to understanding the kinetics of the trauma, and the potential interventions. The degree of direct and surrounding tissue damage depends on the mechanics of the projectile and the tissue density that is penetrated

☛ Dense tissues such as bone and solid organs will absorb more energy and result in greater injury than low density tissues such as the lung

- Tissue damage caused by:
  - *Permanent cavitation:* direct injury by object thus the wound tract.
  - *Temporary cavitation:* tissue stretching due to medium to high energy penetrating force
  - *Remote injury:* caused by propagation of shockwave forces to distant tissues
- 3 broad categories of velocity and tissue damage
  - Low velocity mechanisms (knives, etc.)
    - Permanent cavitation or local injury
    - Damage to the pathway of penetration by physical displacement of the tissue resulting in wound tract.
  - Medium velocity mechanisms (most handguns and shrapnel)
    - Cause temporary and permanent cavitation
    - Bullets from handguns will cause damage to the primary pathway of penetration (permanent cavitation) and local surrounding tissue damage (temporary cavitation)
  - High velocity mechanisms (rifles)
    - Cause significant tissue damage both at local (permanent cavitation) and close (temporary cavitation) to site of penetration; as well as other tissues due to propagation of shockwaves (remote injury)
- Up to 95% of abdominal gunshot wounds (GSWs) and up to 33% of abdominal stab wounds require operative repair

Diagnosis and Evaluation

- **Primary survey: ABCDE** (airway, breathing, circulation, disability, exposure)
  - Stop active external hemorrhage immediately

☛ TIP

- **Vitals:** signs of hemorrhage, hemodynamic compromise, evidence of shock (shock index > 1)
- **Secondary Survey**
  - AMPLE
    - Allergies
    - Medications (special attention to blood thinners, blood pressure medications)
    - Past medical history
    - Last meal
    - Everything else
  - **Accident details**: elucidate the details of the mechanism of injury (eg, type and size of weapon)
- **Physical exam**
  - Assess for peritoneal signs (distention, rigidity, guarding)
  - Local wound exploration is an option for abdominal and extremity wounds; however, should be performed by those with appropriate experience and expertise.
  - ATLS TIP Do not probe wounds on the neck or chest.
  - **Note** — Ascites due to liver disease is a confounder requiring further consideration, and may alter the findings of the eFAST exam (see below)
  - ATLS TIP Penetrating abdominal injuries may have unpredictable trajectories. *Completely undress the patient and carefully assess axilla, skin folds, perineum.*
- **Gun Shot Wounds**
  - ATLS TIP Evaluate for shock, peritonitis, and evisceration — all are indications for immediate operative intervention
  - Most commonly injured organ in GSW is small bowel
  - Do not attempt to differentiate between entrance and exit wounds as they may appear identical depending on range and mechanism, rather injuries should be described as they appear ("ballistic")
- **Stab Wounds**
  - Evaluate for shock, peritonitis, evisceration, and impalement: all are indications for immediate operative intervention.
  - Stable patients with low velocity penetrating trauma, without shock, peritonitis, evisceration may not require OR
  - Most commonly injured organ is liver

Imaging and Work-Up

- **eFAST**
  - All stable patients should undergo a bedside eFAST to assess for free fluid in abdomen or chest
  - Hollow viscus injuries bleed minimally and may not initially produce enough blood to detect on US

- **X-ray**
  - Plain films are of limited utility for abdomen unless suspicion for retained foreign object
  - CXR to evaluate for thoracic injury; however, eFAST is more sensitive for pneumothorax
  - Free air under diaphragm on an *upright* chest x-ray may provide evidence of peritoneal violation in an otherwise stable penetrating trauma
  - ☛ Consider placing a radiopaque marker (EKG lead) adjacent to cutaneous injury to help identify underlying pathology on plain film
- **CT abdomen and pelvis with IV contrast**
  - If high suspicion for intra-abdominal injury and patient is stable (regardless of eFAST findings), obtain CT with IV contrast to highlight areas of injury and active bleeding
  - Consider CT with IV and oral/rectal contrast for low velocity penetrating trauma to flank or back for evaluation of retroperitoneal or hollow viscus injuries
  - Limitations of CT: low sensitivity for identifying hollow viscus injuries

Critical Interventions

- **External hemorrhage control** during primary survey
- **Access** (as central as possible, 18G or larger, bilateral): Start with the least invasive (peripheral IV) and advance as necessary to gain adequate access (IV, IO, cordis introducer central line)
- **Oxygen** for hypoxia or pre-oxygenation in anticipation of airway intervention, or in the case of pneumothorax
- **Cardiac monitor** in all patients despite initial benign presentation, alterations in heart rate may be the first indication of shock
- **Volume Resuscitation**
  - if hemodynamically unstable or evidence of large volume bleeding, give blood
  - minimize fluids to maximum of 1000 mL of LR
  - avoid worsening **"trauma triad"** (*coagulopathy, acidosis, hypothermia*)
  - consider permissive hypotension resuscitation in the correct clinical context in order to reduce the risk of destabilizing "soft" clot formation
  - Consider TXA
- **Cover patient** with warm blankets to prevent hypothermia
- **Intubate** for airway control, inadequate breathing, or anticipated course (maximally resuscitate and optimize oxygenation before intubation)
- **Early surgical consultation** if concern for urgent (versus emergent) laparotomy
  - Stable patients with low velocity penetrating trauma, without shock, peritonitis, evisceration may not require exploratory laparotomy
  - Definitive care for the unstable penetrating trauma patient requires surgical intervention

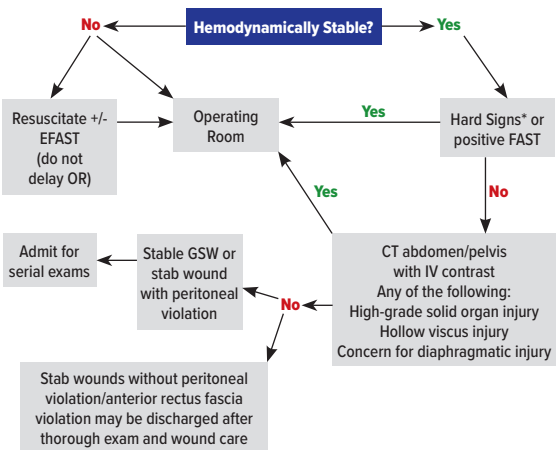
☛ TIP

- Consider broad spectrum antibiotics and tetanus immunization
- Consider reversal of anticoagulation

Additional Considerations

- Impaled objects should only be removed in OR unless it interferes with critical resuscitative efforts
- Local wound exploration is a surgical procedure and can be done at bedside by an experienced emergency physician or surgeon
  - — If no violation of anterior rectus fascia, patient may be discharged after appropriate management of injuries
  - — If peritoneal violation, obtain CT imaging and consult trauma/surgery service
- Up to two-thirds of diaphragmatic injuries are due to penetrating trauma and if missed may result in significant morbidity and mortality
  - — Diaphragm spans from 4th (T4) dermatome anteriorly to 12th dermatome (T12) laterally and posteriorly

Penetrating Abdominal Trauma Algorithm



* Hard Signs: Shock, peritonitis, evisceration

BLUNT ABDOMINAL TRAUMA

D. Cisewski, R. O'Halloran

Definition

- Abdominal injury of varying severity based on magnitude of 3 forces
  - Shearing force*:* rapid acceleration/deceleration causing tearing (eg, motor vehicle collisions)
  - Crushing force*:* pressure from anterior abdominal wall and posterior ribs/vertebrae exerted on intra-abdominal contents (eg, pedestrian struck)
  - External compression force*:* sudden, rapid rise in intra-abdominal pressure leading to rupture of viscus organs (eg, lap belt restraints)
- Causes*:* motor vehicle collisions (most common, 75%), falls, direct abdominal blows, chest compressions during CPR
- Most common injury is splenic injury

ED Presentation

- Initial presentation is often subtle: abdominal pain, nausea, gastric fullness, dyspnea, dizziness/confused (if hypotensive), neck/shoulder pain (referred — diaphragm irritation)
- Retroperitoneal visceral injuries occur deep within the abdomen
  - may not initially present with signs or symptoms of peritonitis
  - difficult to recognize
  - exacerbated by coagulopathy
  - frequent reassessments can be key in recognizing deterioration
- If severe, can present with hypotension, tachycardia, severe abdominal pain
- ☛ Unexplained hypotension in the setting of blunt abdominal trauma is intraperitoneal hemorrhage until proven otherwise (most often from a solid visceral or vascular injury)

Diagnosis and Evaluation

- **Primary survey — ABCDE** (airway, breathing, circulation, disability, exposure)
- **Vitals —** signs of hemorrhage, hemodynamic compromise, evidence of shock (shock index > 1)
- **Secondary Survey**
  - AMPLE
    - Allergies
    - Medications (special attention to blood thinners, blood pressure medications)
    - Past medical history
    - Last meal
    - Everything else
  - **Accident details**: elucidate the details of the mechanism of injury (eg, height of fall, speed of vehicle, type of weapon)

☛ TIP

- **Physical exam**
  - Assess for peritoneal signs (distention, rigidity, guarding)
  - Flank ecchymosis (**Gray-Turner sign**) and umbilical ecchymosis (**Cullen's sign**) indicate retroperitoneal hemorrhage, often late findings
  - **Note** — Ascites due to liver disease is a confounder requiring further consideration, and may alter the findings of the FAST exam
  - Rectal exam is not sensitive and unreliable for viscous injuries
  - Abdominal examination can be unreliable in certain scenarios
    - spinal cord injury (impaired pain sensation, bradycardia)
    - altered mental status/intoxication
    - distracting injuries

Imaging and Work Up

- **FAST examination** — detects as little as **100cc free fluid** (blood, gastric content)
  - RUQ: **Morison's Pouch** (hepato-renal space, identifying tip of liver), sub-diaphragmatic space, lower pole of kidney
  - LUQ: **spleno-renal recess**, sub-diaphragmatic space, lower pole of kidney
  - Pelvic (bladder): peri-bladder space, **pouch of Douglas** (most dependent areas of the pelvis)
  - Cardiac: pericardial space (typically with a sub-xiphoid view, or a para-sternal long view)
- **Chest X-ray** is routine for evaluation of the lungs and ribs. Valuable for identifying pneumothorax, rib fractures, diaphragmatic injury, free air.
- **Pelvic X-ray** is routine for evaluation of pelvic fracture. Pelvis X-ray may be helpful to identify large fractures or dislocations, but should not delay placement of binder in an unstable patient.
- **CT abdomen and pelvis with IV contrast:** definitive test in hemodynamically stable patients with no indication for emergent laparotomy (oral contrast not required but is preferred in some centers in stable patients for identification of hollow viscous injury)
- **Labs:** CBC (hemoglobin/hematocrit often normal in acute bleed); pre-operative labs (PT, PTT, type and screen), alcohol/toxicology labs (if altered, concern for intoxication)

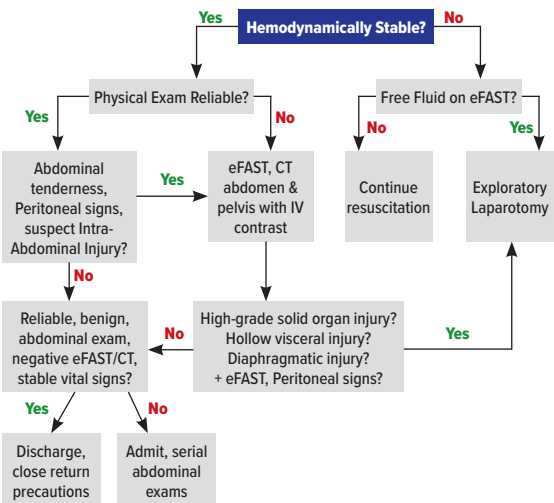
ATLS TIP

Critical Interventions

- **Access** (as central as possible, 18G or larger, bilateral): Start with the least invasive (peripheral IV) and advance as necessary to gain adequate access (ie, IV, IO, cordis introducer central line).
- **Oxygen:** for hypoxia or pre-oxygenation in anticipation of airway intervention, or in the case of pneumothorax.
- **Cardiac monitor:** in all patients despite initial benign presentation, alterations in heart rate may be the first indication of shock

- **Volume Resuscitation**
  - If hemodynamically unstable or evidence of large volume bleeding, give blood
  - Minimize fluids to maximum of 1000 mL of LR
  - Avoid worsening **"trauma triad"** (*coagulopathy, acidosis, hypothermia*)
  - Consider TXA
- **Cover patient** with warm blankets to prevent hypothermia
- **Intubate:** for airway control, inadequate breathing, or anticipated course (maximally resuscitate and optimize oxygenation before intubation)
- **Early surgical consultation** if indicated
- Consider reversal of anticoagulation

Blunt Abdominal Trauma Algorithm



SPLENIC TRAUMA

A. Prabhu, R. O'Halloran

Definition

- Spleen is large organ in left side of thorax/abdomen deep to the 9th, 10th, and 11th ribs
- Can be injured by penetrating trauma, usually to left upper quadrant of abdomen; frequently injured in blunt trauma (40–55%)
- Because it is highly vascularized, injury can lead to hemorrhage and hemodynamic instability and shock
- Initial presentation may be benign

ED Presentation

- Consider in any patient with penetrating or blunt chest, back, or abdominal trauma

TIP

- Left-sided lower rib fractures, specifically ribs 9–12, should raise high clinical suspicion
  - Splenic injury can be missed in isolated left lower rib fractures from simple trauma such as fall from standing, so maintain high clinical suspicion with left-sided lower chest, abdominal, and/or back pain/tenderness to palpation
- Signs of hemodynamic instability (tachycardia, altered sensorium, and/or hypotension) raise suspicion for splenic injury, as they may be early signs of blood loss anemia

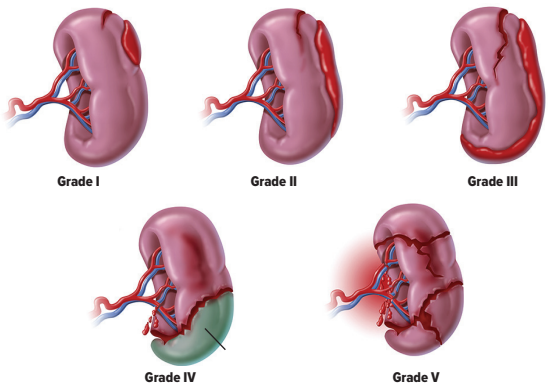
Diagnosis and Evaluation

- **Primary survey: ABCDE**
- **Vitals:** signs of hemorrhage, hemodynamic compromise, evidence of shock (shock index >1)
- **Secondary survey:** AMPLE, accident details
- **Physical exam:** Assess for peritoneal signs (distention, rigidity, guarding), flank or umbilical ecchymosis

Imaging and Work-Up

- **eFAST**
  - Bedside eFAST to assess for free fluid in abdomen or chest
  - Splenic injury leading to intra-peritoneal hemorrhage generally first causes an anechoic band or black rim around spleen in left upper quadrant
  - Negative eFAST does not rule out splenic injury; up to 25% of splenic injuries do not exhibit intra-peritoneal hemorrhage initially
- **Chest X-ray**
  - Plain films are of limited utility for evaluation of the spleen, but left lower rib fractures should heighten suspicion for liver injury

- **CT abdomen and pelvis with IV contrast**
  - Stable patient: CT with IV contrast will highlight areas of active bleeding and determine grade of splenic injury, which helps guide management; 96–100% sensitive for splenic injuries.
  - American Association for the Surgery of Trauma classifies splenic trauma based on CT imaging and/or surgical exploration
  - CT scans may also identify rib fractures, which increases risk for splenic injury



Splenic Injury Scale	
Grade	Description
I	< 1 cm depth and < 10% surface area; laceration or capsular tear, subcapsular hematoma
II	1-3 cm depth and 10–50% surface area, < 5 cm diameter; laceration, intraparenchymal hematoma, subcapsular hematoma
III	> 3 cm depth and > 50% surface area, ≥ 5 cm diameter; laceration, intraparenchymal or ruptured subcapsular hematoma, subcapsular hematoma
IV	Confined active parenchymal bleed; a pseudoaneurysm or AV fistula constitutes a splenic vascular injury; 25–75% devascularization; laceration, vascular injury, intraparenchymal hematoma
V	Vascular injury and active bleed into peritoneum; shattered spleen

Critical Interventions

- **IV access, oxygen, cardiac monitoring, volume resuscitation, cover patient** (see blunt abdominal trauma algorithm for details)
- **Intubate:** for airway control, inadequate breathing, or anticipated course (maximally resuscitate and optimize oxygenation before intubation)
- **Early surgical consultation**
  - Grade I–III lesions, hemodynamically stable: possible non-operative management in ICU setting (for frequent exams and vital signs monitoring)
  - CT contrast "blush" or active pooling of contrast within or around spleen occurs in about 17% of cases and is an important predictor of failure of non-operative management
  - Grade IV or V lacerations often cause hemodynamic instability; consider immediate laparotomy or IR embolization
- **Early interventional radiology consultation** for patients with grade II–III lesions or hemodynamically stable patients with concern for active bleeding on CT (contrast blush, pseudo-aneurysms, AV fistula)
- Consider reversal of anticoagulation

Additional Considerations

- Delayed splenic rupture may occur up to 10 days following an injury; always admit hemodynamically stable patients with known splenic injury to surgical service for close monitoring and serial abdominal exams
- Diaphragm injuries are difficult to diagnose with initial CT imaging
  - More common on left than right side
  - If suspicion is high, exploratory laparotomy or laparoscopy may be needed

LIVER TRAUMA

N. Louras, R. O'Halloran

Definition

- Solid organ made of the left and the right lobe with the falciform ligament separating the two anteriorly.
- The liver is a highly vascular solid organ whose blood supply includes:
  - The Common Hepatic Artery, which provides 25% of blood flow and 50% of oxygenation to the liver.
  - The Portal Vein, which provides 75% of blood flow and 50% of oxygenation to the liver.
  - The Hepatic Veins and Inferior Vena Cava, which drain blood out of the liver

ED Presentation

- Liver injuries may be subtle with initially benign presentations. Tachycardia (one of the first signs of blood loss), abnormal abdominal exam, or mechanism of injury should guide further diagnostic studies (see below)

☛ The liver is the most commonly involved organ in stab wounds and frequently involved in gun shot wounds. Up to 45% of blunt trauma patients with organ injuries involve the liver.

- Patients may present with referred shoulder pain from diaphragm irritation. There should be a high suspicion of injury if lower right-sided rib fractures are found.

Diagnosis and Evaluation

- **Primary survey — ABCDE**
- **Vitals —** signs of hemorrhage, hemodynamic compromise, evidence of shock (shock index > 1)
- **Secondary Survey** — AMPLE, Accident details
- **Physical exam** — Assess for peritoneal signs (distention, rigidity, guarding), flank or umbilical ecchymosis

Imaging and Work-Up

- **eFAST**
  - eFAST all to assess for free fluid in abdomen or chest
  - eFAST 98% sensitive in Grades III and higher liver injuries; can detect as little as 100 cc of free fluid
  - Negative eFAST does not rule out hepatic injury
- **Chest X-ray**

☛ Plain films are of limited utility for evaluation of the liver, but right lower rib fractures should heighten suspicion for liver injury

☛ TIP

- **CT abdomen and pelvis with IV contrast**
  - Stable patient: CT with IV contrast to highlight active bleeding and determine injury grade; highly sensitive for hepatic injuries
  - American Association for the Surgery of Trauma classifies hepatic trauma based on CT imaging and/or surgical exploration
- **Labs**
  - Include liver enzymes for trending (may be initially normal)

Critical Interventions

- **IV access, oxygen, cardiac monitoring, volume resuscitation, cover patient**
- **Intubate** for airway control, inadequate breathing, or anticipated course (maximally resuscitate and optimize oxygenation before intubation)
- **Early surgical consultation**
  - Hemodynamically stable, Grade I–III blunt injury to liver: consider non-operative management
  - Grades IV and V liver injuries have a higher likelihood of failing non-operative management, but may be observed closely if they remain hemodynamically stable in ICU

TIP

- **Early interventional radiology consult** with CT findings of contrast blush or extravasation; evaluate for catheter-directed intravascular therapy and angioembolization
- Consider reversal of anticoagulation

Additional Considerations

- Especially in solid organ injury, monitor for hypothermia, as this will lead to impaired coagulation, which in turn will worsen bleeding
- Injuries commonly associated with liver trauma: lower rib fractures, splenic injury, diaphragmatic injury

BOWEL TRAUMA

G. Prager, R. O'Halloran

Definition

- Hollow viscus injury: Any injury to the gastrointestinal tract, including the stomach, small intestine, colon or rectum, following blunt or penetrating trauma

ED Presentation

- Depends on severity of the mechanism of injury
- Physical exam findings are not specific, but may suggest intra-peritoneal injury: abdominal tenderness to palpation, distention, guarding, abdominal wall ecchymosis, evisceration, penetrating injury of unclear depth, or to the trunk or proximal extremities
- Minor external signs of trauma (contusions or abrasions) should raise concern for more serious underlying injury; more significant ecchymosis (Cullen or Grey-Turner's sign) are later signs of intra-abdominal hemorrhage
- Hollow viscus injuries may have delayed presentation in patients with rapid deceleration injuries, as well as in poorly assessable patients (intubated, intoxicated, distracting injuries)
- ☛ Any penetrating abdominal trauma (gunshot, stab wound, blast injury) with hemodynamic instability, peritonitis, or evisceration will require operative exploration

Diagnosis and Evaluation

- **Primary survey: ABCDE** (airway, breathing, circulation, disability, exposure)
- **Vitals:** hemodynamic compromise, evidence of shock (shock index > 1)
- **Secondary Survey:** AMPLE, Accident details
- **Physical exam:** Serial abdominal exams critical with blunt abdominal trauma, as presence of peritoneal signs (distention, rigidity, guarding) often appear later

Imaging and Work Up

- Imaging modalities depend on hemodynamic stability
- **eFAST**
  - eFAST for all to assess for free fluid in abdomen or chest
  - Hollow viscus injuries bleed minimally and may not produce enough blood to detect on an eFAST
  - ☛ Unstable trauma patients with positive FAST go emergently to OR for exploratory laparotomy
- **Chest X-ray**
  - Upright CXR showing free air under diaphragm suggests hollow viscus injury and should prompt further imaging (or immediate laparotomy)

- **CT abdomen and pelvis with IV contrast**
  - Best imaging test for hemodynamically stable patients regardless of eFAST findings.
  - CT findings suggestive of intra-abdominal injury: pneumoperitoneum, intra-peritoneal contrast blush, free intra-abdominal fluid, IV contrast extravasation, mesenteric hematoma
  - CT should be performed with IV contrast; the role of oral and rectal contrast is debated and can be considered depending on patient stability and location of injury
  - Consider rectal contrast for low velocity penetrating trauma to flank or back for evaluation of retroperitoneal or hollow viscus injuries
  - Confirmed intestinal perforation on CT requires immediate laparotomy
  - American Association for the Surgery of Trauma grading scales classify GI tract injuries; grades are organ-specific (stomach, small bowel, colon, rectum) and help guide surgical management
- **Diagnostic peritoneal lavage (DPL)**
  - Can evaluate for hemoperitoneum
  - Rarely performed given advances in availability, sensitivity, and speed of CT and ultrasound
  - No role in initial ED trauma management

TIP

Critical Interventions

- **IV access, oxygen, cardiac monitoring, volume resuscitation, cover patient** (see blunt abdominal trauma algorithm for details)
- **Intubate** — for airway control, inadequate breathing, or anticipated course (maximally resuscitate and optimize oxygenation before intubation)
- **Early surgical consultation**
- Prophylactic antibiotics should be given; broad-spectrum coverage is appropriate for patients with suspected hollow viscous injuries.

Additional Considerations

- Challenging diagnosis, easy to miss; > 24 hrs observation often required; admission likely (even for nonoperative management)

Negative eFAST does not rule out intra-abdominal injury. Serial eFAST exams increase sensitivity and should be always be repeated with hemodynamic change

PELVIC TRAUMA ED MANAGEMENT

D. Goodin, M. George

Definitions

- True Pelvis: Extends from pelvic brim to pelvic diaphragm
- False Pelvis: Extends from the top of the pelvic brim to top of the iliac crests
- Pelvic ring fracture: Any disruption of the large, central pelvic ring
  - Unstable pelvic ring fractures: Need two or more fractures in pelvic ring with rotational instability, including open book fractures
  - Stable pelvic ring fractures: Does not involve, or has minimal displacement of a pelvic ring fracture or transverse sacral fracture

Young-Burgess Classification			
Anterior-Posterior Compression (eg, "open book" pelvic fracture pattern)	APC I	Pubic Symphysis diastasis < 2.5 cm	Stable
	APC II	Diastasis > 2.5 cm, anterior sacral ligaments torn	Rotationally unstable, but vertically stable
	APC III	Hemipelvic separation with complete symphysis and posterior ligament disruption	Fully unstable
Lateral Compression: Transverse fracture of the pubic rami	LC I	Posterior Compression of the Sacroiliac (SI) Joint without disruption of the ligaments	Stable
	LC II	Posterior SI ligament disruption, sacral crush injuries, or iliac wing fracture	Rotationally unstable but vertically stable
	LC III	LC II with open book fracture, APC, to contralateral pelvis	Completely unstable
Vertical Shear (Malgaigne Fracture)	VS	Vertical displacement of the symphysis and sacroiliac joint	Rotational and vertical instability

General

- Most commonly caused by direct blunt trauma
- Mechanisms
  - **High energy:** Motor vehicle crashes (MVCs), pedestrians struck by cars or bicycles, are associated with more injuries
  - **Low energy:** fall from standing elderly patients
- Clinical significance
  - Hemorrhage: disruption of pelvic vasculature causes extensive bleeding; can accumulate > 1.5 L of blood
  - Bowel injury secondary to bone fragments

- GU/reproductive injury
- Neurovascular injury (incontinence, lower extremity numbness/weakness)

Primary Survey

- Evaluate ABCs
- Secure IV access
- Place patient on monitor
- Provide supplemental oxygen, if necessary
- Monitor heart rate and blood pressure to assess hemodynamics

Evaluation

- **Inspection**
  - Undress patient completely
  - Look for gross deformities of the pelvis
    - Limb-length discrepancies
      - shortened and external rotation suggests hip fracture
      - shortened and internal rotation suggest hip dislocation
    - Rotational deformities
    - Genital bruising/bleeding
    - Blood on removed clothing
  - Control bleeding as necessary
- **Palpation**
  - Done before rolling patient to limit additional shearing trauma
  - Assess for pelvic instability by medially compressing bilateral iliac crests simultaneously
  - If there is any laxity, movement or instability, **STOP**. Avoid repeat exams if pelvis unstable
    - Instruct someone else to place sheet or pelvic binder around greater trochanters
    - Do not overtighten the binder; too much pressure can worsen trauma and hemorrhage
    - Assess reduction by re-examining greater trochanters and patellae (neutral, central position)
- **Assess for secondary injuries**
  - Perineal and lower extremity loss of sensation and pulses
  - Serial abdominal exams to assess for increasing abdominal pressure and distension
  - Vaginal, perineum, and rectal lacerations could be signs of open pelvic fracture that require antibiotics and tetanus vaccine

TIP
ATLS

Imaging

- Ultrasound: in polytrauma, FAST exam helps evaluate source of bleeding
  - Unable to identify retroperitoneal/pelvic bleeding

- In a hemodynamically stable patient:
  - FAST negative: go to CT; if bleeding identified in pelvis, IR likely
  - FAST positive: go to CT to identify source of hemorrhage
- In a hemodynamically unstable patient:
  - FAST negative: IR to identify and coil bleeding vessels; if IR unavailable, consider pre-peritoneal packing in OR
  - FAST positive: hemorrhage control in OR via laparotomy; if concern for significant pelvic fracture and pelvic bleeding, consider pre-peritoneal packing in OR before IR evaluation

- Pelvic X-Ray
  - Trace the large pelvic ring in the center and 2 smaller obturator foramina
    - Look for a break in the rings. If there is one, there is likely another!
  - Check joint spaces are equal distance
  - Normal pubic symphysis ≤ 5 mm; increased distance should alert to possible open book pelvic fracture
  - Follow proximal femurs up and around iliac crests, always look for symmetry!
  - Get retrograde cystourethrogram if there is blood at urethral meatus or urinary retention before placing Foley to rule out urethral injury
- CT abdomen and pelvis with IV contrast
  - Only if the patient is hemodynamically stable
  - A patient may need a CT angiogram of the pelvis if concerned for active bleeding
    - "Blush" on CT suggests active bleeding that may require IR embolization

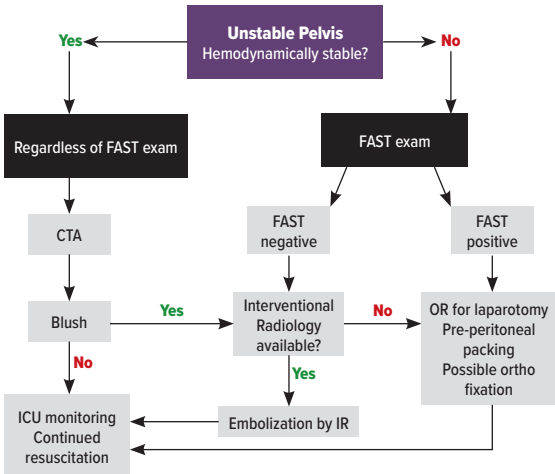
TIP
NEW

PELVIC TRAUMA

Critical Interventions

- Resuscitation
  - Start massive transfusion protocol early for patients who are hypotensive, actively bleeding and/or anticoagulated
  - Consider tranexamic acid
  - Reverse anticoagulation when possible
  - Do NOT place vascular access in lower extremity (femoral central line or tibial IO) as fluids and medications may extravasate through sheared vessels in pelvis
- Consult early!
  - Orthopedics, interventional radiology, trauma surgery
  - If appropriate, transfer to your nearest trauma center
- REBOA
  - Novel treatment approach actively being researched for pelvic hemorrhage management
  - Can be temporizing measure to decrease blood to pelvis in unstable patients with negative FAST

Pelvic Trauma Algorithm



VERTICAL SHEAR (MALGAIGNE) FRACTURE

T. Webb, M. George

Definition

- Two ipsilateral fractures of pelvic ring (one in each anterior and posterior columns)
  - Complete ligamentous disruption (especially those ligaments that provide vertical stability)
  - Vertical displacement of the hemipelvis resulting in disruption of sacroiliac joint
- Always unstable fracture
- 5% of all pelvic fractures

ED Presentation

- High energy, blunt axial force directed medially over one or both hemipelvis
- Examples: fall from height landing on lower extremities, high speed motor vehicle accident, crush injury from above
- Very high risk for hemodynamic instability from pelvic hemorrhage

Evaluation

- May reveal pelvic tenderness, deformity, or gross instability
  - Pelvic tenderness has high sensitivity and specificity for unstable fractures
  - Pelvic deformity and unstable pelvic ring are highly specific
- Pelvic instability
  - Assess with gentle, medially directed bimanual compression of both iliac wings
  - Only attempt once (risk of disrupting a blood clot/tamponade effect)
  - Do not examine further if pelvis feels unstable
- Consider GU injuries in presence of hematuria, blood at meatus, scrotal/penile or vaginal hematoma/lacerations, and difficulty/inability to void

Imaging

- Ultrasound: in polytrauma, FAST exam helps evaluate source of bleeding
  - Unable to identify retroperitoneal/pelvic bleeding
  - In a hemodynamically stable patient:
    - FAST negative: go to CT; if bleeding identified in pelvis, IR likely
    - FAST positive: go to CT to identify source of hemorrhage
  - In a hemodynamically unstable patient:
    - FAST negative: IR to identify and coil bleeding vessels; if IR unavailable, consider pre-peritoneal packing in OR

    - FAST positive: hemorrhage control in OR via laparotomy; if concern for significant pelvic fracture and pelvic bleeding, consider pre-peritoneal packing in OR before IR evaluation
- X-ray
  - AP pelvis can quickly identify significant pelvic injuries
  - For vertical shear fractures, pay close attention to
    - Vertically directed fractures
    - Superior displacement of the ipsilateral hemipelvis
    - Possible disruption of pubic symphysis (> 5 mm) or ischial ring
- CT abdomen and pelvis with IV contrast
  - Best imaging modality for pelvic ring injuries
  - IV contrast needed to identify arterial extravasation ("blush")

Critical Interventions

- Survival depends on early recognition of hemorrhagic shock and aggressive resuscitation
- Involve Ortho and Trauma surgery early
- Fluid resuscitation via massive transfusion with 1:1:1 ratio of pRBCs, platelets, FFP
- Consider tranexamic acid 1 g IV
- Venous bleeding can be often controlled via mechanical stabilization and external compression
  - Pelvic binder (bed sheet or commercial device)
    - Place over greater trochanters
    - Goal to close pubic symphysis separation & minimize bone edge movement
    - Reduces pelvic volume, creates tamponade effect, minimizes clot disruption
  - Longitudinal traction
    - Can be performed in consultation with orthopedics
- Arterial bleeding may require angiographic embolization by IR
  - Arterial hemorrhage may occur in up to 15% of hemodynamically unstable fractures
  - IR indicated in patients with:
    - Continued hemodynamic instability despite resuscitation
    - Partially responsive patients with extravasation on CT imaging
    - Declining hemoglobin requiring > 4 units in 8 hrs
- Pelvic packing in OR
  - Indicated for patients with abdominal hemorrhage requiring OR exploration or when angiography is unavailable
  - Provides tamponade effect for bony or venous bleeding
  - Requires re-operation to remove packing
  - Does not always identify source of bleed

ATLS
TIP

PELVIC TRAUMA

Additional Considerations

- ☛ Vertical shear fractures have highest risk of hypovolemic shock (up to 60%)
  - Retroperitoneum can accumulate 4L of blood prior to tamponade
- Mortality in vertical shear fractures can be up to 28%
  - Higher in patients with arterial injury
  - Hemorrhage is the most common cause of death in the first 24 hours
- Most patients with a vertical shear fracture have additional orthopedic and non-orthopedic injuries. Closed head trauma and visceral injuries (especially urological) are most common non-orthopedic injuries
- In resource-limited hospitals, consider early transfer to a trauma center for definitive management

LATERAL COMPRESSION FRACTURE

M. Villars, M. George

Definition

- Disruption of the pelvic ring from a side impact
- Leads to *internal rotation* of the pelvic ring, which can result in overlapping of pubic bones or a windswept pelvis

ED Presentation

- Most common type of pelvic fracture
- Typically present with high-energy impact on their side (MVC with impact on door, pedestrian struck on side, etc). Lateral compression fractures driven by lateral force directed medially

Diagnosis

- Pelvic radiograph useful in screening for fractures
- ☛ CT pelvis has better sensitivity and specificity for fracture than pelvic radiograph but may not be appropriate in hemodynamically unstable patients unsafe for transport to CT
- 3 fracture types: each progressive type requires greater force and results in increased instability
  - Type I (stable): Sacral compression fracture on side of impact and horizontal pubic rami fracture
  - Type II (unstable): Anterior sacrum acts as pivot as anterior pelvis rotates inward, leading to fracture in ipsilateral ilium (type I + ilium fracture)
  - Type III (unstable): Windswept pelvis. Type II fracture + contralateral anterior posterior compression fracture; requires severe force (rollover MVC or pedestrian vs. auto)

☛ TIP

Evaluation

- Check for signs of massive hemorrhage into pelvis as this can be a devastating consequence
- See pelvic algorithm for details
- Due to internal rotation of pelvis in lateral compression fractures, the area within the pelvis for blood to accumulate is actually less than in open book or vertical shear fractures so morbidity from hemorrhage is less common

Critical Interventions

- Place IV access in upper extremities; avoid femoral veins for central access
- Massive transfusion protocol (refer to General Trauma section, chapter on Fluid Resuscitation for further details)
- Consider tranexamic acid 1 g IV

- ☛ If lateral compression fracture suspected:
  - — Tight pelvic binder is *not desired* as it could worsen the degree of internal rotation of pelvis
  - — Pelvic binder is working to stabilize the pelvis rather than create a smaller volume for blood loss
- Consult orthopedic surgery early
- Consult interventional radiology early for angiography
  - — See pelvic fracture algorithm for further details

Additional Considerations

- Address hemodynamic instability; mortality rate for pelvic hemorrhage is about 50%
- Hemodynamically unstable patient with severe trauma: presence of other intra-abdominal injuries determine whether a patient goes for a laparotomy, peritoneal packing, or angiography
- ☛ REBOA is another option for pelvic hemorrhage management
- While Type I lateral compression fracture is considered stable, as in it does not need fixation and is weight bearing as tolerated, do not be fooled; 10% mortality rate due to a high incidence of associated injuries

☛ TIP
☛ NEW

OPEN BOOK PELVIC FRACTURE

S. Hickey, M. George

Definition

- Disrupts the pelvic ring and pubic symphysis, opening the pelvis like a book

ED Presentation

- Results from anteroposterior compression injury to pelvis caused by high energy mechanisms (motor vehicle accidents, pedestrian struck, elderly falls)
- Usually associated with other injuries and major hemorrhage

Diagnosis

- Pelvic radiograph often used but CT pelvis has better sensitivity and specificity
- There is a poor correlation between the anatomy of the pelvic fracture and hemodynamic instability, thus radiography needs to be interpreted in correlation with the dynamic clinical picture
- In the Young-Burgess Classification, open book fractures are the result of anterior-posterior compression (diastasis of the pubic symphysis or vertical fracture of the pubic rami)

Evaluation

- Once an unstable pelvis is identified on exam, no repeat exams should be performed.
- As with all pelvic fractures, evaluate patient for signs of massive hemorrhage into the pelvis as this can be a devastating consequence of any pelvic fracture
- **FAST Exam**
  - Perform to exclude intraperitoneal bleed.
    - ☛ In an unstable patient with a positive FAST exam and a pelvic fracture, hemorrhage control should be in the OR for laparotomy with possible pre-peritoneal packing.
    - In an unstable patient with a negative FAST exam and a pelvic fracture, the source of bleeding is likely pelvic or retroperitoneal; hemorrhage control is ideally obtained through angiography and embolization.
    - In stable patients, the results of the FAST exam are irrelevant as a CT is warranted to characterize the injuries.
- **CT abdomen and pelvis with IV contrast**
  - CT imaging is very sensitive for detecting bony injury and the IV contrast will reveal retroperitoneal and pelvic bleeding.
  - Venous bleeding is common with pelvic injuries and often resolves with binding the pelvis.
  - If arterial extravasation (“blush”) on CT is present, the patient should be considered for angiography regardless of hemodynamic stability.

Critical Interventions

- IV access should be placed in upper extremities. Avoid femoral veins for central access.
- ☛ If an open book pelvic fracture is suspected, immediate binding is imperative to decrease pelvic volume, increase tamponade effect, and prevent clot disruption
  - — Use a bedsheet or a commercial pelvic binder and wrap it around the greater trochanters.
  - — Do not overtighten the binder. Too much pressure can cause worsening trauma and hemorrhage.
- Immediate consultation with trauma surgery, orthopedics, and interventional radiology
- Massive transfusion protocol (Refer to General Trauma section, chapter on Fluid Resuscitation for further details)
- Consider tranexamic acid 1 g IV

Additional Considerations

- Unstable with a high mortality rate; addressing hemodynamic instability is first priority
- ☛ REBOA is a novel treatment approach actively being researched for pelvic hemorrhage management

GU TRAUMA: ED MANAGEMENT

C. Ju, E. Steinberg

Primary Survey

- Assess for hemodynamic instability; proceed directly to OR without further imaging if hemodynamically unstable
- Urological trauma is rarely life-threatening, so primary survey is priority to identify potentially more significant injuries

Secondary Survey

- Head-to-toe exam, specifically for: blood at urethral meatus, perineal hematoma, flank ecchymosis, pain with voiding, inability to void, gross or microscopic hematuria, vaginal bleeding
  - Absence of these signs does NOT exclude injury!
- Keep urological trauma in mind with other associated injuries: injury to flank, abdomen, lower chest, displaced pelvic fracture, low posterior rib fracture, lumbar transverse process fracture

Emergency Considerations

- Prioritize all other life-threatening injuries FIRST
- First line imaging is CT abdomen/pelvis with IV contrast (with immediate and delayed phase images)
- If urethral injury is suspected, a single attempt at placing a Foley can be made by the most experienced team member
- Obtain urologic consult early

Imaging

ATLS
TIP

GENITOURINARY TRAUMA

- Renal: CT with IV contrast
  - Indicated in blunt trauma with gross hematuria
  - Used to assess severity and extent of injury in penetrating trauma
- Ureter: CT with IV contrast with delayed images
- Bladder: Cystography test of choice (x-ray and CT cystography equally sensitive and specific)
  - MUST rule out urethral injury before evaluating the bladder
  - Imaging needed in patients with gross hematuria, pelvic fractures other than acetabular fractures, and/or patients with fluid in the pelvis
    - Relative indications:
      - Gross hematuria in the absence of pelvic fracture
      - Microhematuria with associated pelvic fracture
      - Isolated microhematuria
      - Clinical symptoms such as suprapubic pain and voiding difficulties

- Urethra: Retrograde urethrogram
  - Imaging indicated before attempting a Foley if blood at urethral meatus, inability to void, or concern for urethral injury
  - Absence of blood at urethral meatus, gross hematuria, and pelvic fracture does not exclude injury
- Scrotum/Testicles/Penis: Ultrasound
  - MRI with immediate urology consult only if US is inconclusive because repair is time sensitive

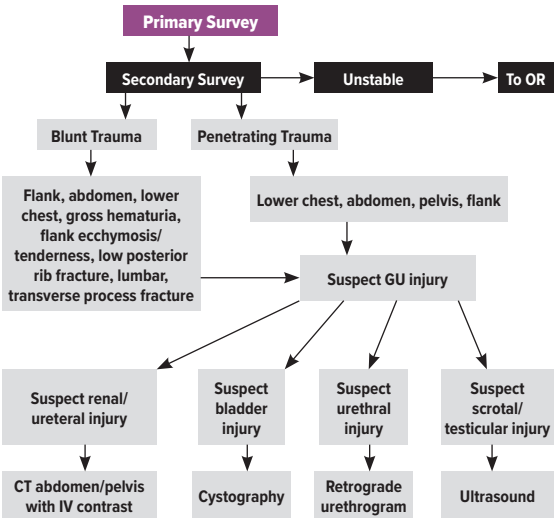
Emergency Interventions

- Any unstable patient with urological trauma goes to OR for immediate surgical exploration
- Level of hemodynamic instability and grade of renal injury determines management
- Surgical intervention for urethral injuries depends on patient stability, grade and location of injury
- ☛ Intraperitoneal bladder injuries are surgically repaired while extraperitoneal injuries are managed with urinary catheter drainage
- Penetrating injuries to external genitalia require surgical intervention to maintain sexual and reproductive functionality

Disposition

- Most patients with GU injury require admission
- All patients need outpatient urology follow up to monitor for long term sequelae of injury (renal demise, urethral stricture, erectile dysfunction, etc.)

GU Trauma Algorithm



TIP

URETHRAL TRAUMA

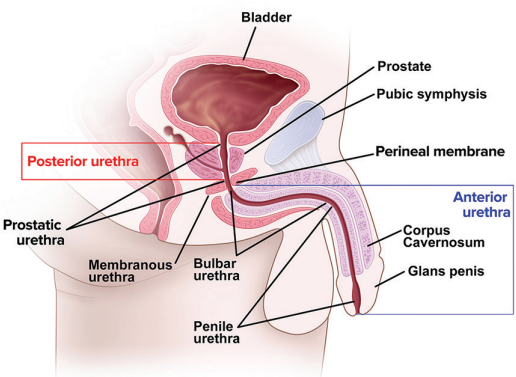
S. Rimm, E. Steinberg

Anatomy

- Two main anatomical parts: anterior and posterior

Location	Anatomy	Mechanism of Injury
Anterior • more common	Distal to perineal membrane Further divided into bulbar segment and pendulous (penile) segment	Straddle injury (bulbar) Blunt trauma to perineum Penile fractures (intraluminal) Iatrogenic (catheter placement) Penetrating
Posterior • pelvic ring fractures	Proximal to perineal membrane. Prostate and membranous portions- relatively insulated by bone and soft tissue	Blunt forces from deceleration injuries (car accidents, falls) Occurs in 10% of patients with pelvic fractures

- ***Anterior urethral injuries*** more common
  - Bulbar injuries are from iatrogenic causes and crush mechanisms
  - Penile urethral injuries tend to occur from sexual misadventure, penetrating injuries, or tears from blunt trauma
- ***Posterior urethral injuries*** strongly associated with pelvic fractures
  - Occur only with pelvic ring disruption; typically lateral compression injuries and/or rotationally unstable injuries



- Traumatic bladder neck injuries secondary to a vertical tear mechanism, such as MVC or fall, can lead to disruption at bulbo-membranous junction (more common in women because the equivalent in men would require a transverse rupture of the prostate)

ED Presentation

- Mechanism: penetrating perineal injuries, straddle injuries, car accidents, falls, pelvic injuries, or iatrogenic injuries
- Symptoms: inability to void, hematuria, dysuria
  - Hematuria not specific or sensitive enough to diagnose urethral injury
- Physical Exam
  - Evidence of perineal hematoma highly suggestive of injury
  - ☛ Identifying a high riding prostate is no longer recommended as it is neither sensitive nor specific
  - "Classic" signs may not develop within first hour
    - Butterfly hematomas from straddle injuries may take 48 hrs to develop
    - Initial urethral bleeding may not be noticed for > 1 hr
    - Urological injury in pelvic fractures often overlooked because of absent physical exam signs or misleading imaging
- ☛ Urinary retention and blood at meatus highly suggestive of posterior urethral injury
- Most females will present with vaginal bleeding; exam may reveal blood at vaginal introitus

Classification of Urethral Injury

- Three types of urethra trauma
  - Urethral contusion: incomplete rupture of part of circumference of urethra
  - Partial urethral injury: total rupture of part of the circumference of urethra
  - Complete urethral rupture: complete rupture of the entire circumference of the urethra
- Urethrography can help distinguish types of injuries
- If even part of urethra is intact after injury, healing without stricture is possible

Evaluation and Diagnosis

- OK to place Foley in severe trauma if no clear signs of urethral injury
- Inability to pass a catheter may be first sign of urethral trauma; Foley placement efforts should cease until further investigation

- Diagnosis of urethra injury is made by retrograde urethrogram (RUG)
  - Inject 20–30 mL contrast into urethra and obtain a radiograph; extravasation identifies urethral tear
  - Perform when hemodynamically stable and life-threatening injuries addressed
  - Extravasation of contrast along fascial planes of perineum indicates urethral disruption

Management

- In males with urethral injury secondary to pelvic fracture, consult urology for US-guided suprapubic catheter for:
  - Prevention of further urethral injury
  - Avoidance of pelvic hematoma disruption
  - Reduced rates of urethral stricture
  - Equally good potency and continence outcomes
- Penetrating injuries to anterior urethra require surgical exploration and repair
- Female urethral injuries are more challenging to diagnose by RUG and usually require concomitant cystography as bladder injury needs to be excluded.

PEARLS

- Urethra anatomically divided into anterior and posterior parts
- Common mechanisms of injury: penetrating perineal injuries, straddle injuries, car accidents, falls, pelvic fractures, iatrogenic injuries
- Immediate risk of urethral injury is extravasation and secondary infection leading to gangrene and septicemia; long-term complications such as stricture and fibrosis possible
- Commonly associated with multiple life-threatening injuries that should be addressed first; prioritize ABCs and resuscitation
- Retrograde urethrogram, radiographs, cystograms commonly used in diagnosis
- Communication and joint decision-making with trauma team is critical; obtain early urological consult

BLADDER TRAUMA

G. Cassidy, E. Steinberg

Definition

- Contusion: partial thickness injury that produces hematoma at site of injury
- Extraperitoneal rupture: full thickness injury of anterior or anterolateral bladder wall that results in communication between bladder and extraperitoneal space
- Intraperitoneal rupture: full thickness injury of bladder dome, resulting in extravasation of urine into peritoneal cavity

ED Presentation

- Classic triad of hematuria, suprapubic pain, and inability to void
- Blunt injury more common (60–80% of cases) than penetrating trauma
- Consider bladder injury in patients presenting with macroscopic hematuria with a pelvic fracture
- Consider bladder injury in cases of trauma to the lower abdomen. Exam may demonstrate lower abdominal bruising or swelling, perineal or scrotal edema, urinary retention, or suprapubic tenderness

Diagnosis

- Retrograde cystogram or CT cystography should be performed only after life-threatening injuries are stabilized or ruled out

Evaluation

- Retrograde cystography should be performed in stable patients with gross hematuria and a pelvic fracture or any mechanism concerning for bladder injury
  - TIP
  - 10–15% of patients with pelvic fractures have an associated bladder injury
- Retrograde cystography should also be performed in patients with pelvic fluid seen on abdominal imaging with associated pelvic fracture
- Cystography not required for isolated pelvic fractures or hematuria alone
- Cystography may be performed using conventional plain films or CT

Critical Interventions

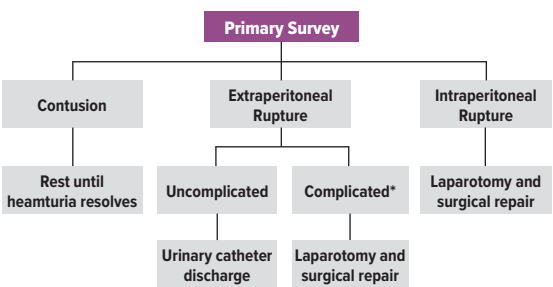
- Bladder contusion: self-limiting and requires no immediate intervention; recommendation is rest until hematuria resolves
- Intraperitoneal rupture: laparotomy and surgical repair usually required
- Extraperitoneal rupture
  - Surgical management depends on the presence of complications:
    - Urinary catheter does not allow appropriate bladder drainage
    - Associated rectal or vaginal injury
    - Associated bladder neck injury

    - Open fixation of a pelvic fracture (to avoid contamination of surgical hardware)
    - Patients undergoing surgery for other indications
  - Uncomplicated cases only require urinary catheter drainage for 10–14 days
- Consider urology consultation in all cases of bladder injury

Additional Considerations

- Cystography via urethral catheter should only be performed after urethral injury has been excluded
- CT of the abdomen and pelvis without cystography is not adequate to detect bladder rupture
- CT cystography is comparable to conventional plain film cystography in detecting bladder rupture
- Bladder contusion may be seen after intense physical activity such as long-distance running
- Bladder contusion is diagnosis of exclusion; for isolated bladder contusion, patients may be discharged home
- Pregnant women and intoxicated patients are particularly high risk for bladder rupture due to bladder fullness
- Admit bladder rupture due to high incidence of associated injuries
- 5–8% of bladder ruptures will be combined intra-/extraperitoneal ruptures

Bladder Trauma Algorithm



Complicated: (1) Urinary catheter does not allow appropriate bladded drainage, (2) associated rectal or vaginal injury, (3) associated bladder neck injury, (4) a need for open fixation of a pelvic fracture, or (5) patients undergoing surgery for other indications.

TIP

RENAL TRAUMA

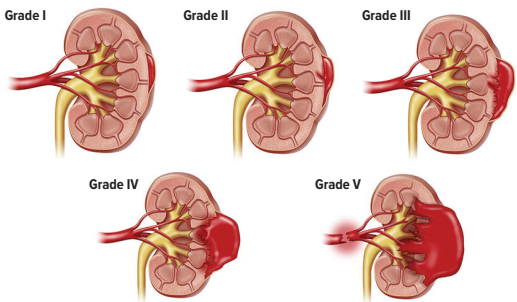
M. Fucci, E. Steinberg

General Considerations

- Renal injury is present in up to 10% of patients with abdominal trauma
- Blunt injury is most commonly caused by falls, assaults, motor vehicle crashes, sports injuries
- Penetrating injury is most commonly caused by gunshot and stab wounds

ED Diagnosis

- Obtain detailed history to determine time, mechanism, and magnitude of forces involved (restrained, seat location, speed, weapon caliber, knife type/length, retained foreign body)



Renal Injury Scale	
Grade	**Description**
I	Hematuria with normal anatomic studies (contusion), or subcapsular nonexpanding hematoma; no laceration*
II	Perirenal, nonexpanding hematoma or < 1 cm renal cortex laceration without urinary extravasation
III	> 1 cm renal cortex laceration with no collecting system involvement or urinary extravasation
IV	Laceration through cortex and medulla and into collecting system, or segmental renal artery or vein injury with hematoma
V	Shattered kidney, or vascular injury to renal pedicle, or avulsed kidney *

*In a study of 2,467 patients with renal trauma, rate of nephrectomy ranged from 0% in grade I and II injuries, to 82% in grade V injuries

- Physical exam findings and injuries that mandate consideration of renal injury include: lower rib fractures, flank contusions or ecchymosis, palpable mass, penetrating wounds to the flank
- Urinalysis: no direct relationship between presence, absence, or degree of microscopic hematuria and severity of renal injury in adults
  - Gross hematuria should prompt further investigation for more severe renal injury
  - Renal medical injuries and segmental arterial thrombosis may be present without hematuria

Imaging

- CT
  - CT with IV contrast of the abdomen and pelvis is gold standard for stable patients
  - Early contrast extravasation consistent with ongoing hemorrhage
  - If abnormal fluid collection found, delayed scan recommended to exclude urinary extravasation; can be detected once contrast-enhanced urine is excreted into collecting system (10 min)
- Ultrasound
  - Ultrasound may be used in children, but CT is preferred
- Additional Imaging
  - Intravenous pyelogram is inferior but may be used when CT unavailable

Imaging for Renal Trauma

Suspected Injury	Imaging	Comments
Renal parenchymal or vascular injury	IV contrast-enhanced abdominal-pelvic CT	Delayed films are needed to identify urinary extravasation
Any visceral injury resulting in free intra-peritoneal fluid	FAST	Identifies free fluid, but does not specify type of visceral injury
Renal artery injury	Renal angiography	Details vascular injuries

TIP

Critical Interventions

- Hemodynamic monitoring
- Blood transfusions as needed
- Bed rest
- Consider ICU admission
- Management Based on Severity of Injury:
  - Grade I and II: Usually nonoperative
  - Grade III–IV: May be operative, depending on clinical status
  - Grade V: Usually operative

Additional Considerations

- Children are more susceptible to renal injury due to lack of peri-adipose tissue and larger kidney size relative to body
- Selected patients with bleeding from segmental renal vessels may benefit from angioembolization
- Hemodynamic instability despite resuscitation, expanding or pulsatile retroperitoneal hematoma requires immediate intervention (angioembolization or surgery)

EXTREMITY AND SOFT TISSUE TRAUMA: ED MANAGEMENT

J. Novy, L. Shutler

Primary Survey

- Follow primary survey according to ATLS
- Pay special attention to patients with isolated extremity and soft tissue injuries
- Significant circulatory compromise can occur with extremity or soft tissue injury
  - Hemodynamic compromise from external or internal sources of blood loss
  - Scalp and facial lacerations can bleed profusely and need prompt attention; ask EMS if there was significant blood loss in the field
  - Isolated femur fractures can result in significant blood loss into thigh compartment and significant hypovolemic shock
  - Isolated peripheral arterial injury can cause significant blood loss
- Control all external bleeding with direct pressure
- If extremity hemorrhage cannot be controlled with direct pressure, consider tourniquet until definitive management

☛ Tachycardia is first vital sign abnormality in life-threatening hemorrhage and may not occur until 15–30% loss in blood volume; do not wait for low blood pressure to intervene!

Secondary Survey

- Full head-to-toe exam after addressing life-threatening injuries
- Special injury considerations:
  - Burns
    - Determine severity and total body surface area percentage (TBSA) (see Burn Chapter)
    - Circumferential burns to extremities may cause compartment syndrome and interrupt arterial inflow distal to burn; immediate escharotomy indicated
    - Early and aggressive fluid resuscitation (see Burn chapter)

    ☛ ATLS recommendations
      - Electrical injury: 4 mL Lactated Ringers x kg x TBSA
      - Flame/scald injury
        - > 14 years: 2 mL LR x kg x TBSA
        - Age < 14 years: 3 mL LR x kg x TBSA
- **Dislocations/Fractures**
  - Complete neurovascular exam of any extremity with suspected dislocation or fracture

  ☛ If concern for neuromuscular compromise, imaging should not delay immediate closed reduction

☛ TIP
☛ ATLS

- After reduction, repeat neurovascular exam and splint extremity prior to obtaining radiographs
- **Crush Injuries**
  - May involve profound injury to skin, muscle, bone, peripheral nerves
  - When possible, obtain baseline neurologic and vascular status
  - Involve orthopedics and vascular surgery early
  - Consider rhabdomyolysis and obtain CPK and potassium levels
- **Bites**
  - Typically mammalian: dog, cat, human, rodent
  - Evaluate for damage to underlying tissues (bone, tendon, joint, muscle) and risk factors for infection and poor wound healing
  - Avulsion and crush injuries characteristic of dog bites (strong force of jaw)
  - Puncture wounds with bone/joint inoculation seen with cat bites (long, fine teeth)

Critical Interventions

- Obtain tetanus immunity status when possible
- Consider rabies immune globulin and vaccine for animal bites
- Immediately administer IV calcium gluconate for any patients (notably burn victims and those with crush injuries) with EKG changes consistent with hyperkalemia to stabilize myocardium and prevent/correct life-threatening arrhythmia
- Immediate fluid resuscitation of burn victims and crush injuries to prevent/limit renal injury; do not wait for lab results!
- Provide antibiotics for bite wounds
  - Amoxicillin/clavulanate 875 mg/125 mg po BID x 7–10 days
  - If PCN allergy, consult *EMRA Antibiotic Guide* for alternatives
- Do not close puncture wounds due to high risk of deep tissue infection

Additional Considerations

- Head, scalp, and face are highly vascular; significant blood loss can occur. Importantly, pediatric patients can suffer extensive volume losses.
- Copiously irrigate large or deep lacerations and examine carefully to rule out foreign material before closing wound
- Although burn victims are at risk for hyperkalemia this is typically not present during initial evaluation
- Significant soft tissue injuries, especially those involving skeletal muscle such as crush injuries and extensive burns, can result in rhabdomyolysis and kidney injury

☛ Prolonged extrication from crush injury may lead to hyperkalemia at presentation; avoid succinylcholine if intubation needed

- For human bites, consider Hepatitis B and HIV prophylaxis

- Extremity trauma may be accompanied by vascular injury. Examine injured extremities for hard and soft signs of extremity arterial injury
  - Hard signs: pulselessness, bruit/thrill, pulsatile hemorrhage, distal ischemia, pulsating or expanding hematoma
  - Soft signs: injury is in close proximity to a vascular structure, major single nerve deficit, non-expanding hematoma, diminished pulses, posterior knee or anterior elbow dislocation, hypotension or moderate blood loss prior to arrival

AMPUTATION

M. Rivera, L. Shutler

Definition

- Two broad categories
  - — Partial amputations: still connected by bone, muscle, or tissue
  - — Complete: no connection

Mechanism of Injury

- Guillotine/sharp
  - — Minimal damage to surrounding tissue, well-defined
  - — Best candidate for revascularization/reimplantation
- Crush
  - — General damage to surrounding tissue, poorly defined
  - — Lower success rates with revascularization/reimplantation
- Avulsion
  - — Significant damage to nerves and vasculature, often at different location from primary site due to stretching and tearing
  - — Revascularization/reimplantation unlikely
- Blast
  - — Extensive deformity and destruction, multiple zones
  - — Usually not amenable to revascularization/reimplantation

Evaluation

- History
  - — Mechanism of injury as discussed above
  - ☛ Time of amputation is an important factor in determining prognosis of revascularization/reimplantation
    - Warm ischemia time (absence of cooling): 6 hrs, up to 12 for digits
    - Cold ischemia time (appropriate cooling): 12 hrs, up to 24 for digits
  - — Comorbidities that may detract from successful revascularization/reimplantation
    - Smoking
    - Peripheral vascular disease
    - Diabetes
    - Rheumatological disease
  - — Considerations for reattachment: handedness, occupation, hobbies
- Physical Exam
  - — Neurologic
    - Assess for range of motion
    - Assess for 2-point discrimination in each nerve distribution

☛ TIP

- Vascular (partial amputations)
  - Assess capillary refill
  - Assess for presence of pulses distal to injury
  - Note color of at site of amputation (eg, dusky or cyanotic)
- Soft tissue and bone
  - Assess skin and muscle integrity, note any exposed bone or fracture sites

Critical Interventions

- Always begin with ABCs and ATLS and address any life-threatening conditions to stabilize patient
- Establish IV access
- Control bleeding: If tourniquet used, place as close to site of amputation/hemorrhage as possible, but not over injury
- Note the time
- Consult specialists as soon as possible
- Management of severed part
  - Wash with warm water
  - Wrap in moist gauze
  - Place in dry, sealed plastic bag
  - Place bag with amputated part in another bag with ice
- Antibiotics: cefazolin 2 g IV q4 or vancomycin 15 mg/kg IV (2 g max)

PEARLS

- Get Vascular Surgery involved as soon as possible
- Handling of Severed Limb
  - Rinse severed body part with saline to remove any debris that may contaminate the wound
  - Wrap the cleaned severed body part in saline soaked gauze
  - Place the severed body part in a sealable plastic bag
  - Place the sealed plastic bag in an ice water bath
  - DO NOT put the severed body part directly in contact with water or ice
- DO NOT make the decision on whether a body part can be reattached
- DO NOT make the decision that a body part is too small to be reattached

TIP

OPEN FRACTURE

K. Kim, L. Shutler

Definition

- Any fracture associated with breakage of overlying skin allowing direct communication between the fracture and the environment

ED Presentation

- Typically present after traumatic events (MVCs, falls, blunt or penetrating trauma)
- Can be obvious with direct visualization of bone, but can also be subtle; look for lacerations, avulsions, or puncture wounds over areas with confirmed fractures

Diagnosis

- Radiographic confirmation of fracture with clinical visualization of skin breakage overlying fractured area
- Saline load test (has replaced the need for methylene blue injection) is useful to assess for laceration communicating with the joint space

Classification

- Gustilo Anderson classification system most common. Studies demonstrate higher grade injury correlated with higher risk of infection and other complications
  - Type I: Laceration < 1 cm and no signs of contamination

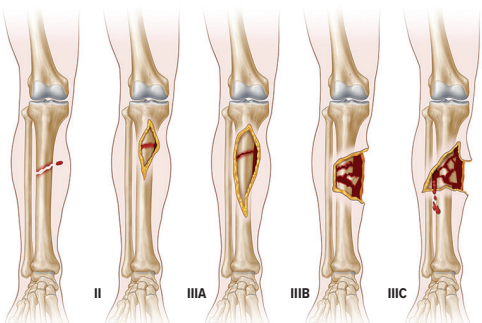


IMAGE ADAPTED FROM KANAKARIS NK, ET AL. OPEN FRACTURES. IN: LASANIANOS NG, KANAKARIS NK, GIANNOUDIS PV. EDS. TRAUMA AND ORTHOPAEDIC CLASSIFICATIONS: A COMPREHENSIVE OVERVIEW. SPRINGER;2014:487–493.

NEW

EXTREMITY/ SOFT TISSUE TRAUMA

- Type II: Laceration 1–10 cm with moderate signs of contamination
- Type III: Laceration > 10 cm with extensive soft tissue injury and massive contamination; further subdivided
  - IIIA: Adequate soft tissue coverage with no periosteal stripping
  - IIIB: Extensive soft tissue loss with periosteal stripping and bone damage
  - IIIC: Associated arterial injury requiring vascular repair, regardless of level of soft tissue injury

Evaluation

- Control bleeding and follow ABCs
  - Open fracture may be a distracting injury
- Assess for active bleeding and apply direct pressure if necessary
- Hemodynamically stable and no life-threatening injuries: begin to examine open fracture
  - Perform neurovascular exam — assess pulses, sensation, ROM distal to injured site
    - ☛ Immediately reduce gross deformities or dislocations associated with decreased or absent pulses
    - If high concern for vascular injury, obtain CTA
    - If concern for vascular injuries, obtain an ankle brachial index (ABI)
      - ABI > 0.9 is normal
      - ABI < 0.9 is concerning for vascular injury
  - If concern for traumatic arthrotomy, consider saline load test
  - If concern for compartment syndrome, measure compartment pressures (> 30 mmHg or delta pressure > 30 abnormal)
- If stable enough for extensive imaging, consider radiographs, including joint above and below the fracture

Critical Interventions

- If active bleeding from fracture site, control with direct pressure or tourniquet proximal to injury
- If concern for neurovascular injury, reduce promptly in ED
- Fasciotomy if compartment pressures are elevated
- Immobilize affected limb
- ☛ Administer antibiotics within 3 hrs of presentation (preferably within 1 hr)
  - Grade I and II: 2 g cefazolin (consider vancomycin if allergies)
  - Grade III: Add aminoglycoside
- Administer tetanus if no booster within past 5 years

☛ TIP

Additional Considerations

- Appropriate analgesia
- Consult orthopedic surgery
- Prompt irrigation and debridement
  - Typically performed in OR
  - If ortho unavailable, irrigate with low pressure, sterile, isotonic saline solution
- Additional antibiotic recommendations
  - Farm injuries, heavy contamination, or possible bowel contamination: consider high-dose penicillin G
  - Freshwater wounds: consider fluoroquinolones or 3rd/4th generation cephalosporin
  - Saltwater wounds: consider doxycycline and ceftazidime or a fluoroquinolone

SCALP LACERATION

S. Alazar, L. Shutler

ED Presentation

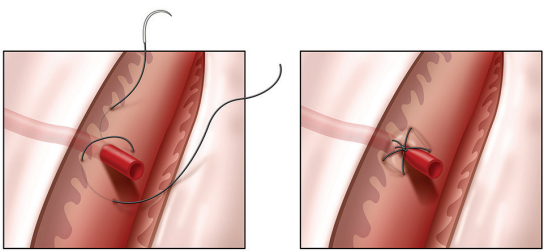
- Common injuries; typically fall under secondary survey during a trauma resuscitation unless there is a significant amount of hemorrhage, warranting immediate hemostasis

Evaluation

- Length, depth, shape of the laceration
- Significant hemorrhage can occur in pre-hospital setting: ask EMS for field blood loss!
- Age of the wound
- Any foreign body or other contamination
- Laceration of the galea
- Skin loss
- Any bony injury
- Ask about anticoagulant or antiplatelet medications

Scalp Laceration Repair

- Hold direct pressure up to 15 minutes to achieve hemostasis
- Irrigate the wound (thoroughly) with normal saline or sterile water
- Apply lidocaine (preferably with epinephrine) as the local anesthetic
- Forceps with teeth can be used to bring the edges of the skin together
- Repair should be performed with either staples or 3.0 or 4.0 nonabsorbable or absorbable interrupted sutures
- Hemostasis of bleeding vessels can be achieved quickly with a figure-of-8 stitch



Achieve hemostasis from injured tissue or small "arterial pumper" by placing stitch above and then below the site of the bleeding ("figure-of-8 stitch"). Tying the suture together tamponades the bleeding vessel with surrounding tissue.

TIP
NEW

- Staples and sutures should be removed in 7 to 10 days for small wounds and 10 to 14 days for large wounds (See Wound Repair and Closure appendix)
- Staple v. sutures for scalp laceration repair
  - Similar morbidity associated with both wound closure techniques
  - Staples frequently less painful and often faster
  - Staples significantly less risk of needlestick
- Hair apposition technique may be a useful alternative to staples or sutures
- Deep scalp lacerations may result in injury to the galea aponeurosis

Additional Considerations

☛ Galeal laceration repair
  - Useful for cosmetic purposes
  - Prevents potential spread of hematoma or infection
  - Perform if laceration is at least 0.5 cm
  - Use 3.0 or 4.0 absorbable simple interrupted sutures
- Neurosurgical consultation, especially if there is any bony deformity or fracture
- Consider CT head if patient on anticoagulation or any concern for skull fracture or intracranial injury
- Update tetanus vaccination if necessary

☛ TIP

PERIPHERAL ARTERY INJURY

M. Sumicad, L. Shutler

Definition

- Blunt or penetrating trauma to an extremity causing vascular compromise
- Most common causes are knives or guns, but also industrial accidents, MVA, falls, and explosions

ED Presentation

- Ongoing hemorrhage, obvious arterial bleeding, and presence/necessity of a tourniquet are positive signs.
- Should be considered in a persistently hypotensive patient with adequate fluid resuscitation.

Diagnosis

- Look for the Hard and Soft signs of vascular injury

Hard Signs	Soft Signs
Pulselessness	Diminished pulses
Expanding hematoma	Stable hematoma
Palpable thrill	Proximity to vascular structures
Audible bruit	Peripheral nerve injury
Ischemic limb	Unexplained hypotension
Pulsatile bleeding	Hemorrhage at scene

- "Hard signs": OR exploration; no need for imaging with one exception: shotgun wound to evaluate fragmentation
- "Soft signs": More detailed physical exam. Assess vascular integrity, nerve function, skeletal injury, and soft tissue injury; always helpful to compare to contralateral side
- Arteriogram is gold standard imaging; CTA and US more commonly used

Evaluation

- Patients with suspected peripheral vascular injury (soft signs or concerning mechanism) should get an Ankle Brachial Index (ABI)
  - ABI > 0.9 is normal
  - ABI < 0.9 is concerning for vascular injury
  - Abnormal ABI requires further investigation and imaging, most commonly with CTA
- If upper extremity injured, compare to contralateral limb with a Brachial/Brachial Index
- Normal physical exam and normal ABI or BBI, in the absence of other injuries, can be safely discharged; peripheral artery injury extremely unlikely
- Blood tests are not vital for evaluation of arterial injury but are commonly drawn as part of trauma protocol

TIP

Critical Interventions

- Immediately reduce displaced or angulated fractures or dislocations
- For obvious bleeding, apply external pressure or tourniquet proximal to injury for up to 6 hrs
- ☛ Do not apply clamps or hemostats to control bleeding as they can lead to unintended vascular or nerve damage
- Give antibiotics prior to surgery; 3rd generation cephalosporins preferred

Additional Considerations

- Brachial artery is the most commonly injured upper extremity artery. Early management is critical because rapid surgical repair has a higher recovery rate.
- Subclavian artery is uncommonly involved. Penetrating mechanism is the usual cause and up to 60% of patients have concomitant pneumothorax or hemothorax.
- Popliteal artery injury is typically from a posterior knee dislocation.

☛ TIP

DISLOCATION

T. Huang, L. Shutler

Definition

- Common traumatic injury, frequently found during secondary survey
- Complete separation of bone from a joint (vs. subluxation, which involves partial separation)
- May be associated with fracture, neurovascular injury, and/or damage to other adjacent structures

ED Presentation

- Typically present after high-speed injury or direct blow to affected limb
- Pain/deformity of involved joint, with characteristic appearance depending on specific type of dislocation

Diagnosis

- X-rays usually diagnostic
- CT may be needed if x-rays inconclusive and high index of suspicion

Evaluation

- Assess for skin, neuromuscular function, vascular injury, evidence of skeletal or ligamentous injury
- ☛ Evidence of vascular compromise (cool to touch, prolonged capillary refill, diminished pulses, decreased ankle/brachial index) indicates potential limb-threatening injury
  - — Needs emergent reduction (foregoing x-ray confirmation is prudent)
  - — If unable to reduce: splint, x-ray, and obtain emergent surgical consultation (CT angiogram may be warranted)
- ☛ Perform and document neurovascular examination before and after splinting/reduction

Notable Dislocations

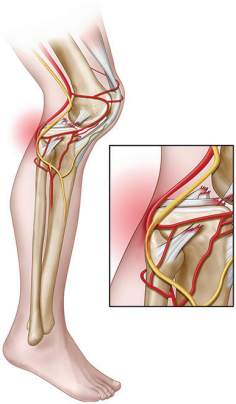
- Sternoclavicular
  - — Anterior dislocation more common than posterior
  - — Mechanism: high-speed, direct blow
  - — Presentation: anterior chest and shoulder pain, worse with arm movement
    - Prominence of sternoclavicular joint if anterior dislocation
    - May have dyspnea or dysphagia if posterior dislocation
  - — Best visualized on CT
  - — Posterior dislocation concerning for internal injury to mediastinal structures (eg, trachea, subclavian and brachiocephalic vessels, lungs, laryngeal nerve)
  - — Posterior dislocations need emergent reduction; consult ortho/CT surgery

- Shoulder
  - Anterior dislocation most common
  - Mechanism: trauma from fall or forceful throwing motion
  - Presentation: shoulder squared off, patient holding arm in slight abduction and external rotation
  - Associated injuries:
    - Axillary nerve injury: sensory deficit over lateral shoulder and motor deficit of deltoid preventing abduction of arm
    - Bankart lesion: disruption of glenoid labrum +/- bone avulsion
    - Hill-Sachs deformity: cortical depression of humeral head, greater tuberosity fracture
- Elbow
  - Posterior dislocation most common
  - Most common dislocation in children
  - Mechanism: Fall on outstretched hand
  - Presentation: prominent olecranon posteriorly
  - Associated injuries:
    - Ulnar nerve: sensory deficit in little finger and motor deficit reduces index/little finger abduction
    - Median nerve: motor deficit reduces index tip flexion
    - Brachial artery: compromised vessel can lead to Volkmann's contracture
- Hip
  - Posterior dislocation most common
  - Mechanism: high-speed injury, typically in young patients
  - Presentation
    - Posterior dislocation: hip flexed, adducted, internally rotated
    - Anterior dislocation: hip extended, abducted, and externally rotated
  - Associated injuries:
    - Sciatic nerve: sensory deficit in foot and motor deficit reduces ankle dorsiflexion/plantarflexion
    - Posterior acetabulum and femoral head fractures
    - Knee injury

TIP

- Knee
  - **Limb-threatening injury!** Associated with a high rate of vascular injury, necessitates **emergent reduction and potential imaging of vessels in popliteal fossa**
  - Mechanism:
    - Posterior: direct blow to proximal tibia (eg, from dashboard)
    - Anterior: hyperextension injury
  - Presentation: knee with loss of normal contour, held in extension

— Beware: *knee may spontaneously reduce prior to exam* in half of all cases
  - May present without obvious external or radiographic evidence of injury
  - Evaluate for potential vascular injury if any concern of knee dislocation:
    - ♦ Ankle-branchial index measurements
    - ♦ Definitive testing with CTA
— Dimple sign
  - Groove at medial joint line indicating posterolateral dislocation
  - Reduction in ED contraindicated (needs OR reduction) because skin and soft tissue get stuck in medial joint space, preventing reduction
— Associated injuries
  - Common peroneal nerve: sensory deficit of dorsum of foot and lateral shin; motor deficit reduces ankle dorsiflexion/eversion,
  - Posterior tibial nerve: sensory deficit of sole of foot and motor deficit of toe flexion
  - Popliteal artery



☛ Ankle/brachial index is a fairly reliable non-invasive test to identify vascular injury in a suspected knee dislocation
  - ABI > 0.9 ➙ continue serial exams
  - ABI < 0.9 ➙ concerning for vascular injury therefore obtain arterial duplex or CT angiogram

☛ TIP

BURNS

C. Reisig, A. Katz

Introduction

- Nearly 500,000 patients receive treatment for burns in the United States annually
- Approximately 3,000 people die annually from smoke/inhalation injuries

Burn Assessment

- Characterized by anatomic location, mechanism, depth, and size

Mechanism

- **Thermal** burns occur when skin is exposed to excessive heat and can be caused by:
  - Fire, open flame, combustible materials
  - Scalding from grease, liquid, or steam
  - Contact with hot objects (irons, coils, etc.)
- **Chemical** burns result from exposure to acid and alkali materials
- **Electrical** burns are caused when electrical currents pass through the body. Internal injuries are typically worse than external skin findings due to different conduction/resistance of superficial and deep tissue
- **Radiation** from radiofrequency energy or ionizing radiation can cause burns to skin and tissue. The most common type is a sunburn

Depth

- American Burn Association (ABA) classifies burns by thickness rather than by "degrees"
- Single burn may contain regions with different depths; burn is classified by deepest thickness

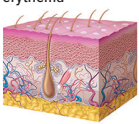
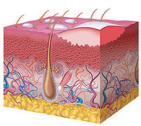
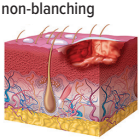
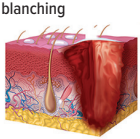
☛ Make special note of **circumferential full-thickness burns,** as high risk for compartment syndrome and may require emergent escharotomy

Size

- Quantified by determining percent body surface area (% BSA)
- % BSA often estimated by "rule of nines" or Lund and Brower chart
- Patient's palm can also be used to estimate burn size: 1 palm correlates with ~1% BSA
- **Superficial burns do not count toward % BSA estimates**

☛ TIP

SPECIAL POPULATIONS

Burn Thickness (Outdated "Degree" rating)	Skin Structure Involved	Appearance	Pain	Prognosis without surgery
Superficial (1st degree)	Epidermis	Dry, blanching erythema 	Painful	No scarring, heals 5–10 days
Superficial partial thickness (2nd degree)	Upper dermis	Blisters, wet blanching erythema 	Painful	No scarring, heals < 3 weeks
Deep partial thickness (2nd degree)	Lower dermis	Yellow or white, dry, non-blanching 	Decreased sensation	Potential for scarring, heals 3–8 weeks
Full thickness (3rd degree)	Subcutaneous structures	White or black/ brown, non-blanching 	Decreased sensation	Will scar; heals by contracture > 8 weeks

Initial Management

- **Airway**
  - Intubate early if concern for inhalation injury or dynamic airway: facial burns, singed facial or nose hair, soot or carbonaceous debris in nares/oropharynx, stridor, hoarse voice, respiratory distress
  - Anticipate difficult intubation secondary to laryngeal edema or eschar. First pass success is critical, as each subsequent attempt will likely worsen intubation conditions
  - Once intubated, employ a lung-protective ventilation strategy
  - When possible, use an endotracheal tube size 7.5 mm ID or larger, which will make ventilation, clearing secretions, and bronchoscopy easier.
- **Breathing**
  - Apply 100% FiO_2 for any patient with suspicion for inhalation injury or carbon monoxide toxicity
  - Consider concomitant cyanide toxicity with inhalation injuries
  - Check for circumferential thoracic burns that could restrict chest wall excursion; perform escharotomy when indicated
- **Circulation**
  - Establish multiple large-bore IVs, going through burned skin if necessary
  - Remove all jewelry or restrictive attire before soft-tissue edema develops

Diagnostic Studies

- Minor burns (< 20% BSA in patients free of vital sign abnormality, inhalational injury, and/or polytrauma) do not require lab work
- For major burns, lab work should focus on assessing end-organ perfusion (BMP, ABG/VBG, lactate, carboxyhemoglobin) and anticipatory need for surgical intervention (CBC, coags, type and screen)
- Obtain pregnancy test in all appropriately aged patients (pregnancy lowers threshold to initiate hyperbaric oxygen in carbon monoxide toxicity)
- CXR for intubated patients or those with suspected smoke inhalation injury
- If available, fiberoptic laryngoscopy or bronchoscopy may better characterize inhalational injuries

Volume Resuscitation

TIP

- Major thermal burns (> 20% BSA in adults and > 10% BSA in pediatrics and elderly) result in large fluid shifts and losses due to capillary leak from inflammation, requiring aggressive volume resuscitation
- Volume resuscitate with **crystalloid**; colloids not recommended in ED burn management

SPECIAL POPULATIONS

☛ Due to concern with over-resuscitation when using Parkland formula (4 mL LR x weight (kg) x %TBSA), current ABA consensus modifies formula for initial fluid resuscitation:
  - **2 mL of lactated ringer's x weight (kg) x % TBSA**
  - Infuse half of total volume over the first 8 hour and remainder over subsequent 16 hrs
- Fluid resuscitation should be titrated to a target urine output of 0.5 cc/kg/h in adults

Treatment

- **Aggressive pain control is essential to burn care**. Major burns may require large doses of narcotics and/or other analgesics such as ketamine
- Update tetanus vaccines in all burn patients; if < 3 prior tetanus vaccines (or status unknown), administer tetanus immunoglobulin as well
- If high clinical suspicion for cyanide toxicity and labs not immediately available, consider consulting toxicology
- Elevated carboxyhemoglobin levels, especially in an obtunded and/or pregnant patient, should prompt timely coordination of care with a hyperbaric facility
- **Systemic antibiotics not routinely indicated in acute burn care**

Emergent Escharotomy

- Circumferential, full-thickness burns can result in compartment syndrome as soft tissue swells
- Extensive deep burns to torso can limit chest wall excursion and compromise ventilation
- Escharotomy (incision through eschar to the subcutaneous fat) indicated by signs of limb ischemia (decreased pulses or new neurologic deficits) or poor ventilation
- Escharotomy incisions should attempt to avoid neurovascular structures when possible

Wound Care

- Goal is **wound cleanliness and barrier protection**
- Initially clean all thermal burns with sterile water or normal saline
- Decontamination crucial for chemical burns; treatment includes removal of all contaminated clothing and copious irrigation
- **Superficial burns**: routine skin care, pain control
- **Partial-thickness burns:** topical agents (bacitracin or mupirocin) to provide barrier and antimicrobial protection. Wide range of acceptable occlusive dressings (both with and without antimicrobial properties) can be used; choose based on burn location, patient's comfort with dressing changes, and product availability

☛ NEW

- **Full-thickness burns:** may be treated additionally with topical silver sulfadiazine
  - ☛ **Avoid silver sulfadiazine in partial-thickness burns as it can impair healing**
- No best practice consensus for deroofing or aspirating blisters; reasonable to open tense, painful blisters or blisters that cross joint lines for patient comfort

ABA indications for burn center transfer

- Partial-thickness burns > 10% body surface area
- Burns that involve the face, hands, feet, genitalia, perineum, or major joints
- Full-thickness burns in any age group
- Electrical burns, including lightning injury
- Chemical burns
- Inhalation injuries
- Burn injury in patients with preexisting medical disorders that could complicate management, prolong recovery, or affect mortality
- Any patients with burns and concomitant trauma (such as fractures) in which the burn injury poses the greatest risk of morbidity or mortality. **Conversely, if the trauma poses the greater immediate risk, the patient may be stabilized in a trauma center before transfer to a burn unit.**
- Burned children in hospitals without qualified personnel or equipment for the care of children
- Burn injury in patients who will require special social, emotional, or rehabilitative intervention

PEDIATRIC TRAUMA

T. Walsh, A. Katz

Overview

- Trauma is leading cause of death in children across all age groups
- > 10,000 children in U.S. die from serious injury each year
- Blunt trauma constitutes majority of injuries in children

Pediatric Vital Signs

Age	Weight (kg)	Heart Rate (beats/min)	Blood Pressure (mmHg)	Respiratory Rate (breaths/min)
0–12 mos	0–10	< 160	> 60	< 60
1–-2 yrs	10–14	< 150	> 70	< 40
3–5 yrs	14–18	< 140	> 75	< 35
6–12 yrs	18–36	< 120	> 80	< 30
≥ 13 yrs	36–70	< 100	> 90	< 30

Essential Formulas

- Minimum SBP: 70 + (age x 2)
- ETT size: (age/4) +3.5 (cuffed ETT; add 0.5 size for uncuffed ETT)
- ETT depth: 3 x ETT size
- Weight (kg): 10 + (age x 2)
- Broselow™ Pediatric Emergency Tape to rapidly determine weight based on length for appropriate drug doses and equipment size

Initial Management

- **Airway**
  - Large occiput and anterior airway are risks factors for airway obstruction and apnea
    - Place 1-inch layer of padding beneath torso to preserve neutral alignment of spinal column
  - Use cuffed endotracheal tubes for children > 1 yr
  - Use RSI when intubating to optimize first pass success
- **Breathing**
  - **Most cardiac arrests in pediatric trauma are due to hypoxia and not hypovolemia.** Pre-oxygenation is critical.
- **Circulation**
  - Peripheral access can be more difficult, especially in shock. IO access should be obtained after two failed attempts at peripheral IVs.
  - **Hypotension is a late finding in children and is an indicator of decompensated shock with severe blood loss of greater than 45% of the circulating blood volume.**

— For initial fluid resuscitation, administer warm isotonic crystalloid 20 mL/kg bolus, followed by 1–2 additional boluses. If there is no improvement, administer 10 ml/kg of pRBCs.

☛ There is a movement towards crystalloid restrictive balanced blood product resuscitation in children presenting with hemorrhagic shock.

- Consider starting with an initial 20 mL/kg bolus of isotonic crystalloid followed by 10–20 mL/kg of pRBCs and 10–20 mL/kg of FFP and platelets.
- Published studies supporting this approach are lacking and have not been able to demonstrate a survival advantage.

■ **Disability**

— Pediatric GCS

- Score ≤ 8 = intubate

	Child	Infant	Score
Eye opening	Spontaneous	Spontaneous	4
	To speech	To speech	3
	To pain only	To pain only	2
	No response	No response	1
Best verbal response	Oriented, appropriate	Coos and babbles	5
	Confused	Irritable cries	4
	Inappropriate words	Cries to pain	3
	Incomprehensible sounds	Moans to pain	2
	No response	No response	1
Best motor response*	Obeys commands	Moves spontaneously, purposefully	6
	Localizes painful stimulus	Withdraws to touch	5
	Withdraws to pain	Withdraws to pain	4
	Flexion in response to pain	Abnormal flexion posture to pain	3
	Extension in response to pain	Abnormal extension posture to pain	2
	No response	No response	1

■ **Exposure**

— Increased risk for hypothermia due to high ratio of body surface area to body mass. Keep patient covered and use warm fluids or blood when possible

NEW

SPECIAL POPULATIONS

Pediatric Injuries by System

- **Head Injury**
  - Leading cause of death in pediatric traumas
  - Bulging fontanelles in infants concerning for intracranial injury
    - Infants may develop symptoms of elevated ICP **later** than adults due to compensation from open cranial sutures and fontanelles
  - Infants can lose a significant amount of blood from scalp lacerations or intracranial bleeds, leading to hypotension
  - Seizures more common in pediatric population after head injury, but usually self-limited
- **Chest Injury**
  - > 2/3 of injuries involving chest have multiorgan system involvement
  - **Pulmonary contusion** is most common injury; may not be seen on initial x-ray
  - Rib fractures and mediastinal injuries uncommon; if present, presume significant mechanism of injury
  - Mobility of mediastinal structures makes children more susceptible to tension pneumothorax
  - Needle decompression: 2nd intercostal space in the midclavicular line
  - Tube thoracostomy: 5th intercostal space in the anterior axillary line
- **Abdominal Injury**
  - Blunt abdominal injuries more common than penetrating injuries
  - Children with severe injuries can have minimal physical exam findings
  - **Spleen is most commonly injured solid organ,** followed by liver and bowel
  - Blunt hepatic injury most common cause of fatal intra-abdominal injury in children
  - Pancreatic injury relatively rare, caused by direct blow to epigastric region (eg, handlebar injury while riding a bicycle)
  - Hollow viscus injuries caused by direct blow or acceleration-deceleration injury
    - Symptoms may be mild and non-specific initially, making it difficult to diagnose
    - Consider in setting of abdominal pain, peritonitis, fever, and vomiting
    - Duodenal injuries often present days later when hematoma causes partial or complete obstruction, leading to bilious emesis and abdominal pain
  - FAST exam less reliable in children
    - Negative in 30% of children with solid organ injury
    - FAST unable to evaluate retroperitoneal structures
    - Should not be relied upon as sole diagnostic test to rule out intra-abdominal injury

- A CT or FAST that is positive for blood alone does not mandate a laparotomy in children who are hemodynamically normal or stabilize rapidly with fluid resuscitation
- Bleeding from liver, spleen, or kidney may be self-limited

- **Genitourinary Injury**
  - Uncommon in children
  - Associated with pelvic fractures
  - Bladder is less protected by pelvis, making it more susceptible to injury
  - Microscopic hematuria is poorly predictive of urologic or intra-abdominal injury but often used for screening after blunt trauma
  - Gross hematuria is more indicative of injury, but still unreliable
  - Microscopic hematuria > 25 RBC/HPF warrants CT scan
- **Spinal Injury**
  - Plain radiographs to evaluate for cervical spinal fractures
  - Spinal cord injury without radiographic abnormalities (SCIWORA) more common in children
  - Up to 2/3 of children with spinal cord injury have normal x-rays
  - Increased laxity of ligaments and weaker supporting musculature make spinal injuries without bony injury more common
  - CT/MRI should be used only if neurologic deficits are found on exam or if x-rays are inconclusive
  - **Chance fracture** caused by high energy flexion injury
  - Associated with seatbelt use and intra-abdominal injury such as hollow viscous injury and mesenteric lacerations
- **Extremity Injuries**
  - Incompletely calcified bones lead to more radiographically negative or greenstick injuries
  - Blood loss from long bones are less common in children. Evaluate for other injuries in a patient in shock
  - ☛ Suspect child maltreatment with:
    - Multiple subdurals
    - Retinal hemorrhages
    - Perioral injuries
    - Genital and perianal injuries
    - Long bone fractures in children < 3 years old
    - Posterior rib fractures or skull fractures in children < 24 months
    - Burns or bites

☛ TIP

GERIATRIC TRAUMA

P. Huynh, A. Katz

Introduction

- Injury to adults ≥ **65 years of age**
- 5th most common cause of death in elderly
- Falls are leading cause of trauma in elderly; consider medical etiology of falls in addition to addressing injuries
- Physiological changes associated with aging can make assessment challenging
- Maintain high suspicion for serious injury in all geriatric patients with trauma

Initial Management

- **Airway**
  - **Geriatric patients are more prone to hypoxia;** consider early supplemental oxygen
  - Evaluate for dentures or other loose dental appliances
    - ☛ Leave in dentures for bag-valve-mask ventilation and remove for intubation
  - Airway can be difficult due to floppy epiglottis, nasopharyngeal fragility, and/or cervical arthritis
  - Increased risk for aspiration due to diminished gag and cough reflexes
  - Consider dose reduction with intubation sedatives during RSI to minimize cardiovascular decompensation
- **Breathing**
  - Elderly patients have decreased vital capacity and lung compliance
  - Minor chest injuries can have significant thoracic complications and morbidity
  - Rib fractures common and can result in dyspnea, hemo/pneumothorax, and splinting, leading to atelectasis and/or pneumonia
  - Multimodal analgesia regimen to decrease risk of respiratory distress or failure
- **Circulation**
  - ☛ "Normal" hemodynamic parameters such as blood pressure are not reassuring in geriatric populations. **Suspect hypotension in geriatric patients with a systolic blood pressure of < 110 mmHg**
  - Certain medications (beta blockers) and devices (pacemakers) may blunt tachycardia
  - Limited bedside echo useful adjunct to hemodynamic monitoring. Ultrasound can assess for estimated ejection fraction, presence or absence of pericardial effusion, and fluid responsiveness

☛ TIP

- **Disability**
  - **Greater risk for traumatic brain injury** due to decreased brain mass, cerebral atrophy, and increased adherence of dura to the skull
  - Increased risk for spinal fractures and spinal cord injuries due to degenerative changes and osteoporosis
- **Exposure/Environment**
  - **Higher risk for hypothermia** due to decreased subcutaneous fat and decreased metabolic rate

Emergency Considerations

- Vital Signs
  - **Normal vitals not entirely reassuring** due to diminished functional reserve and blunted physiological responses to trauma
- Comorbidities
  - Consider comorbid conditions and medications that contribute to or precipitate the trauma
  - Elderly patients with a history of cirrhosis, coagulopathy, COPD, ischemic heart disease, and diabetes mellitus are nearly 2 times more likely to die when presenting with traumatic injuries
- Anticoagulation Reversal
  - Anticoagulation, antiplatelet, and direct thrombin inhibitor use is prevalent in the geriatric population. Inquire specifically about its use and reverse when indicated
- Goals of Care
  - Obtain collateral information early
  - Involve family members, health care proxies, and determine patient's code status and goals of care

Additional Considerations

- Elder abuse can present as physical, sexual, emotional, and psychosocial maltreatment, neglect, financial exploitation and/or violation of rights
  - Be suspect of any unusual or unexplained injuries, especially injuries that occur on head, neck, and upper extremities
  - Large bruises (> 5 cm) on the face, posterior torso, lateral right arm should raise suspicion for elder abuse
  - Injuries to neck, ulnar forearm, and left periorbital areas have been studied to be more associated with elder abuse
- Disposition
  - **Admit** nearly all with multiple traumatic injuries

ATLS TIP

SPECIAL POPULATIONS

Signs of Elder Abuse (adapted from ATLS, 10th ed.)	
Contusions on inner arms, inner thighs, palms, soles, scalp, ear, mastoid area, buttocks	Multiple and clustered contusions
Abrasions to axillary area (from restraints) or wrist and ankles (ligatures)	Nasal bridge and temple injury (from being struck while wearing eyeglasses)
Periorbital ecchymoses	Oral injury
Unusual alopecia pattern	Untreated pressure injuries or ulcers in non-lumbosacral areas
Untreated fractures	Fractures not involving hip, humerus, or vertebrae
Injuries in various stages of healing	Injuries to eye or nose
Contact burns, scalds	Scalp hemorrhage or hematoma

TRAUMA IN PREGNANCY

N. Patel, A. Katz

Introduction

- Trauma is leading cause of maternal death during pregnancy
- In U.S., motor vehicle accidents account for nearly half of all obstetric trauma, followed by falls and assaults
- Patients of reproductive age presenting with traumatic injuries should be considered pregnant until proven otherwise
- Optimizing pregnant patient's resuscitation is best treatment for fetus

Anatomical Considerations

- Uterus remains an intra-pelvic organ until 12 weeks gestation; by 20 weeks, uterus reaches umbilicus and by 34–36 weeks it reaches costal margin
- As uterus enlarges, it becomes more vulnerable to trauma

Physiological Changes

- Hematologic changes
  - **Physiologic anemia** of pregnancy occurs secondary to increased plasma volume compared to red blood cell volume
  - **Leukocytosis** common during pregnancy
- Cardiac output
  - **Cardiac output increases** by 1.0–1.5 L/min secondary to increased plasma volume and decreased vascular resistance in uterus and placenta
  - While supine, the gravid uterus compresses the inferior vena cava; cardiac output can be reduced by 30%
- Heart rate
  - **Heart rate increases** 10–15 beats above baseline by third trimester
- Blood pressure
  - **Both systolic and diastolic blood pressure decrease** by 5–15 mmHg in second trimester but generally returns to baseline in third trimester
  - Screen for history of hypertension and preeclampsia
- Respiration
  - **Minute ventilation increases** secondary to increased tidal volume
  - Basal oxygen consumption increases in pregnancy
  - A normal $PaCO_2$ is 25–30 mmHg in pregnant patients. A $PaCO_2$ of 35–40 mmHg may indicate impending respiratory failure

TIP

SPECIAL POPULATIONS

Primary Survey

- **Airway**
  - **Intubation may be more difficult** due to increased airway edema and mucosal friability; utilize smaller endotracheal tubes and airway adjuncts

- Decreased gastric motility and compression of upper gastrointestinal tract increases aspiration risk; early placement of nasogastric tube warranted in unconscious or semiconscious pregnant patient
- Common induction and paralytic agents generally safe in pregnancy

- **Breathing**
  - Maintain oxygen saturation > 95% using supplemental oxygen as indicated
  - Adjust ventilator settings with a goal PCO_2 of 25–30 mmHg
  - ☛ In third trimester patient, diaphragm may be elevated superiorly by 4 cm. **Insert chest tubes at 2nd or 3rd intercostal space** in the setting of a hemo/pneumothorax
- **Circulation**
  - Manually displace uterus to the patient's left or place patient in 15–30° of left lateral tilt to reduce compression of gravid uterus on IVC and increase venous return to heart
  - Pregnant patients have increased plasma volume and can lose up to 1.5L of blood before showing any signs or symptoms of hypovolemia. **Vital signs can be normal, while fetus may be in significant distress**
  - Give crystalloid fluids as early as possible in resuscitation
  - Consider cross-matched blood early
  - Vasopressors constrict blood flow to uterus, resulting in fetal hypoxia. Avoid unless patient continues to be hemodynamically unstable despite hemorrhage control and adequate volume resuscitation

Secondary Survey

- Same in both pregnant and non-pregnant patients
- Abdominal exam should assess for uterine tenderness, frequent uterine contractions, or uterine irritability, which suggest **placental abruption**
- Abdominal tenderness, rigidity, guarding, rebound, palpable fetal parts, or abnormal fetal lie suggest **uterine rupture**
- Both placental abruption and uterine rupture can present with profound hypotension and shock
- Pregnant trauma patients should have a pelvic exam performed if > 20 weeks gestation, preferably by an obstetrician
  - Amniotic fluid in canal suggests ruptured membranes
  - Vaginal bleeding suggests possible placental injury or abruption
  - Up to 1/3 of placental abruptions do not have associated vaginal bleeding
  - Cervical dilatation and concomitant uterine contractions signal preterm labor if the patient is < 36 weeks pregnant

☛ TIP

Evaluation of Fetus

Once the initial surveys are complete and resuscitation has begun on the pregnant patient, the fetus should be assessed

- Fetal heart tones should be evaluated with Doppler ultrasound. An abnormal fetal heart rate can be a sign of impending fetal/maternal decompensation
- Patients > 20 weeks gestation should be placed on continuous cardiotocography
- Notify obstetrical and pediatric teams early

Diagnostic Studies

- Normal trauma labs; include d-dimer and fibrinogen for DIC screening
- FAST exam; in pregnant patients, the sensitivity and specificity of the FAST exam for detecting intra-abdominal injuries is similar to non-pregnant patients; a negative FAST does not rule out intra-abdominal bleeding (low sensitivity), however, a positive FAST is fairly reliable (high specificity)
- ☛ CT imaging when indicated, particularly in 3rd trimester; radiation dose significantly below amount required for fetal demise/anomalies

Indications for Admission

- Abdominal pain or tenderness
- Absence of or abnormal fetal heartbeat
- Leakage of amniotic fluid
- Vaginal bleeding
- Hypovolemia

Perimortem C-Section

- Data limited and weak for perimortem c-section in hypovolemic cardiac arrest secondary to trauma
- ☛ Perimortem c-section should be done within 5 minutes of maternal cardiac arrest
- Continue CPR while c-section is being performed and after delivery; increased venous return may result in ROSC
- For details on the procedure, see Perimortem C-section chapter

Other

- All Rh negative pregnant trauma patients should receive Rh immunoglobulin (300g IM) within 72 hrs
- Tetanus prophylaxis is safe and recommended in pregnancy

☛ TIP

WOUND REPAIR AND CLOSURE

M. Dauer

Indications

- Tissue approximation to promote better wound healing and prevent infection

Contraindications

- Animal/Human bites in non-cosmetic areas
- Deep puncture lacerations
- Old lacerations (up to 18 hours for clean, non-infected lacerations to the body and up to 24 hours on the face; however, this is controversial)

Irrigation

- Can be performed using tap water directly under sink; tap water has been shown to be no worse than sterile water or saline
- Can be performed with jet irrigation
- Betadine or chlorhexidine are not acceptable alternatives because force and volume of irrigation is key to the process of cleaning a wound

Wound Exploration

- Necessary to rule out foreign bodies, tendon laceration, depth of wound, joint involvement
- Probe wound gently in all directions (can be done after anesthetic) unless located on neck or deep chest wounds
- If difficult exam or shattered material (eg, glass or road rash), x-ray is appropriate

Anesthesia

Anesthetic	Maximum Dose without Epi (mg/kg)	Maximum dose with Epi (mg/kg)	Duration
Lidocaine	5	7	30–90 min
Bupivacaine	2.5	3	6–8 hrs
Mepivacaine	7	8	2–3 hrs
Ropivacaine	3	n/a	6 hrs
Prilocaine	6	n/a	30 min
Tetracaine	1	1.5	3 hrs
Procaine	7	10	30min

Of note, to calculate amount of drug, percent in solution is amount of g/100mL of solution (Ex: 1% Lidocaine contains 1g/100mL solution OR 10mg/mL)

Suture Types

Absorbable Sutures	Tensile Strength Duration	Time to Absorption
Chromic Gut	7 Days	90 Days
Vicryl	2–3 Weeks	70 Days
Vicryl Rapide	10 Days	42 Days
Polydioxanone (PDS)	14 Days	180–240 Days

Non-Absorbable Sutures	Tensile Strength	Body Reactivity
Silk	Low	High
Prolene	Moderate	Low
Nylon	High	Low

Suture Size by Location

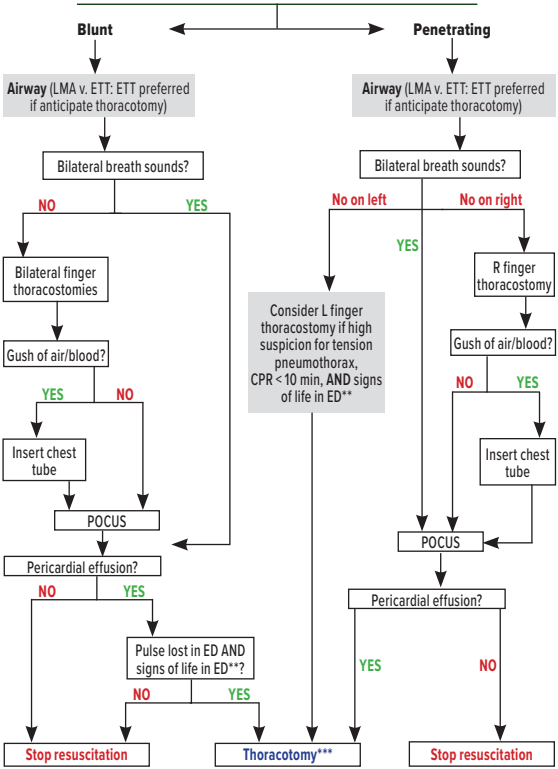
Body Location	Suture Size	Suture Type	Removal
Scalp	4-0 or Staples	Non Absorbable	10–14 days
Ear	6-0	Non Absorbable	5 Days
Eyelid	6-0 or 7-0	Either	3 Days
Eyebrow	5-0 or 6-0	Either	5 Days
Nose	6-0	Either	5 Days
Lip	6-0	Absorbable	n/a
Oral Mucosa	5-0	Absorbable	n/a
Cheeks/Forehead	6-0	Either	5 Days
Chest	4-0	Non Absorbable	10 Days
Abdomen	4-0	Non Absorbable	10 Days
Back	4-0	Non Absorbable	7 Days
Arms/Legs	4-0	Non Absorbable	7 Days
Hands	5-0	Non Absorbable	7 Days
Feet	4-0	Non Absorbable	12 Days
Vagina	4-0	Absorbable	n/a
Penis	5-0	Non Absorbable	7–10 Days
Scrotum	5-0	Non Absorbable	7–10 Days

Aftercare

- Antibiotic ointment followed by nonadherent gauze with regular gauze or wrapping is adequate for most dressings.
- Dressing should not be removed for 24 hours and then washing, not scrubbing, with regular soap and water is appropriate.
- Consider systemic antibiotics for heavily contaminated wounds, animal bites, exposure to fresh water, puncture wound through shoe sole, involvement of joint/tendon/cartilage/bone.
- Update tetanus prophylaxis when indicated.

Pulseless Trauma Patient Algorithm*

H. Neher



*Special Considerations
- — Abdominal Trauma: consider ED thoracotomy to clamp aorta if anticipated time to OR less than 30 min
- — Extremity injuries: consider ED thoracotomy if pulseless from exsanguination (for open cardiac massage) and no improvement after massive transfusion

**Signs of life = PEA, pupillary/corneal/gag reflexes, GCS > 3

***Contraindicated if: massive head trauma

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