UNIVERSITY OF SASKATCHEWAN
TRAUMA MANUAL

1ST EDITION
Foreword

This manual will be of great benefit to our trauma patients and will encourage all of us to refresh our memories and our approach to the resuscitation and management of trauma. Dr. Sothilingam, our first Trauma Program Director, and his collaborators have spent considerable time and effort in creating this useful manual.

It is our hope that this manual provides guidance to our trainees for the utilization of resuscitation and trauma algorithms and with time, under the leadership of Dr. Sothilingam, its repertoire is expanded.

-Ivar Mendez MD, PhD, FRCSC, FACS, FCAHS
F. H. Wigmore Professor & Unified Head of Surgery
This manual was designed to aid in the resuscitation and management of trauma patients. It should serve as a concise, evidence based resource for common trauma topics and treatment algorithms.

Thank you to all who contributed their time and knowledge to help create the 1st Edition of the University of Saskatchewan Trauma Manual.

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Initial Resuscitation

Suzie Harriman
Niroshan Sothilingam

The trauma team responds to all level I traumas

Trauma Activation Criteria – See Appendix

All members of the trauma team must wear personal protective equipment:
  ▪ Cap, gown, gloves, mask, protective eyewear/shield

The members of the trauma team will include many individuals who all have a very specific role. It is critical for the safety of the team members and the patient that everyone is aware of their roles and where to stand.

  ▪ Trauma Team Leader (TTL)
    ▪ The most responsible physician (MRP) who runs and controls the room
    ▪ The TTL will stand at the foot of the bed
    ▪ Directs team members in their actions
    ▪ Keeps track of the whole state of the patient
    ▪ Receive and interpret all results of investigations
    ▪ Consult with other specialties
    ▪ Decide on appropriate disposition
    ▪ Will accompany patient out of the trauma bay for all investigations
    ▪ Talk to family members

  ▪ Learner Trauma Team Leader (TTLST)
    ▪ Senior level trainee under the direct supervision of the TTL
    ▪ Will stand at the foot of the bed with the TTL
- Role is to oversee trauma patient and critical procedures under direction of the TTL, provision of/or right and left sided procedures.

- **Airway Management**
  - Will stand at the head of the bed
  - Is the Anesthesia resident on-call
  - Role is airway assessment & management
  - Endotracheal intubation if necessary
  - C-spine control
  - Assist with fluid and drug administration
  - Respiratory therapist (RT)/Anesthesia assist (AA) will stand beside them at the head of the bed

- **Primary Survey**
  - Will stand on the right side of the patient
  - Is the General Surgery JR resident on-call
  - Responsible for right sided procedures (e.g. chest tube)
  - Responsible for the primary and secondary survey

- **Scribe Nurse**
  - Role is to record events of trauma resuscitation

- **Circulating Nurse (x 2)**
  - Obtain IV access, attach cardiac monitoring and pulse oximeter on arrival
  - Remove all clothing and keep patient warm with blankets
  - Administer drugs and hang fluids
  - Place foley catheter if necessary
  - Help role the patient
  - Help transport the patient when necessary
Primary Survey

All trauma patients on arrival should have:

- 2 large bore IV started (14 or 16 gauge)
- Cardiac monitoring
- Blood pressure cuff
- Pulse Oximeter

- Assess and establish treatment priorities.
- Assess vital signs quickly and efficiently.
- Adhering to the sequence of ABCDEs of trauma.

- The primary survey can and should be repeated frequently to reassess any change to patient’s status with subsequent intervention if required.
- Important to be cognoscente of special populations (i.e. elderly, pediatric, pregnant, athletes) as they will have different ability to
compensate, more/less reserve, medication profiles and “normal” vitals.

- **Airway and cervical spine protection:**
  - Ascertain patency of airway. Is that patient verbalizing? Significant facial trauma causing possible loss of airway? Is GCS <8? (likely unable to protect airway)
  - Always have suction ready at head of bed when assessing airway.
  - Clear the oropharynx of blood, mucus and foreign bodies.
  - Avoid excessive cervical spine movement while assessing and managing airway.
  - Immobilization of cervical spine should be maintained – assume cervical spine injury in all trauma patients with blunt mechanism, multisystem involvement or altered LOC

- **Breathing and Ventilation:**
  - Is there adequate gas exchange – oxygenation and carbon dioxide elimination?
  - Respiratory rate; Oxygenation saturation
  - Expose neck and chest and inspect chest movement and palpate for injury that may compromise ventilation
    - i.e. flail chest, tension pneumothorax and open pneumothorax
  - Percussion may be helpful to identify a pneumothorax or hemothorax, but is very difficult to perform in a noisy resuscitation bay
  - Auscultation for bilateral breath sounds
  - Injuries impairing ventilation should be identified and treated immediately:
    - Pneumo/hemothorax: Chest tube placement
• Tension pneumothorax: Needle decompression/chest tube
• Open pneumothorax: Three-sided occlusive dressing
• Positive pressure ventilation may exacerbate or cause pneumothorax or a tension pneumothorax – ensure frequent re-evaluation.

▪ Circulation (including hemorrhage control):
  ▪ Recognize signs of organ hypoperfusion
    • Level of consciousness
    • Skin color/temperature
    • Pulse rate/character
  ▪ Identify hemorrhage (external vs internal)
    • External – direct pressure, tourniquets if direct pressure fails
    • Internal – chest, abdomen, retroperitoneum, pelvis, long bones
      ◦ Identify through physical exam, CXR, pelvic x-ray, FAST
      ◦ Management: chest tube, pelvic binder, splint application, surgical consult
  ▪ Restore volume
    • Start with crystalloid followed by PRBCs
      ◦ If obvious hypovolemic shock, may consider initially resuscitating with blood products
      ◦ May need activation of massive transfusion protocol (MTP)
        - See Appendix for MTP activation protocol

▪ Disability:
  ▪ Baseline neurologic exam
- Glasgow coma scale – predictive of patient outcome
- Pupillary size and reaction
- Lateralizing signs
- Spinal cord injury level

**Objective is to prevent secondary brain injury by ensuring adequate oxygenation and perfusion**

- **Exposure and Environmental Control**
  - Fully expose patient for assessment of additional injuries while preventing hypothermia
    - Warm blankets, warming devices, warm IV fluids and room temperature

**Adjuncts to Primary Survey**

- Determine occult bleeding and source of shock
  - **ECG:** Continuous monitoring
    - Dysrhythmias – blunt cardiac injury
    - Pulseless electrical activity – cardiac tamponade, tension pneumothorax and/or hypovolemia
    - Note: hypothermia can cause dysrhythmias
  - **Foley catheter and nasogastric tubes**
    - Indwelling bladder catheter useful to monitor volume status and renal perfusion
      - Relatively contraindicated if:
        - Blood at meatus
        - Perineal ecchymosis
        - High-riding or high riding prostate
    - Nasogastric tube can reduce stomach contents and distention and decrease risk of aspiration. Can also assess hemorrhage from injury to upper digestive tract
Contraindicated if:
- Suspected fracture of Cribiform
  › Orogastric tube can be inserted in this case

• Arterial blood gas
• X-Rays
  › AP chest and AP pelvic films (portable)
  › Should not interrupt resuscitation process
• FAST
  › Initial test for detection of occult intra-peritoneal hemorrhage
  › Cardiac tamponade
  › Pneumothorax (E-FAST)

Secondary Survey

▪ Begins when primary survey has been completed and resuscitation is succeeding in normalizing vital functions.

▪ It is a head to toe evaluation, including a complete history and physical exam.

  ▪ History: AMPLE
    • A: allergies
    • M: medications
    • P: past illnesses/pregnancy
    • L: last meal
    • E: events/environment related to the injury

  ▪ Physical exam
    • Head
      ◦ Scalp
      ◦ Eyes
      ◦ Ears (Blood/CSF leak)
      ◦ Penetrating Injuries
    • Maxillofacial Structures
Bony structures, intraoral, and soft tissues

• Cervical Spine and Neck
  • Dependent on mechanism of injury – may leave immobilized until cervical spine radiological studies performed
  • Examine neck, c-spine tenderness, bruits, subcutaneous emphysema,

• Chest
  • Palpation of entire chest, auscultation, heart sounds

• Abdomen
  • Frequent re-evaluations and high index of suspicion.
  • Look for evidence of seat belt sign
  • Avoid excessive manipulation of the pelvis

• Perineum, Rectum, Vagina
  • Contusions, hematomas, lacerations and urethral bleeding
  • Digital rectal exam – examine for rectal tone, blood, high riding prostate
  • Pelvic fractures can cause vaginal injury

• Musculoskeletal System
  • Contusions, deformities
  • Palpation of bones for tenderness or abnormal movement with/without pain
  • Ensure examination includes the back or significant injuries can be missed

• Neurological System
Motor and sensory evaluation of the extremities
Re-evaluation of GCS and pupillary size and response
Ensure protection of spinal cord at all times

Adjuncts to Secondary Survey

- Does the patient require further diagnostic tests?
- Is the patient’s condition/vitals appropriate for further diagnostic tests?
  - Spinal x-rays
  - CT of the chest, abdomen, and/or spine
  - Extremity x-rays
  - Transesophageal Ultrasound
  - Bronchoscopy
  - Esophagoscopy

- Spinal Immobilization
  - Transport boards should be used for extrication purposes only, not for transport
    - Not shown to reduce movement of the spine or neurological complications
    - Pressure ulcers can begin 30 minutes after immobilization
    - Can affect airway management and breathing
  - C-collars and C-spine immobilization
    - Please see Appendix for U of S C-spine clearance protocol
    - Clinical Decision Rules – Radiography?
      - NEXUS vs Canadian C-spine rules
    - In an evaluable patient ➔ If C-spine CT normal, can remove collar
Canadian C-spine rules\textsuperscript{4}

- In an obtunded patient ➔ Normal C-spine
  - CT read by a staff radiologist, can remove collar

EAST\textsuperscript{5}

- Vascular Access\textsuperscript{6}
  - Percutaneous Peripheral Venous Access
    - Two large bore (16g) IV catheters
  - Central Venous Access
    - If unable to obtain peripheral IV access
    - Similar complication rate in non-emergent situation
    - Internal jugular – carotid artery puncture (most common complication)
    - Subclavian – pneumothorax (most common complication)
    - Femoral – not recommended for intra-abdominal trauma

- Venous Cutdown
  - If peripheral or central access is contraindicated or impossible to achieve
    - U/E: cephalic, basilic and median antecubital veins
    - L/E: Greater saphenous vein

- Interosseous Catheters
  - Most successful in patients less than 5 years of age
    - Tibial tuberosity in pediatrics
    - Proximal to tip of medial malleolus in adults
References

Traumatic brain injury (TBI) is a disruption of brain function due to external force. This is a dynamic process therefore, all injuries and symptoms, regardless of how minor on initial exam, should be taken seriously since injuries may rapidly progress and become life threatening.

- **Primary injury:**
  - Results from the forces imparted at the time of the event:
    - Disruption of scalp (laceration)
    - Bone (cranial vault, skull base, facial bones)
    - Vasculature (SDH, EDH, IPH, IVH)
    - Brain parenchyma (Contusion, DAI)

- **Secondary injury:**
  - After the initial impact and may become more insidious and more difficult to control (failure of autoregulation/loss of normal hemostasis):
    - Hypoxemia
    - Ischemia
    - Initial hyperemia
    - Cerebral edema
    - Increased ICP
    - Seizures

**Etiology:**
- Falls – 28%
- MVC – 20%
- Pedestrian impact – 19%
- Assault – 11%

**Pathophysiology:**
- The intracranial volume (approximately 1500 ml) is equal to the sum of its components:
  - Brain (85-90% of volume)
  - Blood (10%)
  - Cerebrospinal fluid (< 3%)
**Monro-Kellie Doctrine:**
- The brain is contained within the rigid and inelastic boundary of the skull.
- Small increases in volume within the intracranial compartment can be tolerated before pressure within the compartment rises.

- With a significant head injury, cerebral edema develops, therefore increases the relative volume of the brain.
- Pressure within this compartment rises unless some compensatory action occurs, such as a decrease in the volume of one of the other intracranial components.

The brain has very limited compliance and cannot tolerate significant increases in volume that can result from diffuse cerebral edema or from significant mass lesions such as a hematoma.

**Cerebral perfusion pressure (CPP)**

- CPP = MAP – ICP

- CPP: Net pressure of blood delivery to the brain.

- Normally, cerebral blood flow (CBF) is constant when mean arterial pressure (MAP) is within the range of 50-150 mmHg.

- **Pressure-Passive Flow**
  - When the MAP is less than 50 mm Hg or greater than 150 mm Hg, the arterioles are unable to auto regulate and blood flow becomes entirely dependent on the blood pressure.
  - This autoregulation is impaired in TBI:
    - The CBF is no longer constant and is dependent on and proportional to the CPP.
    - Therefore, when the MAP falls below 50 mmHg, the brain is at risk of ischemia due to insufficient blood flow, while a MAP greater than 160 mmHg causes excess CBF that results in increased intracranial pressure (ICP).
As a result, pressure-passive flow occurs within and around injured areas.

**Assessment**

Management of traumatic brain injury focuses on stabilization of the patient and prevention of secondary neuronal injury to avoid further loss of neurons. The best way to do this is by providing adequate oxygenation and maintenance of blood pressure so that sufficient perfusion of the brain is achieved. Assessment of brain injury depends on evaluation of the GCS and examination of the pupils. GCS less than 9 indicates severe brain injury.

**Classification of TBI:**

- **Mild:** GCS 13-15. Awake, usually no focal deficits.
- **Moderate:** GCS 9-12. Altered sensorium and may have focal deficits.
- **Severe:** GCS < 9. Usually meet criteria of comatose patient

**Pupillary Examination**

Critical part of the evaluation of patients with TBI, especially in patients with severe injuries.

<table>
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<tr>
<th>Pupil size</th>
<th>Light response</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unilaterally dilated</td>
<td>Sluggish or fixed</td>
<td>CN III nerve compression secondary to tentorial herniation</td>
</tr>
<tr>
<td>Bilaterally dilated</td>
<td>Sluggish or fixed</td>
<td>Inadequate brain perfusion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bilateral CNIII palsy</td>
</tr>
<tr>
<td>Unilaterally dilated or equal</td>
<td>Cross-reactive (Marcus-Gunn)</td>
<td>Optic nerve injury</td>
</tr>
<tr>
<td>Bilaterally constricted</td>
<td>May be difficult to determine</td>
<td>Drugs (opiates)  Metabolic encephalopathy  Pontine lesion</td>
</tr>
<tr>
<td>Unilaterally constricted</td>
<td>Preserved</td>
<td>Injured sympathetic pathway, eg. Carotid sheath injury</td>
</tr>
</tbody>
</table>
The following should also be noted in the assessment:

- Check ears and nose for bleeding and/or CSF leakage.
- Check for signs of basilar skull fracture.
- Full neurologic exam including cranial nerves, strength, tone and reflexes.
- Associated injuries.

**Acute management of severe traumatic brain injury**

1. Protect the airway & oxygenate
2. Ventilate to normocapnia
3. Correct hypovolaemia and hypotension
4. CT Scan when appropriate
5. Early Neurosurgery consultation in patients with moderate or severe head injury
6. Admission to Intensive Care Unit

**Hypoxia and hypotension are the greatest threat to functional outcome in brain injury.**

Rapid sequence intubation (RSI) should be used to secure the airway and maximally oxygenate the patient. Hypovolemia and hypotension must be corrected and take priority over other interventions for the brain injury.

Many of the interventions used in the management of intracranial pressure may have a detrimental effect on cardiopulmonary resuscitation, which may have a detrimental effect on cerebral perfusion.

- Certain measures may be counterproductive when used without adequate monitoring (eg. hyperventilation).
  - These interventions are used without guidance from CT scans or ICP monitoring only when there is evidence of impending brain herniation (unilateral posturing and/or unilateral dilated pupil).
- CT scan of the head should be obtained when appropriate.
  - Dependent on the presence of other injuries and hemodynamic stability.
This delineates the brain injury and determine whether surgery is indicated to remove an intracranial mass lesion (epidural / subdural hematoma), as well as the degree of diffuse injury and cerebral swelling.

- Due to potential ongoing cerebral ischemia, time is critical:
  - No unnecessary investigations or procedures should be undertaken.
  - Damage control techniques should be employed.
  - No spinal or long bone imaging should be ordered prior to CT scan of the head as these investigations will not affect the immediate patient management.
  - The hemodynamically unstable patient should have minimum investigations, control of hemorrhage by the simplest means appropriate, head CT scan and treatment of the brain injury.

**Canadian CT Head Guidelines**
- please see Appendix
Specific Types of Brain Injury
Focal Cerebral Injuries Vs. Diffuse Cerebral Injuries

Focal Cerebral Injuries

- **Cerebral Contusion**
  - Injuries to the superficial gray matter of the brain caused by a focal force.
  - Coup Lesion: Ipsilateral to the impact site and can be associated with adjacent calvarial fractures.
  - Countercoup Lesion: Opposite to coup lesions and result from gyral crests of the rebounding brain striking the inner table of the skull.
  - Most common: Temporal and frontal poles.
  - CT findings: Patchy, hyperdense lesions with a hypodense background.

- **Subdural Hemorrhage:**
  - Occurs in 10-20% of severely head-injured.
  - Originates in the potential space between the dura and arachnoidal meningeal layers.
  - Tearing of cortical bridging veins that cross the subdural space and drain into a dural sinus.
  - CT findings: Crescent shaped, cross suture lines, and layer along the tentorium.
  - Types:
    - Hyperacute (< 6 hours)
    - Acute (6 hours to 3 days)
    - Subacute (3 days to 3 weeks)
    - Chronic (3 weeks to 3 months)
**Epidural Hemorrhage:**
- Seen in 1% of all head trauma admissions
- 4 times more common in males
- Bleeding from middle meningeal artery
- Usually occur at site of impact:
  - Lateral convexity of a cerebral hemisphere (70%)
  - Frontal (5-10%)
  - Parieto-occipital (5-10%)
  - Posterior fossa (5-10%)
- Patients experience lucid interval followed by subsequent neurologic deterioration minutes to hours after the injury.
  - This classic finding is present only 27-50% of cases.
- Deterioration is caused by expansion of the hematoma until the brain’s compensatory mechanisms fail.
- CT findings: Hyperdense, biconvex (lenticular) mass adjacent to the inner table of the skull. Bound by cranial suture lines.

**Subarachnoid Hemorrhage**
- Seen in 33% of patients with moderate head injury
- Caused by venous tears in the subarachnoid space
- Blood pools between the pial and arachnoid membranes.
- Blood is spread diffusely so does not cause mass effect
- May predispose to cerebral vasospasm, leading to extensive infarcts

**Diffuse Cerebral Injuries**

**Diffuse Axonal Injury (DAI)**
- Sudden rotational forces
- Traumatic axonal stretch injury caused by overlying cerebral cortex and underlying deep brain structures moving at different speeds.
- Does not require impact, and can be caused by rapid acceleration and deceleration.
- Small petechial hemorrhages and axonal disruption.
- 80% of DAI is microscopic and non-hemorrhagic
  - Impaired axonal transport and delayed axonal swelling
- CT is normal 50-80% of time.

**Mild Traumatic Brain Injury (Concussion)**
- Alteration of consciousness resulting from non-penetrating injury to the brain.
- May cause a transient increase in cerebral blood volume due to loss of vascular autoregulation.
  - In some cases, this may cause mild cerebral swelling or hyperemia.
  - In more severe cases, may cause cerebral edema with increase in ICP.
- CT finding: Normal

<table>
<thead>
<tr>
<th>Grade</th>
<th>Criteria</th>
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<tbody>
<tr>
<td>I</td>
<td>Confused temporarily but does not display any memory changes</td>
</tr>
<tr>
<td>II</td>
<td>Brief disorientation and anterograde amnesia of less than 5 minutes duration are present</td>
</tr>
<tr>
<td>III</td>
<td>Retrograde amnesia and loss of consciousness for less than 5 minutes are present, in addition to the 2 criteria for a grade II concussion</td>
</tr>
<tr>
<td>IV</td>
<td>Similar to a grade III, except the duration of loss of consciousness is 5-10 minutes</td>
</tr>
<tr>
<td>V</td>
<td>Similar to a grade III, except the loss of consciousness is longer than 10 minutes</td>
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Management of raised ICP

IV Fluids
- Resuscitate to maintain normovolemia
- Prefer NS

Hypertonic Saline
- Lower ICP:
  - Acts by establishing an osmotic gradient that reduces brain water content.
  - Will maintain efficacy with repeat dosing even in patients who have stopped responding to Mannitol.
    - Unlike Mannitol, hypertonic saline does not cause profound osmotic diuresis, therefore the risk of hypovolemia as a complication is decreased
- Administered as a continuous infusion of 25-50 mL/h of 3% solution.
- Must monitor serum sodium levels.

Elevation of the head
- Elevate head of bed to 30-45°
  - Cause venous outflow from the brain to improved, therefore helping to reduce ICP
- Contraindications: hypovolemia, spine injury

Hyperventilation
- Used as a bridge to more definitive therapy
- Peak effect may be seen as soon as 8 minutes and lasts up to 20 minutes.
- Maintain PCO₂ at 32-35 mmHg
- Reducing PCO₂ cause cerebral vasoconstriction and helps reduce intracranial volume ➤ decreased ICP
- Use in moderation and for limited periods
- Ventilate to normocapnia and avoid hypocapnia (PCO₂ 25 – 30 mmHg)

Mannitol
- Used to reduce ICP:
  - Establishes an osmotic gradient between plasma
and parenchymal tissue, resulting in a net reduction in brain water content.
- Rapid onset of action and maintains its effect for a period of hours.
- 1 gm/kg IV bolus of 20% solution over 5 minutes.
- Potential side effects of hyperosmolarity, hypovolemia, electrolyte imbalance, and acute renal failure.
  - More common with chronic or high-dose administration.
  - Serum osmolarity, serum electrolytes, and renal function should be measured at least every six to eight hours.

- **Indications for ICP Monitoring**
  - GCS < 8 with abnormal CT scan
  - GCS < 8 with normal CT scan and 2 of the following:
    - Age > 40
    - B/P < 90 mmHg systolic
    - Posturing

- **TBI Coagulopathy**

Patients with TBI are at increased risk of developing venous thromboembolic events with their accompanying morbidity and mortality. The risk of developing deep venous thrombosis (DVT) in the absence of prophylaxis is estimated to be 20% after severe TBI.

  - Some evidence supports the use of compression stockings placed for DVT prophylaxis for patients with severe TBI,
    - Lower extremity injuries prevent their use.
  - Evidence supports the use of prophylaxis with LMWH for prevention of DVT in patients with severe TBI.
    - No reliable data can support a recommendation regarding when it is safe to begin pharmacological prophylaxis.
    - No recommendations can be made regarding medication choice or dosing regimen.
**Outcome of TBI**

All patients with admitted with head injury should be assessed by a multidisciplinary team including speech/language pathology, occupational therapy, physiotherapy and social work. They should also be referred to the Saskatchewan Acquired Brain Injury Program.

- **Glasgow Outcome Scale (GOS)**
  - Widely used outcome grading system
  - Used to interpret and compares the effectiveness of various treatment and common end points.
  - Assessment of general functioning of patient who suffered a head injury

5-level score:

1. Dead
2. Vegetative State (patient is unresponsive, but alive)
3. Severely Disabled (conscious but the patient requires others for daily support due to disability)
4. Moderately Disabled (the patient is independent but disabled)
5. Good Recovery (the patient has resumed most normal activities but may have minor residual problems)

The Extended GOS (GOS-E), extends the scale to an 8-level score:

1. Dead
2. Vegetative State
3. Lower Severe Disability
4. Upper Severe Disability
5. Lower Moderate Disability
6. Upper Moderate Disability
7. Lower Good Recovery
8. Upper Good Recovery
- Disability Rating Scale
  - Used to rate the effects of injury and decide how long recovery might take.
  - The rating system gives insight into the cognitive impairment of patients who suffer from the TBI.
  - Advantages of this scale is that it tracks the patient’s progress over time.
    - Unlike the GOS which is used to determine the extent of a brain injury.
  - A person without disability scores zero.
  - The maximum score a patient can obtain on the DRS is 29 (vegetative state).

**Frequent Sequelae of TBI:**
- Cognition
  - Thinking, memory, reasoning
- Behavior
- Mental Health
  - Depression, anxiety, personality changes, aggression, acting out, and social inappropriateness

Severe TBI is clearly related to long-term cognitive defects and there is suggestive evidence that this is true for moderate TBI as well.

TBI is strongly associated with several neurologic disorders 6 months or more after injury:
- Seizures
  - 25% of patients with brain contusions or hematomas and 50% of patients with penetrating head injuries will develop seizures within the first 24 hours of the injury.
  - Seizure prophylaxis should be given at the discretion of the neurosurgery consult service. Prophylactic anticonvulsants are only beneficial for the first 7 days.
These immediate seizures do not seem to be linked to the development of post-traumatic epilepsy (recurrent seizures occurring more than 1 week after the initial trauma).

After penetrating TBI 32%-53% suffer from seizures.

After a closed TBI the seizure risk varies with the initial TBI severity. Compared to a healthy population the risk increases 17-95 times after severe TBI, 3 to 7 times after moderate TBI and doubles in mild TBI resulting in LOC.

- Neurodegenerative disorders
  - Dementia of the Alzheimer’s type (DAT) and Parkinsonism are related to mild and moderate TBI. DAT is a progressive disease characterized by dementia, memory loss, and deteriorating cognitive abilities.
  - Parkinsonism may develop years after TBI as a result of damage to the basal ganglia.
    - The association between TBI and parkinsonism has not been studied as extensively as in DAT.
    - However, significant associations between Parkinsonism and TBI have been established.

- Language and communication:
  - Common in TBI patients.
  - Aphasia may occur in 19%
  - Dysarthria in 30%
  - Dysphagia in 17%
  - Some experience difficulty with the more subtle aspects of communication, such as body language and emotional, non-verbal signals called prosodic dysfunction.
References


I. Introduction

Craniofacial trauma involves bony and soft tissue injuries of the face and skull. Its severity can range from superficial soft tissue injury to complex injuries of the craniofacial skeleton with significant morbidity and mortality. Motor vehicle collisions, assaults, and falls represent the main etiologies of these injuries, and younger males are disproportionately affected. Given the frequent occurrence of these injuries the trauma team must be competent in their assessment, diagnosis, and acute management.

The goal of this chapter is to provide the trauma team with a framework for identifying, assessing, and diagnosing craniofacial injuries. Pearls for acute management will also be discussed. “What not to miss” will be an important theme. It is important to remember that patients with craniofacial injuries are TRAUMA PATIENTS FIRST. That means you must employ the ABCDEs of trauma management. These patients can often “look good” but have serious injuries. Greater than 10% of facial injuries are associated with injuries outside of the craniofacial skeleton, and 5% involve neurosurgical injury (brain or cervical spine).

Airway management is a primary concern, and can become difficult in these patients given the proximity of the injuries to the airway. As such, it is important consider securing the airway early if necessary with an ET tube. Bleeding is another significant cause of morbidity and mortality -- getting quick control of bleeding with nasal packing, stapling or suturing of large wounds, gross reduction of unstable fractures, or other maneuvers is critical in the acute setting.

II. Facial Fractures

Familiarity with the bones comprising the skeletal architecture of
the face and orbit is essential. These include the frontal bone, zygoma, nasal bone, maxilla, and mandible (the other 4 bones which make up the orbit will not be discussed). Facial fractures may be associated acutely with pain, swelling, ecchymosis, and instability, as well as functional problems such as airway concerns, malocclusion or visual disturbance. Untreated or under-treated fractures can result in significant functional impairment and facial deformity.

Facial fractures can be broadly categorized as:

- (1) Fronto-basilar fractures
- (2) Orbito-zygomatic fractures
- (3) Occlusal fractures (those involving the maxilla and/or mandible)
- (4) Nasal and NOE fractures.

The relative frequency of these various fractures will depend on demographics and practice location.

(1) **Fronto-basilar fractures**

- Fractures involving the frontal bone/sinus and skull base
- Very high force injuries – usually MVCs
- *High association with injuries to the CNS* (dura, brain, spinal cord)
- *It is important to rule out C-spine or brain injury*
  - Clinical exam is not reliable to rule out CNS injury in a patient with altered GCS, intoxication or a significant distracting injury.
- GCS score, evaluation for CSF leak is important (tilt test or halo test, or send a fluid sample for beta-2 transferrin).
- These injuries require combined treatment by neurosurgeon and craniofacial plastic surgeon.
- Treatment goals involve protecting the dura and brain, re-establishing drainage of the naso-frontal ducts, and restoring forehead aesthetics.

(2) **Orbito-zygomatic Fractures**

- The most common fracture pattern is the “OZC” (orbitozygomatic) fracture
OZC fractures are typically “tetrapod” fractures, involving fractures at the following anatomic sites:

- The lateral orbital wall at the zygomatico-frontal suture
- The zygomatic arch
- The zygomaticomaxillary buttress
- The orbital floor

Patients will present with pain, ecchymosis, edema, and often numbness in the V2 nerve distribution (ipsilateral cheek, lateral nose, upper lip/gingiva) as the fracture line is usually through/near the infraorbital foramen.

- Lateral scleral hemorrhage is often seen, and ocular symptoms such as double vision (diplopia) are common.
- The zygoma makes up a significant part of the lateral orbital wall and orbital floor. By definition, the majority of patients with OZC fractures have an associated fracture of the orbital floor.

CT scan is mandatory in all of these patients to allow for complete assessment of the injury.

- Isolated orbital fractures (typically orbital floor and/or medial wall) are common following blunt trauma to the globe, and isolated fractures of the zygomatic arch are also common following lateral impact.
- The goal of treatment is to prevent/correct orbital complications and to restore cheek and peri-orbital aesthetics.

Untreated or undertreated zygomatic fractures will result in a flat/wide appearance, and also may result in orbital dystopia, enophthalmos and/or persistent visual disturbances.

- **Remember – Do not forget to examine the patient’s vision, extraocular movements, and globe position. The eye MUST be opened no matter how much swelling is present!! Ophthalmology consultation is warranted if any significant abnormalities are present.

- *Remember - If there was enough force present to break a facial bone, there was enough force to damage the eye!
Traumatic hyphema, globe rupture, traumatic optic neuropathy, extraocular muscle entrapment, retinal detachment and visual loss are all possible associated injuries.

- Entrapment of the extra-ocular muscles is a true plastic surgery emergency.
- This is diagnosed CLINICALLY and is seen when a patient has restriction of their gaze (usually upwards). Often times patients have pain – it is important for them to give their best effort for an adequate assessment.

(3) Occlusal Fractures

- Involving the maxilla and/or mandible
- Chief complaints will be pain and malocclusion
- May also have numbness/paresthesia in the lower lip from injury to the inferior alveolar/mental nerve - important to document at time of injury
- Ask about previous fracture, occlusion prior to the trauma and prior history of dental/orthodontic work
- Be ready to clear airway by suctioning blood, clearing mouth of debris, and dealing with any broken/loose teeth
- Consider dental consult as needed
- Maxillary fractures can be diagnosed clinically using the “drawer test” to assess for instability
- Maxillary fractures are categorized as follows:
  - (1) LeFort 1 (horizontal maxillary fracture)
  - (2) LeFort 2 (a pyramidal fracture with the teeth at the pyramid base and the nasofrontal at its apex)
  - (3) LeFort 3 (complete dissociation of the facial skeleton from the cranium)
- Because of the horseshoe shape of the mandible, the majority of mandible fractures are bilateral – make sure to look for the second fracture!
- Be familiar with the mandibular anatomy: condyle, sub-condyle, ramus, angle, body, parasymphysis and symphysis
- The gold standard for imaging the mandible is CT scan or
Panorex imaging. Plain films are poor to assess the mandible and very often can miss fractures.
- ALL mandibular fractures require plastic surgery consultation - majority of these fractures are operative
- Goal of treatment is to promote bony healing and restore occlusion, which may be obtained through maxillomandibular fixation +/- ORIF

(4) Nasal / NOE Fractures
- Nasal bone fractures are the most common type of facial fracture
- For those with noticeable displacement or functional concerns, closed nasal reduction may be attempted (usually done in the OR sub-acutely once swelling has subsided)
- Nasal bone fractures can be associated with epistaxis – it is important to become competent in anterior and posterior nasal packing. The usual culprit in severe bleeding is the anterior ethmoidal artery. Consider securing the airway.
- Make sure to look in the nose to rule out septal hematoma- must be drained if present to prevent cartilage ischemia and later saddle nose
- It is important to distinguish nasal bone fracture from the more serious naso-orbital ethmoid (NOE) fracture. The (NOE) complex is the confluence of the frontal sinus, ethmoid sinuses, anterior cranial fossa, orbits, frontal bone, and nasal bones. NOE fractures can be a significant cause of morbidity. Have suspicion if the trauma was high force, there is significant flattening of the nasal bridge or if there is any hint of telecanthus (eyes appearing further apart due to lateral displacement of medial canthal bearing bone). If any of these are present get a CT scan to evaluate.
Radiographic Imaging in the Craniofacial Trauma Patient

CT scan is the gold standard in diagnosing craniofacial injuries. The CT scan should have fine cuts (less than 1mm) and include axial, coronal, and sagittal images. 3D reconstructions of these images are also helpful, but not required. It is important that images go from the vertex of the skull to the mentum to ensure that no injuries are missed. Consider a CT of the cervical spine if indicated.

Soft Tissue Facial Injuries – Pearls
- Facial lacerations- most of the time there is not any missing tissue! You will be surprised how well things come together
- Small sutures for facial lacerations– 5-0 or 6-0 sutures (Nylon, Prolene, Novafil, Catgut (FAST absorbing))
- 2 layer closure if wound is gapping or there is any tension on the wound– use 5-0 Vicryl or Monocryl for deep layer
- For lacerations involving the specialized units of the face– eyelid, lip, nose, ear – use marking pen to match up borders prior to injecting local anesthetic
- Always rule out injuries to the globe, facial nerve, parotid duct
- For blunt force injuries to the ear, make sure to rule out otohematoma- must be drained if present to prevent future “cauliflower ear” deformity

Discharging the Craniofacial Trauma Patient – Pearls
- Soft diet for all patients with occlusal injuries or zygoma fractures
- HOB elevation
- Avoid nose blowing in all orbital floor fractures
- Frequent visual checks
- Temporary eye patch is reasonable for significant diplopia (rarely needed)
- Mandible Fractures- Clavulin 875mg PO BID until fracture is fixed; Peridex 15 ML PO TID
Final Reminders

- These patients are trauma patients first – don’t forget your ABCDEs and remember that many of these patients will have injuries outside of the craniofacial skeleton
- Always examine the eyes!
- Do not forget to rule out injury to the brain and cervical spine- when in doubt, get imaging
- CT is the gold standard for facial fractures
- Do not neglect a bleeding scalp—life-threatening bleeding can happen surprisingly quickly. Staple or suture closed
References


2. Advanced Trauma Life Support (ATLS®): The Ninth Edition ATLS Subcommittee; American College of Surgeons’ Committee on Trauma; International ATLS working group


Neck Trauma
Niroshan Sothilingam
Kelly Vogt
Zeeshan Rana - Illustrations

Neck trauma accounts for only 1% of all injuries however, carries a mortality rate as high as 10%.

- Multiple vital structures present:
  - Vascular system
    - Carotid, Jugular, subclavian, vertebral, innominate, aortic arch
  - Air passages
    - Pharynx, Larynx, trachea, lungs
  - Upper Gastrointestinal passages
    - Pharynx, esophagus
  - Neurologic system
    - Spinal cord, cranial nerves, peripheral nerves, brachial plexus, sympathetic chain

Borders of the neck:
- Upper – lower margin of the mandible and the superior nuchal line of the occipital bone.
- Lower – Suprasternal notch and the upper borders of the clavicles.
- The sternocleidomastoid separates the neck into anterior and posterior triangles.

Zones of the Neck
- Zone I
  - Extends from the clavicles to the cricoid cartilage.
  - Includes:
    - The vertebral and proximal common carotid arteries, the subclavian and innominate vessels and the jugular veins.
    - Superior mediastinum, lungs, esophagus, trachea, thoracic duct, and spinal cord.
- Zone II
  ▪ Extends from the cricoid cartilage to the angle of the mandible.
  ▪ Includes
    ▪ The common carotid artery, carotid bifurcation, the vertebral arteries and the jugular veins.
    ▪ Esophagus, trachea, larynx, and spinal cord.

- Zone III
  ▪ Extends from the angle of the mandible to the mastoid process.
  ▪ Includes:
    ▪ The branches of the external carotid artery, the internal carotid artery, vertebral artery and the internal jugular and facial veins.
    ▪ Pharynx and spinal cord.

Wounds to the posterior triangle require operative management for control of bleeding and wound repair. There are no hidden structures that lead to late complications unlike the anterior triangle.

**Principles of Management**

- Follow ATLS principles:
  ▪ Maintain C-spine precautions if unknown history/mechanism
    ▪ However, make sure to examine with collar off and c-spine immobilized to identify any lacerations or penetrating wounds.
- Airway
  ▪ May rapidly lose airway due to:
    ▪ Tracheal/laryngeal injury
    ▪ Expanding neck hematoma
    ▪ Significant oropharyngeal trauma
  ▪ Secure if any doubt
    ▪ Endotracheal intubation +/- airway adjuncts
If unsuccessful, a cricothyroidotomy is performed rapidly
- Injury to the larynx could make cricothyroidotomy difficult/ineffective.
  In this case, a tracheostomy may be required

- Control Hemorrhage
  - Most bleeding can be controlled with direct pressure

**Penetrating Neck Trauma**

Penetrating mechanisms account for most neck injuries. Penetrating injuries can result in injury to vascular, aero-digestive structures, and nervous structures, therefore all of these structures must be investigated.

- **Hard signs** – Indications for immediate surgical intervention:
  - Vascular
    - Expanding hematoma
    - Pulsatile bleeding
    - Shock not explained by other injuries
    - Absent carotid pulse
    - Bruit or palpable thrill
    - Signs of stroke/cerebral ischemia
  - Airway
    - Airway compromise
    - Wound bubbling
  - Esophageal
    - None
  - Nervous
    - None

- **Soft signs** – Indications for further workup/imaging/observation:
  - Vascular
    - Stable hematoma
    - Non-pulsatile bleeding
    - Seatbelt sign
    - History of bleeding at scene
  - Airway
- Extensive subcutaneous emphysema
- Stridor
- Hoarseness
- Hemoptysis

- Esophageal
  - Extensive subcutaneous emphysema
  - Hematemesis
  - Odynophagia
  - Dysphagia

- Nervous
  - Nerve injury
    - CN IX, X, XI and XII
    - Brachial Plexus injury
      - Axillary, musculocutaneous, radial, median and ulnar nerves

97% of patients with hard signs have a vascular injury, as opposed to only 3% of those with soft signs.

Management

- Unstable Patient
  - Zone I & II
    - OR
  - Zone III
    - IR

- Stable Patient
  - Zone I
    - FAST to rule out pericardial fluid
    - CXR to rule out pneumothorax/hemothorax
  - Zone II
    - Hard signs?
      - Yes -> Operative exploration
      - No -> CTA/esophagram/bronchoscopy for high index of suspicion
    - Additional Investigations dictated by physical exam findings
Zone III
- Stable -> CTA/Angiogram head and neck
- Additional investigations dictated by physical exam findings

All Patients with penetrating trauma require a complete head and neck neurologic exam.

Blunt Neck Trauma
Blunt injuries to the neck can cause compression, with fracture of the larynx or trachea. Blunt pharyngeal or esophageal injuries are extremely rare but can result in leakage into the surrounding soft tissues with sepsis if not properly addressed.

Vascular Injuries
Blunt cerebrovascular injuries (BCVIs) involving the carotid arteries commonly result from compression by a seatbelt. The vertebral arteries are vulnerable to severe flexion and extension mechanisms. Stroke secondary to thromboembolism developing from the disrupted vessel wall is a major concern in this type of injury.

While rare (1% of blunt trauma patients) these injuries confer a significant risk of morbidity (up to 58%) and mortality (up to 59%)

The most common mechanism of blunt carotid injury is hyperextension of the carotid vessels over the lateral articular processes of C1-C3 at the base of the skull, which is typically a result of high-speed collisions.

Mechanisms
- Seatbelt
- Direct blunt trauma
- Hyperflexion
- Hyperextension/rotation
- Hanging
- Fracture in proximity to the internal carotid or vertebral artery

As these injuries typically present with no signs/symptoms, CTA is used as the imaging modality of choice when there is
suspicion for a BCVI.

Blunt carotid arterial injury grading scale³:
- Grade I: Luminal irregularity or dissection with a 25% narrowing
- Grade II: Dissection or intraluminal hematoma with > 25% luminal narrowing, intraluminal thrombus, or raised intimal flap.
- Grade III: Pseudoaneurysm
- Grade IV: Occlusion
- Grade V: Transection with free extravasation

EAST Practice Management Guidelines⁵:
- Level I:
  - No recommendations
- Level II:
  - Patients presenting with any neurologic abnormality that is unexplained by a diagnosed injury should be evaluated for BCVI.
  - Blunt trauma patients presenting with epistaxis from a suspected arterial source after trauma should be evaluated for BCVI.
- Level III:
  - Asymptomatic patients with significant blunt head trauma as defined below are at significantly increased risk for BCVI and screening should be considered. Risk factors are as follows:
    - Glasgow Coma Scale score < 8
    - Petrous bone fracture
    - Diffuse axonal injury
    - Cervical spine fracture particularly those with:
      - Fracture of C1 to C3
      - Fracture through the foramen transversarium
    - Cervical spine fracture with subluxation or rotational component
    - LeFort II or III facial fractures
  - Pediatric trauma patients should be evaluated using the same criteria as the adult population.
Approximately 30% of BCVI are still missed following these guidelines.6

Management
The mainstay of treatment for BCVI is antithrombotic therapy with either ASA or heparin11.

- Cochrane review on use of antithrombotic drugs for carotid artery dissections failed to identify a difference in efficacy between ASA and anticoagulants.

Patients with pseudoaneurysm or free extravasation may require additional intervention (typically IR).

All patients treated medically should undergo a CTA at 1-3 month follow-up to reevaluate the injury and determine the need for ongoing therapy.

Laryngotracheal Injuries

- Symptoms
  - Hoarseness
  - Pain
  - Bubbling/air through wound
  - Dyspnea*
  - Dysphagia*
  - Aphonia*
  - Odynophagia*

* Less common

The immediate goal of the examination of a patient with suspected laryngeal trauma is to determine the severity of injury and quickly identifying patients who require immediate airway intervention.

- Airway evaluation
  - Once the airway is secure, initial evaluation of the larynx should be done in conjunction with ENT and may include a flexible fiberoptic laryngoscopy and CT scan.

- Radiologic Evaluation
  - Cervical spine injuries must be ruled out in all cases of
laryngeal trauma.
- Chest x-ray to rule out pneumothorax, tracheal deviation, or pneumomediastinum.
- CT scans diagnose laryngeal fractures and aid in operative planning for the repair and reconstruction of the fractured larynx.
- It is also important to rule out concomitant head injuries.

Small laryngotraheal injuries can be observed safely, however major injuries require surgical repair.

**Esophageal Injury**

Esophageal and pharyngeal injuries may be difficult to diagnose, but the morbidity and mortality of missed esophageal injuries is high.

Esophageal injury should be suspected in all patients with penetrating neck trauma, and especially where there is a gunshot wound traversing the midline.

- The incidence of esophageal trauma ranges from 3.9% to 5.4% in penetrating neck injuries¹.

Patients may complain of odynophagia or hemoptysis/ hematemesis.

Esophagoscopy and gastrograffin swallow are both used for diagnosis.

- Flexible esophagoscopy has a sensitivity of 96% and specificity of 99%¹.
- A water-soluble (gastrograffin) study has a sensitivity rate of 60% -75%⁹.

Treatment:
- Minimum contamination and short interval: Primary repair and drain.
- Contaminated and long interval: Divert and drain.

**Principles of Repair of the Trachea**

Most penetrating injuries of the cervical trachea are straightforward and may include vascular injuries.
- No debridement is necessary
- One-layer repair with absorbable suture if small or moderate-size hole
- Larger injuries may require insertion of tracheostomy tube into the defect, and/or more complex reconstructions

Note: Please see Appendix for SHR C-spine Clearance Protocol
References


Chest injuries are common in trauma. All trauma patients should have a chest x-ray in the trauma bay. More complex blunt injuries may require additional investigations such as CT scanning.

Most blunt injuries are managed non-operatively, with simple interventions such as chest tube insertion.

In contrast, penetrating injuries are more likely to require operation, and typically require only a chest x-ray for diagnosis. Patients with penetrating trauma may deteriorate rapidly, and recover much faster than patients with blunt injury.

Physical examination is the primary tool for diagnosis of acute thoracic trauma. This may be difficult in the busy trauma bay or emergency room, and it is important for the physician to optimize the environment in the room to maximize diagnostic ability.

Physical examination includes:

**Look**
- Respiratory rate and depth
- Chest wall asymmetry, penetrating wounds and paradoxical chest wall motion
- Bruising, seat belt or steering wheel marks

**Listen**
- Breath sounds on both sides:
  - Apices, axillae and at the back of the chest

**Feel**
- Tracheal deviation
- Subcutaneous emphysema
- Chest wall tenderness
Major threat to life:
- Tension Pneumothorax
- Cardiac Tamponade
- Massive Hemothorax
- Flail Chest*
- Open pneumothorax*

* Less common

An initial normal examination does not exclude any of the above, therefore serial examinations and use of diagnostic adjuncts is important.

<table>
<thead>
<tr>
<th>Definition</th>
<th>Symptoms</th>
<th>Diagnosis</th>
<th>Trachea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tension Pneumothorax</td>
<td>Progressive build up of air within the pleural space, due to a lung laceration allowing air to escape into the pleural space but not to return</td>
<td>Dyspnea, cyanosis, tachypnea, shock, distended neck veins</td>
<td>Clinical</td>
</tr>
<tr>
<td>Simple Pneumothorax</td>
<td>Air in the potential space between the visceral and parietal pleura</td>
<td>Dyspnea, tachypnea &amp; decreased breath sounds however, many are asymptomatic</td>
<td>CXR</td>
</tr>
<tr>
<td>Haemothorax</td>
<td>Collection of blood in the pleural space that may be caused by blunt or penetrating trauma</td>
<td>Dimished breath sounds, dullness due to percussion however, may be asymptomatic</td>
<td>CXR</td>
</tr>
<tr>
<td>Pulmonary Contusion</td>
<td>Injury to lung parenchyma, leading to oedema and blood collecting in alveolar spaces and loss of normal lung structure &amp; function</td>
<td>Asymptomatic. May have crackles.</td>
<td>CXR</td>
</tr>
<tr>
<td>Sucking Chest Wound</td>
<td>Defect in the chest wall that allows for equilibration of intrathoracic and ambient pressure</td>
<td>Breathing is rapid, shallow and labored. Reduced expansion of the hemithorax, reduced breath sounds, increased percussion.</td>
<td>CXR</td>
</tr>
</tbody>
</table>

Injuries identified & treated on secondary survey
- Simple Pneumothorax
- Simple Hemothorax
- Blunt aortic injury
- Blunt myocardial injury
- Pulmonary Contusion
- Rib Fractures

**Investigations**

- Chest X-ray
- E-FAST Ultrasound
- CT
- ECG/Troponin
- Arterial Blood Gas

The Chest X-Ray is central in the initial workup of trauma patients. It is an inexpensive, quick and safe modality with a high diagnostic yield.

The following injuries should be assessed for on an A/P view:

- Rib Fractures
- Pneumothorax
- Hemothorax
- Lung Contusion
- Subcutaneous/mediastinal emphysema
- Widening mediastinum
- Free air under the diaphragm
- Foreign body

**Tube Thoracostomy**

Most common procedure preformed following chest trauma.

Chest tube insertion carries a complication rate of 2-10%. Most of these are minor, however, some require operative intervention and deaths can still occur.

Absolute Indications

- Pneumothorax (simple, tension, open) on chest x-ray
- Hemothorax
- Blunt Traumatic Arrest (bilateral)

Relative Indications

- Occult Pneumothorax
- Profound hypoxia / hypotension & penetrating chest injury
Profound hypoxia / hypotension and unilateral signs to a hemothorax
Subcutaneous emphysema without obvious pneumothorax

**Tube Thoracostomy Placement**

Chest Tube insertion technique:
1. The area is prepped and draped appropriately
2. An incision is made along the upper border of the rib below the intercostal space behind pectoralis major, 4th-5th intercostal place. The drain track will be directed over the top of the lower rib to avoid the intercostal vessels lying below each rib. The incision should easily accommodate the operator’s finger.
3. Using a curved clamp the track is developed by blunt dissection only. The clamp is inserted into muscle tissue and spread to split the fibers. The track is developed with the operator’s finger.
4. Once the track comes onto the rib, the clamp is angled just over the rib and dissection continued until the pleural is entered.
5. A finger is inserted into the pleural cavity and the area explored for pleural adhesions. Lung is felt to confirm entry into the thoracic cavity.
6. A large-bore (28 or 32F) chest tube is mounted on the clamp and passed along the track into the pleural cavity.
   - Blunt trauma: Drains should be placed anteriorly in the chest. Prevents a tension pneumothorax developing if chest tube is blocked by dependent lung tissue. Normal movement of the lungs will allow drainage of a basal hemothorax through an anterior chest tube.
   - Penetrating trauma: Hemothoraces may be more efficiently drained with a posterior directed drain.
7. The tube is connected to an underwater seal and sutured / secured in place.
8. If desired, a U-stitch is placed for subsequent drain removal (see below).
9. The chest is re-examined to confirm effect.
10. A chest X-ray is taken to confirm placement & position.

Management of Specific Injuries

Pneumothorax
- Simple
  - Air in the potential space between the visceral and parietal pleura.
  - Symptoms include dyspnea, tachypnea & decreased breath sounds however, many are asymptomatic.
  - Lung laceration with air leakage is the most common cause of pneumothorax resulting from blunt trauma.
  - Diagnosed by upright CXR
  - Treatment \(^8,^{12}\)
    - Visible on CXR ➤ requires chest tube
    - Occult - Safe to watch
    - Occult and positive pressure ventilation ➤ requires chest tube pre-op if no one is available in the OR to decompress
    - Small, asymptomatic pneumothorax may be observed with clinical exam and serial CXR.
    - If the patient is being transported by air, even in a pressurized cabin or if the patient receives general anesthesia/positive pressure ventilation; chest decompression is recommended.

- Open “Sucking Chest Wound”
  - Large defect in the chest wall that allows for equilibration of intrathoracic and ambient pressures, therefore causing lung collapse.
  - Clinical Diagnosis
  - Treatment
    - Temporary occlusion of the chest wall defect with a sterile occlusive dressing on three sides to prevent air entering the chest cavity on inspiration and during expiration, the open side allows air to escape from the pleural space.
- Chest tube insertion to re-expand the lung is typically definitive treatment. However, repair in the OR may be required.

- Deep Sulcus Sign
  - Indication of pneumothorax on a supine chest radiograph:

- Tension
  - Occurs if pressure of accumulated air in the pleural space exceeds the ambient pressure:
    - Net positive intrathoracic pressure ➔ mediastinal shift ➔ decreased venous return ➔ compression of contralateral lung ➔ hemodynamic collapse and severe respiratory distress
  - Symptoms include Dyspnea, cyanosis, tachypnea, shock, distended neck veins, tracheal deviation to opposite side.
  - Diagnosis is made clinically.
  - Treatment
    - Needle decompression
      • 14 gauge angiocatheter, 2nd intercostal space, midclavicular line.
      • Chest tube insertion.

Both Tension Pneumothorax and cardiac tamponade have similar signs/symptoms and can be difficult to differentiate. Tension Pneumothorax however, has the following differences:
- Hyperresonant note percussion
- Deviated trachea
- Absent breath sounds over the affected hemithorax

**Hemothorax**
- Collection of blood in the pleural space.
- Majority are the result of rib fractures, lung parenchymal and minor venous injuries from the chest wall and are self-limiting.
- Often asymptomatic, however can include tachypnea, dyspnea and hypovolemia.
- Clinical signs include diminished breath sounds, dullness to percussion
- Diagnosed by upright CXR. It takes approximately 400-500mls of blood to obliterate the costo-phrenic angle on a chest radiograph. FAST exam can detect smaller hemothoraces, although in the presence of a pneumothorax or subcutaneous air ultrasound may be difficult radiograph.
- Treatment
  - The majority of hemothoraces have already stopped bleeding and simple drainage is all that is required.
  - All chest tubes placed for trauma should be of sufficient calibre to drain hemothoraces without clotting.

Indications for Thoracotomy
- 15% of patients with chest injury require a formal thoracotomy.
- > 1500 mL blood loss from chest tube insertion.
- > 200 mL blood loss from chest tube per hour

Complications
  - Retained Hemothorax
    - Failure of the chest tube to evacuate the hemothorax due to small chest tube caliber, clot in tube, poor placement.
    - Diagnosed on CT
    - If left untreated, these retained hemothorax may become infected and lead to empyema formation.
    - If this collection remain uninfected, the clot will organize and fibrose, causing loss of lung volume.
  - Treatment
    - Intrapleural fibrinolytics (Streptokinase/ Urokinase)
    - Surgery
      - Thoracoscopy (< 10 days)
      - Thoracotomy and Decortication (> 10 days)
- Empyema
  - Infected hemothorax
  - Present with fever, raised white cell count, air-fluid levels on CT.
  - Treatment involves surgery.

**Rib Fractures**
- Most common injury with blunt chest trauma.
- Tenderness over fracture and pain with A/P compression.
- Bedside ultrasound may be used to determine the specific location of a rib fracture.
- Management is directed towards protecting the underlying lung and allowing adequate oxygenation, ventilation and pulmonary toilet.
- This is to prevent the development of pneumonia, which is the most common complication of rib fractures.
- Young, healthy patient may be able to manage one or two rib fractures with analgesia alone, however the same injury in an elderly patient is regarded as major and may lead to pneumonia, respiratory failure and even death.
- Treatment\(^{5,6}\)
  - Oral analgesics
  - PCA
  - Epidural
  - Chest Physiotherapy

**Flail Chest**
- The fracture of two or more consecutive ribs in at least two locations.
- It is the result of significant kinetic energy applied to the thorax.
- Patient with multiple consecutive rib fractures may exhibit the respiratory compromise and pulmonary dysfunction classically associated with flail chest.
- The associated respiratory failure is due primarily a result of underlying pulmonary contusion, however the biomechanical changes of multiple rib fractures, severe pain, splinting, and atelectasis are contributing factors.
- Treatment
  - Should be implemented early and aggressive with an emphasis on pain management and pulmonary toilet.
  - Mechanical ventilation may be required in patients with flail chest, even with optimal analgesia and pulmonary toilet.
  - The best method of providing pain relief for these patients is thoracic epidural analgesia, which should be initiated as soon as possible.
  - Intercostal nerve blocks may be useful if long-acting local anesthetics are used.
  - Narcotic use is almost always necessary for analgesia.
  - Operative fixation of rib fractures in flail segments may be considered in a subset of patients.

**Blunt Cardiac injury (BCI)**

- Diagnosis:
  - A high index of suspicion is required as there is no pathognomonic mechanism that leads to BCI, along with a proper evaluation of the mechanism of trauma.
    - More than 75% of all patients with BCI will have other associated thoracic injuries, including rib and sternal fractures, pulmonary contusions, pneumothorax, hemothorax, and great vessel injuries.
    - The presence of a sternal fracture does not predict the presence of BCI and therefore does not necessitate monitoring and further evaluation.
    - The most common complaint in patients with BCI is chest pain, which can be difficult to distinguish from pain associated with chest wall injuries such as rib and sternal fractures.
  - The majority of patients with BCI are asymptomatic.
  - All patients with suspicion for blunt cardiac trauma should have an ECG on admission (level 1 recommendation).
    - The most common finding is sinus tachycardia, which is very nonspecific, as it is commonly found
in trauma patients with a multitude of injuries and is often associated with bleeding or pain.

- The next most common abnormality is premature atrial or ventricular contractions followed by a spectrum of findings, including nonspecific T-wave changes, ST-segment elevation or depression, atrial fibrillation or flutter, ventricular dysrhythmias, conduction delays, bundle branch and heart block, and the presence of Q waves.

- If the ECG reveals any of these findings or other evidence of ischemia, BCI should be ruled out, and the patient should be admitted for continuous ECG monitoring for 24 to 48 hours (level 2 recommendation).
- However, if the ECG shows no abnormality, the chances of having a clinically significant BCI requiring treatment are negligible, and pursuit of the diagnosis should be terminated (level 2 recommendation).
- Those who survive to hospital with more life-threatening types of BCI will present with signs and symptoms of shock. The cause of the shock state needs to be established by differentiating cardiogenic shock secondary to BCI from the more common causes, including tension pneumothorax, neurogenic shock from spinal cord injury, and hypovolemic shock secondary to bleeding.

- Treatment
  - Asymptomatic patients should be observed with ECG and Troponin monitored until levels peak.
  - Antiarrhythmics only if symptomatic
  - Inotropic support for those in cardiogenic shock
Diaphramatic Injury
- Traumatic diaphragmatic ruptures occur in 1-7% of patients with significant blunt abdominal trauma and 10-15% in victims of penetrating trauma.
- Only 25% are diagnosed on the initial chest radiograph.
- Penetrating trauma is often small compared to blunt.
- Injuries due to blunt trauma result from high-energy mechanism causing large rents that are usually obvious.
- 75% of these injuries occur on the left sided as this side is not protected by the large mass of the liver.
- Diaphragmatic ruptures are often asymptomatic initially
- Presentation may be masked by concomitant injuries making an immediate diagnosis difficult.
- In penetrating trauma, any injury to the thoracoabdominal area should raise suspicion for potential injury.
- Sensitivity of CXR is 27-62% for left-sided injuries and 18-33% for right-sided injuries.
- CT for blunt injuries is reported as sensitivity of 71-100% and specificity of 75-100%.

**American Association for the Surgery of Trauma Organ Injury Scale for Diaphragmatic Injuries**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Contusion</td>
</tr>
<tr>
<td>II</td>
<td>Laceration &lt; 2 cm</td>
</tr>
<tr>
<td>III</td>
<td>Laceration 2-10 cm</td>
</tr>
<tr>
<td>IV</td>
<td>Laceration &gt; 10 cm with tissue loss &lt; 25 cm²</td>
</tr>
<tr>
<td>V</td>
<td>Laceration with tissue loss &gt; 25 cm²</td>
</tr>
</tbody>
</table>

- Treatment
  - Laparoscopy vs. Laparotomy vs. Thoracoscopic
  - Non-absorbable suture
  - Airtight closure
  - Thoracostomy tube after chest washout

**Esophageal Injuries**

- Extremely rare injuries
- Most commonly caused by penetrating injury.
- Blunt causes are rare, however deadly if unrecognized.
  - Caused by forceful expulsion of gastric content into the esophagus from a severe blow to the upper abdomen.
  - This causes a linear tear in the lower esophagus.
  - Leakage of gastric content into the mediastinum causing mediastinitis and empyema.

- Diagnosis
  - CXR
    - Patients may present with concomitant pneumothorax/hemothorax/pneumomediastinum
    - Contrast swallow study
      - Start with water-soluble and if no leak is identified,
then study can be repeated with barium. Barium is inert and extravasation into the mediastinum will not cause additional harm.

- Esophagoscopy (flexible)
  - Negative predictive value of 100%
  - Positive predictive value of only 33%.

- Treatment
  - Approach an injury to the upper and mid-thoracic esophagus through a right posterolateral thoracotomy in the 4th intercostal space.
  - Lower thoracic esophagus is accessed though a left posterolateral thoracotomy in the 6th or 7th intercostal space.
  - Minimal sepsis, contamination, short interval: Primary repair and reinforced repair
  - +++ sepsis, contamination, long interval: resection +/- reconstruction
  - Unstable: exclusion and drainage

**Tracheobronchial Injury**

- Infrequent, however this type of injury has possible life-threatening consequences.
- The cervical trachea is more commonly injured from penetrating trauma and the distal trachea from blunt trauma.

- Diagnosis
  - Cervical tracheal injuries may be obvious on physical exam.
  - With penetrating injuries, there may be subcutaneous air, bubbling/fluctuating with the patient’s respirations, air leak, crepitus.
  - In blunt cases, there is often massive subcutaneous emphysema in the neck. Patients may present in respiratory distress and require airway management.
  - Signs of tracheal injury include airway obstruction, subcutaneous air, dysphonia and chest wall contusion.
  - Persistent air leak with chest tube insertion is a common finding in distal trachea/proximal major bronchial injury.
Treatment
- Secure the airway
- Tube Thoracostomy, second tube for persistent air leak if necessary
- All patients with suspected injury should undergo bronchoscopy for evaluation.
  - Management options
    - ETT past injury
    - Operative repair
    - Low pressure ventilation and observation

Penetrating Cardiac Injuries
- Among patients with stab wounds who reach hospital, approximately 35% have an isolated right ventricular injury.
- The left ventricle is involved in 25%, and in 30% more than one chamber is involved.
- Other injuries include coronary artery lacerations (most often the left anterior descending and diagonal branches), valve injury, and ventricular septal defects.
- Management of an unstable patient with penetrating cardiac trauma begins with fluid resuscitation and immediate transfer to the operating room.
- Pericardial Window
  - 3 to 4 cm skin incision can be made just to the left side of the xiphoid process facilitating passage of a blunt-tipped clamp into the pericardium for immediate decompression.
  - Can be done in OR transdiaphragmatically.
- The role of FAST\textsuperscript{14}
  - To determine the presence of pericardial fluid
    - Sensitivity 100%
    - Specificity 97%
Pericardial injury

- False-negative results may occur if the patient is stabbed in the chest and a hole in the pericardial sac decompresses the hemopericardium into the thoracic cavity.
  - If this is suspected, immediate decompression with tube thoracostomy and repeat ultrasound pericardial windows tube\(^1\).
  - This should be considered with a stab wound to the precordium, negative FAST and residual output from a left sided chest tube.\(^1\)

- Emergency department thoracotomy can occasionally salvage trauma patients who arrest.

**Resuscitative thoracotomy (ED thoracotomy)**

- **Absolute Indications:**
  - Penetrating torso injury and VSA < 15 minutes
  - Blunt injury and VSA < 5 minutes
- **Relative indications:**
  - Penetrating non-torso injury VAS < 15 minutes.
- **Survival in penetrating trauma:**
  - Cardiac injury 10-20\(^\%\)\(^{13}\)
  - Non-cardiac injury 3-20\(^\%\)
- **Patient Positioning**
  - Supine, left side slightly elevated with towels/sheets
  - Arms out/above head
  - Left anterolateral thoracotomy
- **Objectives:**
  - Release tamponade
  - Open Cardiac massage
  - Cross clamp descending aorta
- **Technique**
  - Left anterolateral thoracotomy
    - 4th/5th intercostal space from lateral border of sternum to the bed.
Skin, fat, chest wall muscles – divided with scalpel.
Intercostal muscles & pleura divided with heavy scissors.
Rib spreader handle towards axilla

Pericardiotomy
- Incise pericardium anterior and parallel to the phrenic nerve.
- If hemopericardium is present, this should be done with a scalpel and the pericardotomy then extended the entire length using scissors.
- Evacuate blood clot.
- Control areas of bleeding then get to an OR
  - Digital pressure
  - Skin stapler
  - Sew with prolene
  - Foley catheter
- In a non-beating heart, suture the injury, then defibrillate with internal paddles on RA & LA at 10-30 joules +/- epinephrine.

Cross Clamp descending aorta
- Elevate lung anterior & cephalad
- Incise mediastinal pleura, inferior pulmonary ligament
- Bluntly dissect aorta from esophagus (anterior) and prevertebral fascia (posterior), however not circumferentially.
- Place left hand on the thoracic spine and slide anteriorly. The first structure felt is the aorta.
- Bluntly dissect anteriorly and posteriorly at one level to avoid injury to additional structures.
- Cross clamp at the level of the diaphragm with vascular clamp.
Mechanism of injury revealed mortality of 84% for gunshot wounds compared with 35% for stab wounds.

Grades IV, V, and VI injuries had a mortality of 56%, 76%, and 91%, respectively.

Penetrating left atrial and ventricular injuries had a higher mortality rate between 77% and 80%, while right atrial and right ventricular had mortality rates of 63% and 49%, respectively.

**Approach to Great Vessel Injury**
- Principles with all vascular injury:
  - Access
  - Exposure
  - Control
  - Proximal left subclavian: Left high (3rd intercostal space) anterolateral thoracotomy.
  - Distal left subclavian: Left Supraclavicular incision.
  - Proximal right subclavian: Median sternotomy.
  - Distal right subclavian: Right Supraclavicular incision.

- If inadequate exposure: **Clamshell**:
  - Extend incision to right anterolateral thoracotomy.
  - Extend incision to right anterolateral
  - Divide sternum with heavy scissors
  - Flip anterior chest wall cephalad onto patients head.

### American Association of the Surgery of Trauma Cardiac Injury Scale

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description of Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Blunt cardiac injury with minor EKG abnormality (non specific ST of T wave changes, premature atrial or ventricular contractions, or persistent sinus tachycardia</td>
</tr>
<tr>
<td>II</td>
<td>Blunt cardiac injury with heart block or ischemic changes without cardiac failure</td>
</tr>
<tr>
<td>III</td>
<td>Blunt cardiac injury with sustained or multifocal ventricular contractions</td>
</tr>
<tr>
<td>IV</td>
<td>Blunt or penetrating cardiac injury with septal rupture, pulmonary or tricuspid incompetence, papillary muscle dysfunction, or distal coronary artery occlusion without cardiac failure</td>
</tr>
<tr>
<td>V</td>
<td>Blunt cardiac injury with cardiac failure</td>
</tr>
<tr>
<td>VI</td>
<td>Blunt cardiac injury with cardiac failure</td>
</tr>
</tbody>
</table>

- Blunt cardiac injury with septal rupture, pulmonary or tricuspid incompetence, papillary muscle dysfunction, or distal coronary artery occlusion producing cardiac failure

- Blunt or penetrating cardiac injury with proximal coronary artery occlusion

- Stellate injuries, less than 50% tissue loss of the right ventricle, right or left atrium

- Blunt or penetrating left ventricular perforation

- Blunt or penetrating left ventricular perforation

- Blunt avulsion of the heart: penetrating wound producing more than 50% tissue loss of a chamber
Thoracic Aortic Injury
- > 90% of thoracic great vessel injuries are due to penetrating trauma.
- Blunt injury in most often caused by deceleration injuries.
- Aortic blunt injury usually involves the proximal descending aorta.
  ▪ 36% to 54% of blunt aortic injuries occur at the aortic isthmus.
- Approximately 2% to 5% of patients with aortic disruptions survive without operation, or even detection, to form chronic pseudoaneurysms.
- The patients who develop chronic pseudoaneurysms have fewer associated injuries at the time of the traumatic event.
- Diagnosis may be suspected on CXR, but definitive diagnosis requires CT or transesophageal echocardiography.
- Radiographic findings suggestive of a blunt injury to the thoracic aorta:
  ▪ Widened mediastinum
    ▪ > 8 cm at level of aortic knob or mediastinum width to chest ratio > 25% has a sensitivity of 81-100% and specificity of 60%.
  ▪ Obliteration of the aortic knob
  ▪ Depression of the left mainstem bronchus
  ▪ Loss of paravertebral pleural stripe
  ▪ Apical pleural cap
  ▪ Deviation of the NG tube
  ▪ Lateral displacement of the trachea at the T4 level
  ▪ Left hemothorax
  ▪ 1st rib, clavicle or scapula fracture
- Treatment
  ▪ TEVAR
    ▪ In large has replaced the need for open repair\textsuperscript{3,11}
"Cardiac Box" Trauma

ABC’s of Resuscitation

Hemodynamic Stability

2-D Echo (FAST) +/- CT

Negative

Equivocal

Positive

Subxyphoid Window

Negative

Positive

Unstable

ED Thoracotomy

OR

OR Thoracotomy
References


Indications on History & Physical Examination

The abdomen extends from the nipples to the groin crease anteriorly, and the tips of the scapulae to the gluteal skin crease posteriorly.

Even though physical examination remains the most important method to determine the need for exploratory laparotomy, there is little Level I evidence to support this. Several studies have highlighted the inaccuracies of the physical examination in blunt abdominal trauma.

Physical exam can be unreliable due to level of consciousness (drugs, alcohol, head injury), distracting injury and/or spinal cord injury.

Look for signs/symptoms of intraperitoneal injury:

- Abdominal tenderness, peritoneal irritation
- Hypotension/hypovolemia
- Entrance and exit wounds (to determine path)
- Distention – pneumoperitoneum, gastric dilation, bleeding
- Left shoulder tip pain can suggest splenic injury (Kehr’s sign)
- Retroperitoneal hemorrhage
  - Ecchymosis of flanks (Gray-Turners sign)
  - Ecchymosis of umbilicus (Cullen’s sign)
- “Seat belt sign” – highly correlated with intraperitoneal injuries
- DRE: Blood, high riding prostate

Several factors influence the selection of diagnostic testing:

- Capability of hospital - i.e., trauma center vs. peripheral hospital
- Access to imaging (CT scanner vs. FAST)
- Surgeon experience with available diagnostic imaging.

As facilities evolve, technologies mature and surgeons gain new
experience, it is important that any diagnostic strategy constructed be dynamic.

Due to the recognized inadequacies of physical examination, there are a number of diagnostic adjuncts:

- Diagnostic peritoneal lavage (DPL)
- Computed tomography (CT)
- Focused abdominal sonography for trauma (FAST)

**DPL** Whitehouse JS, 2009

- **Largely replaced by FAST and CT**
  - DPL is a safe, rapid and accurate method for determining the presence of intraperitoneal blood in blunt abdominal trauma.
  - It is more accurate than CT for the early diagnosis of hollow visceral and mesenteric injuries, but it does not reliably exclude significant injuries to retroperitoneal structures.
  - Hemodynamically stable patients with equivocal results are best managed by additional diagnostic testing to avoid unnecessary laparotomies.
  - In blunt trauma, DPL can be used to triage patients who are hemodynamically unstable and have multiple injuries with an equivocal FAST exam.
  - Hypotensive patients should not be transported to the CT scanner.
  - In the absence of CT scanning, DPL is also useful in patients with an unreliable abdominal exam due to altered mental status or spinal cord injury.
  - The only absolute contraindication to DPL is previous abdominal surgery
    - May cause injury an intra-abdominal organ with catheter
    - Difficult introducing a catheter due to adhesions
  - Relative contraindications include preexisting coagulopathy, advanced cirrhosis, and morbid obesity.
  - Relative contraindications to the standard infraumbilical approach include patients with a pelvic fracture or females beyond the 1st trimester of pregnancy.
Technique:

- Open technique uses a vertical infraumbilical incision
- Sterile prep and draped widely area
- Attempt to aspirate free peritoneal blood
- Insert lavage catheter by seldinger or open technique
- Lavage peritoneal cavity with warm 1 liter saline

Positive test requires one of the following:

- 10 ml gross blood on initial aspiration
- >500/mm³ white blood cells
- >100,000/mm³ red blood cells
- Presence of enteric content

In the presence of gross blood or enteric matter, immediate laparotomy is indicated in unstable patients.

Otherwise, accurate cell counts should be obtained, which takes time.

- During this time, if the patient’s clinical status deteriorates or signs of peritonitis develop, laparotomy is indicated.

The accuracy of DPL has been reported between 92% and 98% EAST.

DPL has been shown to be more efficient than CT scan in identifying patients that require surgical exploration.

- However, a positive DPL does not necessarily mandate immediate laparotomy in the hemodynamically stable patient.

The complication rate associated with DPL is low.

- Rate of complications is lower for open DPL than closed technique.
  - Closed DPL can be performed more rapidly.

The false positive rate for DPL is increased in patients with pelvic fractures.

- In order to avoid sampling the retroperitoneal hematoma, a supra-umbilical approach has been
recommended, theoretically reducing the chances of a false positive result. Cochran W, 1984

**Focused Assessment with Sonography in Trauma (FAST)**

- FAST is noninvasive, may be easily performed and can be done concurrently with resuscitation.
- Especially useful for detecting intra-abdominal hemorrhage in the multiply injured or pregnant patient.
- Easily portable and may be easily repeated if necessary.
- Can be completed within 5 minutes.
- More cost-effective when compared to DPL or CT.

A major limitation of the FAST examination is that a positive examination relies on the presence of free intraperitoneal fluid.

- Will detect a minimum of 200 mL of fluid (operator dependent)
- Injuries not associated with hemoperitoneum may not be detected by this modality.
  - Not a reliable method for excluding hollow visceral injury.
  - Cannot be used to reliably grade solid organ injuries.
  - In the hemodynamically stable patient, a follow-up CT scan should be obtained if nonoperative management is contemplated.

DPL may also be used as a complementary examination in the hemodynamically stable patient in the presence of an equivocal or negative FAST with strong clinical suspicion of visceral injury.

Overall, FAST has a sensitivity between 73% and 88%, a specificity between 98% and 100% and is 96% to 98% accurate. This level of accuracy is independent of the practitioner performing the study. Surgeons, emergency medicine physicians, ultrasound technicians and radiologists have equivalent results.

**CT Scan**

CT scanners are available in most trauma centers and, with the advent of helical scanners, scan time has been significantly reduced.
Sensitivity between 92% and 97.6% and specificity as high as 98.7% has been reported in patients subjected to emergency CT.

- Requires a cooperative (may require intubation), hemodynamically stable patient.
- Patient must be transported out of the trauma resuscitation area to the radiographic suite.
- Specialized technicians and the availability of a radiologist for interpretation were also viewed as factors which limited the utility of CT for trauma patients.

Negative predictive value (99.63%) of CT is sufficiently high to permit safe discharge of blunt abdominal trauma patients following a negative CT scan. Livingston DH et al, 1998

CT is notoriously inadequate for the diagnosis of mesenteric injuries and may also miss hollow visceral injuries. Patient should be admitted to an observation unit with serial abdominal exam preformed.

**Role of rectal exam in trauma assessment**

The DRE is used to evaluate

- Rectal hemorrhage
- Rectal mucosal injury or wall defects
- Loss of anal tone suggesting spinal cord injury
- Palpable pelvic fractures
- A high riding prostate suggestive of posterior urethral disruption

Traditionally, DRE has been mandatory in trauma patient. However, ATLS now recommends reducing the requirement for a DRE from absolute to selective. Kortbeek et al, 2008

DRE changes management in only in 1.2% - 4% of cases. Porter and Ursic's prospective observational study, 2001, Esposito et al's prospective study 2005

The sensitivity of the DRE is only 2% for detecting urethral injuries. In patients with posterior urethral disruption, 60% of cases did not have any clinical signs prior to insertion of urinary catheter. Ball et al, 2009
95% of patients with posterior urethral injuries had pelvic fractures. Ball et al, 2009

DRE remains clinically relevant in penetrating trauma for the presence of blood surrounding the rectum, pelvic fractures, and spinal cord injuries. Its role in identifying urethral injury via abnormal prostate position is minimal.

Clinical signs of urethral disruption:

- blood at the urethral meatus (20% sensitivity)
- gross hematuria prior to catheter insertion (17% sensitivity)
- abnormal prostate position (2% sensitivity)
- scrotal or perineal echymosis
- inability to void

Hematuria

- Hematuria (micro and macroscopic) is the hallmark for injury to the genitourinary system.
- The amount of hematuria does not correlate to the injury severity.
- All gross hematuria require evaluation of the genitourinary system.
- Microscopic hematuria in a trauma setting in the absence of shock does not need immediate evaluation. (Thomason RB, 1989)

- However, the absence of hematuria does not rule out injury to the genitourinary system. Suspected urethra rupture requires further intervention with retrograde urethrogram to rule out injury before urinary catheter inserted. ATLS

Penetrating Abdominal Trauma

Divided into low velocity (Stab wound and hand guns) & high velocity (high caliber rifles).

Most commonly injured organs with stab woundsATLS:

- Liver (40%)
- Small bowel (30%)
- Diaphragm (20%)
- Colon (15%)
Most commonly injured organs with gunshot wounds\textsuperscript{ATLS}:

- Small bowel (50%)
- Liver (30%)
- Colon (40%)
- Abdominal vascular (25%)

Patients with penetrating abdominal injury fall into 3 categories: \href{Trauma.org}{Trauma.org}

- Pulseless
- Hemodynamically unstable
- Hemodynamically stable

<table>
<thead>
<tr>
<th>Presentation</th>
<th>Injury Type</th>
<th>Management Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulseless</td>
<td>Major Vascular Injury</td>
<td>Emergency laparotomy ED Thoracotomy (for aortic cross clamp)</td>
</tr>
<tr>
<td>Hemodynamically Unstable</td>
<td>Vascular and/or solid organ injury AND/OR Hemorrhage from other sites</td>
<td>Identify &amp; control hemorrhage (with emergent OR laparotomy)</td>
</tr>
<tr>
<td>Hemodynamically Normal</td>
<td>Hollow viscus injury Pancreas or renal</td>
<td>Identify presence of gastrointestinal, diaphragmatic or retroperitoneal injury</td>
</tr>
</tbody>
</table>

**Hemodynamically Normal**

Diagnostic modalities:

- Serial abdominal examination
- CT
- Local Wound Exploration
- Diagnostic Peritoneal Lavage
- Laparoscopy

Patients with clinical signs of peritonitis, or with evisceration of bowel should be taken for surgical exploration/laparotomy.

**Serial Physical Examination**

- Selective non-operative management of penetrating abdominal injuries has become the standard of care.
- 55\% of anterior abdominal stab wounds can be managed non-operatively. \textsuperscript{Navsaria PH et al, 2007}
  - Even in the presence of peritoneal violation, a significant number of patients have no major intra-abdominal injury requiring an operation.
- Admit for observation for 24 hours.
- Hourly checks of hemodynamic status.
- Serial examination of abdomen checking for peritonitis.
Ideally the same surgeon should examine the patient each time.
If this is not possible, during a handover period both surgeons should examine the patient at the same time so they agree on the current status of the abdomen and whether there has been any progression in symptoms.

- Timing of examination can be at 1, 4, 12 and 24 hours after the initial assessment.
  - Some recommend examination every four hours.
- If the patient is well the following day they start a normal diet, and are discharged once diet is tolerated and they have completed the observation period.
- Signs of hemodynamic instability or peritonitis during this period of observation warrants a laparoscopy/laparotomy.
- Development of persistent local symptoms of pain and tenderness, fever or tachycardia at 24 hours, however not frank peritonitis should be evaluated with CT Scan, laparoscopy or laparotomy.
- Requirement admission of patient to monitored bed to evaluate hemodynamic and serial physical examinations.
  - Also require hospital setting with in house surgeons to perform frequent physical examinations.

Local Wound Exploration (LWE)

- Evaluation of a stab wound under local anaesthesia.
- The wound is extended under local anaesthesia and the track followed through tissue layers.
- Penetration of the anterior fascia is considered a positive LWE
  - Penetration of the peritoneum is difficult to identify.

A positive LWE leads to another diagnostic test or laparotomy/laparoscopy.

- When LWE is used alone to determine need for laparotomy, there will be a high non-therapeutic laparotomy rate.
When peritoneum is penetrated by a stab wound, many patients will have no intra-peritoneal injury or injuries that does not require surgical intervention
  - i.e. omental laceration, mesenteric laceration or liver tears that have stopped bleeding.

**Thoracoabdominal injury:**
- Any penetrating injury below the nipple should be considered.
- Must rule out diaphragmatic injury.
- Radiological studies may miss small diaphragmatic tears, therefore laparoscopy / thoracoscopy remains the investigation of choice.
- Laparoscopy is preferred for left sided and anterior diaphragmatic injuries.
- Thoracoscopy for posterior diaphragmatic injuries.
- Diaphragmatic lacerations can be repaired through a laparoscopic or thoracoscopic

**Flank or back wound:**
- Associated with injuries to retroperitoneal organs.
- Of these, the colon is the injury most often missed.
- If suspecting colon injury:
  - Duration of serial physical examination is extended to 72 hrs.
  - Watch for fever or a rise in the white cell count.
  - Triple-contrast CT scan is an option.
  - If the wound track extends up to the colon, or there is evidence of abnormal bowel wall thickening, laparotomy is indicated.

**Wound to buttock/perineum:**
- Any penetrating injury to the gluteal region carries the risk of rectal injury.
- Digital rectal examination is inadequate
- Proctoscopy and sigmoidoscopy should be performed
  - Look for the presence of blood and/or mucosal tear.
Blunt Abdominal Trauma

Mechanism of injury:
- Injury due to broken lower ribs
- Sudden increase in intraabdominal pressure causing rupture of hollow viscus
- Crushing of an organ against the spine, pelvis or abdominal wall
- Deceleration forces

Organs most often injured: ATLS
- Spleen (40-55%)
- Liver (35-45%)
- Small Bowel (5-10%)
- Incidence of retroperitoneal hematoma found on laparotomy is 15%
The American Association for the Surgery of Trauma Organ Injury Scale

- Most commonly used system for grading abdominal solid organ injury.
- Provides a consistent means of comparison from clinical description and decision making with respect to management.
- Most useful tool for comparison in research.
- Grade is assigned based on CT findings.
  - However, grade can be changed with intra-operative findings.

Spleen

- Grade I
  - Hematoma: Subcapsular, <10% surface area
  - Laceration: Capsular tear, < 1 cm. Parenchymal depth

- Grade II
  - Hematoma: Subcapsular, 10-50% surface area. Intraparenchymal, < 5 cm in diameter
  - Laceration: Capsular tear, 1-3 cm parenchymal depth that does not involve a trabecular vessel

- Grade III
  - Hematoma: Subcapsular, > 50% surface area or expanding; ruptured subcapsular or parenchymal hematoma; intraparenchymal hematoma > 5 cm or expanding.
  - Laceration: > 3 cm parenchymal depth or involving trabecular vessels

- Grade IV
  - Laceration: involving segmental or hilar vessels producing major devascularization (> 25% of spleen)

- Grade V
  - Laceration: Completely shattered spleen
- Vascular: Hilar vascular injury with devascularized spleen
  - Splenectomy
    - Unstable patients with grade IV & V will most likely require an operation.
  - Angioembolization (Stable patient)
    - Consider angioembolization in: Stassen NA et al
      - Patients with a grade > III injury
        - Splenic angioembolization for grade IV and V injuries has a success rate > 80% Haan JM et al, Banerjee A et al
      - Presence of intravenous contrast extravasation on CT
      - Moderate haemoperitoneum
      - Evidence of ongoing splenic bleeding
  - Conservative management
    - Requires patient to be admitted to a monitored bed, serial abdominal exams, frequent evaluation of hemoglobin and repeat CT in 24-48 hrs to rule out splenic pseudoaneurysm.
    - Non-operative management is now becoming the gold standard treatment for minor splenic trauma (Grade I & II). Cirocchi R et al
    - Non-operative management can be the initial treatment in some cases of severe splenic trauma; however, the decision between operative and non-operative management depends on careful risk-benefit analysis for each patient, as well as on the expertise of the surgeon and of the multidisciplinary hospital team. Cirocchi R et al
    - Extreme care must be taken with conservatively managing in patients with concurrent head trauma. Any systolic blood pressure drop less than 90 mmHg can cause a significant rise in mortality.
Liver

- Grade I
  - Hematoma: Subcapsular, <10% surface area
  - Laceration: Capsular tear, < 1 cm. Parenchymal depth

- Grade II
  - Hematoma: Subcapsular, 10-50% surface area. Intraparenchymal, < 10 cm in diameter
  - Laceration: Capsular tear, 1-3 cm parenchymal depth, < 10 cm in length

- Grade III
  - Hematoma: Subcapsular, > 50% surface area of ruptured subcapsular or parenchymal hematoma; intraparenchymal hematoma > 10 cm or expanding.
  - Laceration: > 3 cm parenchymal depth

- Grade IV
  - Laceration: Parenchymal disruption involving 25% - 75% hepatic lob or 1-3 Couinaud’s segments

- Grade V
  - Laceration: Parenchymal disruption involving > 75% of hepatic lobe or > 3 Couinaud’s segments within a single lobe
  - Vascular: Juxtahepatic venous injuries; retrohepatic vena cava/central major hepatic veins

- Grade VI
  - Vascular: Hepatic avulsion

Treatment

- A suspicion of hepatic injury is increased with right upper quadrant and/or right chest trauma.
  - However, clinical history and physical examination are not sufficiently sensitive or specific for the presence of liver injury.

- CT scan with IV contrast is the most useful investigation to determine severity of liver injury.
Non-operative management is the treatment of choice for hemodynamically stable patients. This requires appropriate patient selection and resources such as monitored bed, blood bank support, immediate operating room availability, and surgeons and interventional angiographers experienced in managing hepatic injury.

Patients who are hemodynamically stable with CT findings of extravasation from the liver have higher failure rates with nonoperative management. These patients are candidates for angioembolization followed by continued observation and serial hemoglobin evaluation.

Complications:
- Hemobilia
- Abscess formation
- Intrahepatic A/V fistula formation
- Liver parenchyma necrosis
- Biloma

Kidney
- Grade I
  - Contusion: Microscopic or gross hematuria, urologic studies normal
  - Hematoma: Subcapsular, nonexpanding without parenchymal laceration
- Grade II
  - Hematoma: Nonexpanding perirenal hematoma confirmed to renal retroperitoneum
  - Laceration: < 1.0 cm parenchymal depth of renal cortex without urinary extravasation
- Grade III
  - Laceration: < 1.0 cm parenchymal depth of renal cortex without collecting system rupture or urinary extravasation.
Grade IV

- Laceration: Parenchymal laceration extending through renal cortex, medulla, and collecting system
- Vascular: Main renal artery or vein injury with contained hemorrhage

Grade V

- Laceration: Completely shattered kidney
- Vascular: Avulsion of renal hilum with devascularized kidney

Treatment

- The kidney is the most commonly injured genitourinary organ, and is involved in about 1-5% of all trauma patients. Baverstock et al
- Non-operative management is the treatment for all patients who are not exsanguinating from the kidney
  - This results in a lower nephrectomy rate without increasing morbidity or mortality.
  - Patients with urinary extravasation and solitary injuries can be managed expectantly, with a resolution rate of more than 90%. Alsikafi, N. F et al
- 9% of kidney injuries will require surgical exploration, and of these there is on average an 11% nephrectomy rate.
- Surgery is indicated for:
  - Renal pedicle injury (vascular injury)
  - Shattered kidney
  - Expanding or pulsatile hematoma
  - Shocked polytrauma patient
- Relative indications for surgery include:
  - A devitalized renal segment in the presence of other abdominal injuries
  - Persistent extravasation
  - Loculated collections
  - Incomplete grading (CT or angiography)
Bladder/Ureter/Urethra

**Ureter**

The ureter is protected in the retroperitoneum by the bony pelvis, psoas muscle, and vertebrae. Therefore, ureteral injuries due to external trauma are rare.

Damage to the ureter usually results from a penetrating injury or significant traumatic event that is almost always associated with collateral injury to other abdominal structures.  
- 25% of ureteral injuries do not present with microscopic hematuria.
  - They are difficult to diagnose on imaging.
  - Most commonly diagnosed intra-operatively during the trauma laparotomy.
- Grade I
  - Hematoma: Contusion or hematoma without devascularization
- Grade II
  - Laceration: < 50% transection
- Grade III
  - Laceration: > 50% transection
- Grade IV
  - Laceration: Complete transection with < 2 cm devascularization
- Grade V
  - Avulsion with > 2 cm of devascularization

**Bladder**

Bladder injuries (Cass AS, 1987):
- 60%-85% result from blunt trauma
- 15%-40% are from penetrating injury

The most common mechanisms of blunt trauma are motor vehicle collision (87%)

50-70% of bladder injuries are extraperitoneal bladder perforation while 25%-43% are intraperitoneal. 7%-14% are combined.  

Deceleration injuries usually produce both bladder trauma (rupture) and pelvic fractures (which can cause bladder perforation).
Approximately 10% of patients with pelvic fracture also have bladder injury. The propensity of the bladder to sustain injury is positively associated with its degree of distention at the time of trauma.

- **Clinical Presentation**
  - Suprapubic pain
  - Hematuria
  - Inability to void
  - Abdominal distension
  - Urine extravasation in scrotum

- **Investigations**
  - CT Cystogram

- **Grade I**
  - Hematoma: Contusion, intramural hematoma
  - Laceration: Partial thickness

- **Grade II**
  - Laceration: Extraperitoneal bladder wall laceration < 2 cm

- **Grade III**
  - Laceration: Extraperitoneal (> 2 cm) or intraperitoneal (< 2 cm) bladder wall laceration

- **Grade IV**
  - Laceration: Intraperitoneal bladder wall laceration > 2 cm

- **Grade V**
  - Laceration: Intraperitoneal or extraperitoneal bladder wall laceration extending into the bladder neck or ureteral orifice (trigone)

**Treatment**

- Extraperitoneal bladder rupture
  - Transurethral foley catheter
- Intraperitoneal bladder rupture
  - Surgical repair
Urethra

- Clinical Presentation
  - Blood at the urethral meatus
  - Inability to void
  - High riding prostate on rectal exam
  - Urine extravasation in scrotum

- Investigations
  - Retrograde urethrogram:
    - Place small balloon catheter in urethral meatus
    - Infuse 10-15 cc of high osmolality contrast
    - Obtain A/P x-ray view

- Grade I
  - Contusion: Blood at urethral meatus; retrography normal

- Grade II
  - Stretch injury: Elongation of urethra without extravasation on urethrography

- Grade III
  - Partial disruption: Extravasation of urethrography contrast at injury site with visualization in the bladder

- Grade IV
  - Complete disruption: Extravasation of urethrography contrast at injury site without visualization in the bladder; < 2 cm of urethra separation

- Grade V
  - Complete disruption: Complete transaction with > 2 cm urethral separation, or extension into the prostate or vagina.

Treatment

- Avoid transurethral catheterization if suspecting urethral injury.
- Conservative management:
- Suprapubic or transurethral catheter (by urology team) placed for 10 – 14 days.

**Pancreaticoduodenal**

Difficult to assess due to infrequent nature and poorly identified on imaging.

More common in penetrating trauma than blunt abdominal trauma.

In blunt trauma, the mechanism usually involves a direct blow to the epigastric region such as being stuck by a steering wheel or handlebars.

Many pancreaticoduodenal injuries are only identified during exploratory laparotomy.

- **Clinical Presentation**
  - Epigastric pain
  - Peritonitis
  - Symptoms of acute pancreatitis

- **Investigations**
  - **Amylase/Lipase**
    - Normal level early during the resuscitation phase does not exclude pancreatic trauma.
    - Serial evaluation of blood work if high suspicion.
    - However, amylase can also be elevated for other non-pancreatic sources as well
  - **CT scan**
    - May be falsely negative
    - Repeat CT in 6 – 8 hrs. if high suspicion
    - Air or fluid in the retroperitoneum should raise suspicion
  - **MRCP/ERCP**
    - Evaluation of the biliary ductal system
Pancreas

- Grade I
  - Hematoma: Minor Contusion w/o ductal injury.
  - Laceration: Superficial lac w/o ductal injury
- Grade II
  - Hematoma: Major contusion w/o ductal injury or tissue loss
  - Laceration: Major lac w/o ductal injury or tissue loss
- Grade III
  - Laceration: Distal transection or pancreatic parenchymal injury with ductal injury
- Grade IV
  - Laceration: Proximal transection or pancreatic parenchymal injury involving the ampulla
- Grade V
  - Laceration: Massive disruption of the pancreatic head

Duodenum

- Grade I
  - Hematoma: Involving single portion of duodenum
  - Laceration: Partial thickness, no perforation
- Grade II
  - Hematoma: Involving more than one portion
  - Laceration: Disruption < 50% of circumference
- Grade III
  - Laceration:
    - Disruption 50 – 75% of circumference of D2
    - Disruption 50 – 100% of circumference of D1, D3, D4
- Grade IV
  - Laceration: Disruption > 75% of circumference of D2 involving ampulla or distal common bile duct
Grade V
- Laceration: Massive disruption of duodenopancreatic complex
- Vascular: Devascularization of duodenum

Treatment
- Surgical consult
- Minor pancreatic (grade I/II) injuries shown on CT may be treated conservatively.
  - Patient should be admitted to a monitored bed on surgical floor with serial blood work (amylase) and abdominal exams.
- Major pancreatic (> grade III) and the majority of duodenal injuries need surgical exploration.

Hollow Viscous Trauma
- Much more common in penetrating injury rather than blunt.
- Small bowel injury occurs in 2.7% of all blunt abdominal injuries\textsuperscript{NTDB}.
- Colon and rectal injury occur in less than 1% of all blunt trauma\textsuperscript{NTDB}.
  - Due to associated injuries, mortality from blunt colorectal injury is 16.3\%\textsuperscript{Sabiston}.
- Hollow viscous injury associated with blunt trauma is generally caused by rapid deceleration.
  - The small bowel can be crushed between the steering wheel/seatbelt and the vertebral column.
  - Injury surrounding fixed point of attachment.
  - Mesenteric injuries can cause devascularization of sections of small bowel without direct tissue injury (bucket handle injuries).
- Many hollow viscous injuries are discovered at the time of laparotomy.
- Clinical Presentation
Abdominal pain/peritonitis
Seatbelt sign – Increased risk of bowel injury
Chance fracture – Increased risk of bowel injury

Investigations
CT Scan
• The accuracy of CT for evaluating bowel injury is 82%, with a sensitivity of 64% and a specificity of 97%.
• Indications of bowel injury:
  ◦ free intraperitoneal air
  ◦ free intraperitoneal or retroperitoneal fluid
  ◦ focal areas of bowel wall thickening
  ◦ abnormal bowel wall enhancement, bowel wall hematoma (ie, duodenal hematoma)
  ◦ intramural air.
• The most specific finding is the visualization of oral contrast extravasation and bowel wall disruption.
  ▪ Serial abdominal exams
  ▪ Serial blood work
  ▪ Sigmoidoscopy*
  ▪ Gastrograffin enema*

** If suspicious for extraperitoneal rectal injury

Abdominal Great Vessel Injuries
Penetrating trauma accounts for most abdominal vascular injuries and accounts for 90% of cases in urban centers. 5-10% of blunt abdominal trauma present with major abdominal vessel injuries. Trauma

The great vessels of the abdomen are located within the retroperitoneum and abdominal mesenteries.
Abdominal arterial and venous injuries occur with the same incidence.

- The most commonly injured abdominal vessel: Rutherford’s
  - Inferior vena cava (25%)
  - Aorta (21%)
  - Iliac arteries (20%)
  - Iliac vein (17%)
  - Superior mesenteric artery (10%)

Causes of vascular injury in blunt abdominal trauma: Rutherford’s

- Rapid deceleration:
  - High-speed collision
  - Fall from height
- Direct anteroposterior crushing:
  - Seat belt injury
  - Direct blow to anterior abdomen
- Direct laceration of major vessel by bone fragments

Clinical Presentation

- Hypovolemic shock
- Abdominal pain/Peritonitis
- Abdominal distention
- Absence/decrease of lower extremity pulses
  - Asymmetric femoral pulses may indicate iliac vessel injury

- Investigations
  - FAST
    - Useful to rule out associated cardiac/thoracic injuries
    - Will detect free fluid in abdomen
      Not helpful for identifying retroperitoneal bleeding
  - CT Scan with IV contrast
References


In young healthy patients, a high-energy trauma is required to disrupt the pelvis. However, in the elderly with osteoporotic bone, it is possible to obtain a pelvis disruption from falls at standing height. While most pelvic fractures can be managed operatively in a semi-urgent fashion, or even non-operatively, some will present with significant, life threatening bleeding requiring emergent intervention.

Mechanism of pelvic fracture:
- Motor vehicle collision: 20-66%
- Pedestrian vs. Automobile: 14-59%
- Motorcycle: 5-9%
- Falls*
- Crush*

* Less common causes
Organ systems at risk of injury in combination with pelvic fractures:

- Vascular
- Neurological
- Abdominal viscus (rectum, small bowel)
- Genitourinary system (bladder, urethra)

Physical exam consideration:

- Mechanism of injury required to disrupt the pelvis is high energy, therefore the following must be investigated:
  - Physical exam should include rectal and vaginal exams to rule out open fracture communicating with these structures that can be hidden.
  - Bladder and urethral injuries must be ruled out if blood at meatus or gross hematuria.
  - In a patient with unstable vitals assess for intra-abdominal bleed from spleen or liver with abdominal and FAST exam.
  - Injuries to major arteries from the fracture fragments, therefore it is essential to examine lower extremity pulses.

Vasculature:

- Venous:
  - Lumbar venous plexus.
    - Most likely source of bleeding
    - Less likely to be hemodynamically significant source of bleeding

- Arteries:
  - Internal pudendal (27%), superior gluteal (25%), lateral sacral (23%), obturator arteries (16%), inferior gluteal (6%) and iliolumbar arteries (3%)
    - Less likely to be source of bleeding
    - More likely to be hemodynamically significant source of bleeding

Imaging Modalities:

- Plain films
  - AP Pelvis x-ray as an adjunct to primary survey is helpful in the diagnosis of a pelvic fracture and
potential classification of type.

- CT Pelvis

  - Useful in characterizing the fracture and may dictate management in the hemodynamically stable patient.

**Pelvic Fracture Classification:**

- Young and Burgess Classification:

  - A useful classification system that correlates with resuscitation needs

    - Anterior/Posterior compression fracture (APC), also known as “Open Book”
    - Lateral compression fracture (LC)
    - Vertical shear (VS)
    - Combined mechanical (CM) of APC, VS and/or LC

**Mechanism:**

- APC: Force applied in the anterior-posterior plane
- VS: Fall from a height with axial loading through the leg
- LC: Force applied in the lateral plane

Massive transfusion protocol activation should be considered early in patients with pelvic fractures who are hemodynamically abnormal.
Mortality:
- Pelvic fractures are associated with a significant mortality risk, given the significant mechanisms involved and complications of bleeding, infections and multiorgan failure.
- Closed pelvic fractures are associated with has a mortality rate up to 16% and open pelvis fractures are higher with a mortality rate of 45%.

Treatment
Hemodynamically abnormal patient:

Controlling bleeding:
- This typically involves temporizing measures (Sheet/pelvic binder), while preparing for definitive intervention in the OR (External Fixator) or angiography suite.
  1) Sheet
  2) Pelvic binder
  3) Orthopedic external fixator

All three work to reduce pelvic volume and attempt to tamponade bleeding. The pelvic binder and sheet are positioned over the greater trochanter to optimize pelvic stability.

- Consider the fracture classification for its appropriate use.
  - Most effective in APC.
  - Some benefit in vertical shear but requires limb traction on the shortened limb at the same time.
  - Maybe harmful in lateral compression as it can potentially worsen the deformity.
External Fixator:
- Takes more time and expertise for application.
- Very effective in controlling all three fracture patterns and is often used as a temporizing measure for definitive treatment with open reduction and internal fixation at a later time when the patient is more stable.

If temporizing measures are not effective in restoring hemodynamic normalcy, need to consider operative intervention for hemorrhage control.

Retroperitoneal Packing:
- Lower midline incision, extra peritoneal plane is developed to the retroperitoneum.

Pelvic Angioembolization:
- Effective at controlling arterial bleeds in the pelvis and can be done percutaneous without opening the pelvis.

Any combination of the above procedures can be utilized to achieve hemostasis. In the unstable patient, an external fixator, embolization and/or retroperitoneal packing may be required. Utilization of a hybrid OR suite is the ideal location for these patients.
References


8. Wong JML, Bucknil A. Fractures of the pelvic ring. Injury. 2013.11.021
Spine Trauma

Bailey Dyck
Michael Speiss

PHYSICAL EXAM

Inspection & Palpation:
- Four-person log roll maintaining C, T & L-precautions
- Remove from rigid spine board
- Inspect for signs of blunt trauma, penetrating injury, tracheal deviation, contusions, lacerations
- Palpate midline/spinous processes for point tenderness, step off deformity, swelling, bruising.
- Maintain manual in-line immobilization during inspection & palpation, resume rigid immobilization (collar) as soon as possible

Motor Exam:
- UE
  - C5 – elbow flexion (biceps brachii, brachialis)
  - C6 – wrist extension (extensor carpi radialis)
  - C7 – elbow extension (triceps)
  - C8 – finger flexion of middle finger (flexor digitorum profundus)
    ▪ Stabilize PIP, ask patient to flex through DIP
  - T1 – small finger abduction (abductor digiti minimi)
    ▪ Patient keeps fingers fanned out against examiner’s force
- LE
  - L2 – hip flexion (iliopsoas)
  - L3 – knee extension (quadriceps)
  - L4 – ankle dorsiflexion (tibialis anterior)
  - L5 – long toe extension (extensor hallucis longus)
  - S1 – ankle plantarflexion (gastrocnemius, soleus)
- Perineum
  - S4-S5 – anal sphincter tone
    ▪ Resting tone: as determined by examiner with sphincter relaxed
- Active tone: with patient instructed to squeeze finger or bear down as in to pass stool

**Motor Grading**
- 0 – total paralysis
- 1 – palpable or visible contraction
- 2 – active movement, full ROM with gravity eliminated
- 3 – active movement, full ROM against gravity but no resistance
- 4 – active movement, full ROM against gravity and moderate resistance
- 5 – (normal) active movement, full ROM against gravity and full resistance
- NT – not testable (e.g. immobilization, severe pain, amputation, joint contracture)

**Sensory Exam:**

**Sensory Grading**
- 0 – absent
- 1 – altered, either decreased/impaired or hypersensitive
- 2 – normal
- NT – not testable

**Reflex Exam:**
- UE
  - C5 – biceps
  - C6 – brachialis
  - C7 – triceps
- LE
  - L4 – patellar
  - S1 - achilles
- Perineum
  - S3, S4 – bulbocavernosus reflex
    - Pull on foley catheter or penis stimulates anal sphincter tightening
  - S5 – anal wink

**Long Tract Testing:** for cervical myelopathy/upper motor neuron disease
- Hoffman test
  - Place long finger PIP in extension, holding proximal and
middle phalanx. Flick distal phalanx. Positive exam = involuntary flexion of thumb IP joint and index PIP/DIP joint in same hand.

- Babinski sign
  - Firmly stroke lateral plantar foot. Positive sign = extension of great toe, splaying of smaller toes.

- Ankle clonus
  - Rapidly plantar/dorsiflex ankle. Positive test = involuntary repeat contraction of ankle plantar flexion for ≥ 3 beats.

- Post-Void Residual (PVR)
  - Patients with concerns for cauda equina syndrome:
    - Place a foley catheter after a proper post-void residual can be obtained.
    - Proper post-void residual
      - Patient is instructed to voluntarily and completely empty their bladder. Immediately after, an in-and-out foley catheterization is performed and volume of any residual urine is recorded.
      - PVR volumes > 100-150 ml considered abnormal.
      - If patient comes in with foley already inserted, it must be removed and above steps performed.
      - Do not use bladder scanner to assess residual volume (Must use in-and-out catheter).
      - e.g. not taken when asked, but after patient has made concerted effort to void. If one has been placed, have it removed and wait for the PVR before re-insertion.

GENERAL CONSIDERATION

Classification of Spinal Cord Injuries (SCI)*:
- Complete: absence of sacral sparing*
- Incomplete: presence of sacral sparing
- Motor level: lowest muscle function of grade ≥3
- Neurological level: lowest level with intact sensation + anti-gravity muscle function

* Sacral Sparing = Presence of sensory or motor function in the most caudal sacral segments, e.g. preserved light touch/pin prick at S4-S5, deep anal pressure, or voluntary anal sphincter contraction

**ASIA Impairment Scale (AIS):**

**A** = Complete. No sensory or motor function preserved in S4-S5.

**B** = Sensory Incomplete. Sensory but not motor function preserved below neurological level including S4-S5, AND no motor function more than three levels below motor level

**C** = Motor Incomplete. Motor function preserved below neurological level* and > half of key muscles below level of injury have a grade 0-2.

**D** = Motor Incomplete. Motor function preserved below neurological level* and < half of key muscles below level of injury have a grade ≥3.

**E** = Normal. Note: someone without an SCI does not receive a grade.

* Patient must also have either voluntary anal sphincter contraction OR sacral sparing.

**Consequences of High Injury**

- Acute respiratory complications of spinal cord injuries:5
  - 84% of SCI C4 and higher, and 60% of C5 – C8 experience acute respiratory problems
  - 75-80% of tetraplegia above C4 and 60% of tetraplegia below C4 will require invasive mechanical ventilation
  - Vital capacity and ABG should be measured until patient is stable

- Independent risk factors for intubation:6
  - Injury Severity Score
  - SCI above C5
  - ASIA A injury

- Indications for tracheostomy:7
  - Patient with tracheostomy have fewer pulmonary complications
- Early tracheostomy results in fewer on-ventilator days, shorter hospital stay
- Predictors of prolonged mechanical ventilation (> 7 days) after cervical CSI:
  - Injury Severity Score > 32
  - Complete SCI
  - PaO2/FiO2 < 300 3 days after mechanical ventilation initiated
    - Recommended population for early tracheostomy
  - Other variables to consider favoring tracheostomy over extubation:
    - FVC < 830 cc
    - Sputum production requiring more than hourly suctioning
    - PaO2/FiO2 < 190

**Spinal Shock vs. Neurogenic Shock**

Spinal Shock:
- Marked reduction or complete loss of motor and reflex function below level of injury.
- This likely represents an ongoing physiologic continuum consisting of 4 stages
  - This occurs in virtually all patients with severe SCI, beginning within minutes after injury and continuing for up to 12 months.
  - Traditional teaching states patient could not be classified as definitively having a complete SCI unless they were “out of spinal shock”.
  - This was determined by the return of the bulbocavernosus reflex.
  - Practically however, this rarely changes a patient's SCI designation and has little prognostic value.

Neurogenic Shock:
- Hypotension (SBP <90 mmHg supine unrelated to volume depletion, eg blood loss, dehydration) AND bradycardia after acute SCI
Due to a loss of sympathetic nervous system control (disrupted supraspinal control) with intact parasympathetic control (intact vagal nerve), result is loss of vascular tone
- Can last up to 5 weeks post-injury

Role of Vasopressors in Spinal Cord Perfusion
- Neurogenic shock contributes to spinal cord hypoperfusion and further ischemia
- Patients with complete SCI, especially cervical (vs. thoracolumbar) and complete motor deficits should be consider for vasopressor support
- MAP > 85-90 mmHg is the GOAL.
- Regimen:
  ▪ No consensus on one regimen is superior to another
  ▪ Average duration is typically 5 – 7 days
  ▪ Effective regimens include:
    ▪ Cervical injury:
      • Dobutamine (5-15 μg/kg per min) and/or dopamine (2-10 μg/kg per min)
      • Dopamine (2.5-5 μg/kg per min) followed by norepinephrine (0.01-0.2 μg/kg per min), if necessary
      • Dopamine, dobutamine, phenylephrine
      • Epinephrine, terbutaline, dobutamine, ephedrine, isoproterenol
      • Norepinephrine alone
    ▪ Thoracic injury:
      • Dopamine (2.5-5 μg/kg per min) followed by norepinephrine (0.01-0.2 μg/kg per min), if necessary
    ▪ Thoracolumbar injury:
      • Norepinephrine alone
Cervical Spine Injury
The Canadian C-Spine Rule

1. Any High-Risk Factor Which Mandates Radiography?
   - Age > 65 years
   - Dangerous Mechanism *
   - Paresthesias in extremities
   
   Rule Not Applicable if:
   - Non-trauma cases
   - Glasgow coma Scale <15
   - Unstable vital signs
   - Age <16 years
   - Acute paralysis
   - Known vertebral disease
   - Previous C-spine surgery
   - Pregnant

2. Any Low-Risk Factor Which Allows Safe Assessment of Range of Motion?
   - Simple rear-end motor vehicle collision (MVC) **
   - Sitting position in the emergency department
   - Ambulatory at any time
   - Delayed onset of neck pain **
   - Absence of midline c-spine tenderness

1. Able to Actively Rotate Neck?
   - 45° left and right

   Yes
   - Able
   - No Radiography

   No
   - Unable
   - Radiography

*Dangerous Mechanism
- Fall from elevation > 3 feet of stairs
- Axial load to head, e.g. diving
- MVC high speed (>100 km/h), rollover ejection
- Motorized recreational vehicles
- Bicycle struck or collision

**Simple Rear-end MVC Excludes
- Pushed into oncoming traffic
- Hit by bus or large truck
- Rollover
- Hit by high speed vehicle

***Delayed
- Not immediate onset of neck pain
The National Emergency X-Radiography Utilization Study (Nexus)\textsuperscript{12,13}

To determine whether c-spine radiographs can be avoided in the alert, stable trauma patient.

C-spine x-ray is indicated for all patients with neck trauma unless they meet ALL of the following criteria:

- NO posterior midline c-spine tenderness
- NO evidence of intoxication
- Alert (GCS=15)
- NO focal neurological deficits
- NO painful distracting injuries

Caveats:
- NEXUS has no age cutoffs (theoretically applied >1 year old); however, literature cautions against use in patients >65 years old as sensitivity decreases significantly

Special Injury Types

**Atlanto-Occipital Dislocation**\textsuperscript{14}

- A highly unstable craniocervical injury of the occipital-atlanto-axial unit
- Primarily an injury of widespread ligamentous disruption between the occiput and upper cervical spine (= craniocervical junction), often w/o bony #
- 3x more common in children vs. adults
- Caused by any trauma involving large acceleration and deceleration forces, eg. high speed MVC, fall from height
- Often associated with concomitant cervical injuries below C1
- Clinical features: spectrum including lower cranial nerve deficits (abducens, vagus, hypoglossal), unilateral (typically entire side from shoulder to foot) or bilateral weakness including quadriplegia, unconsciousness with respiratory arrest
  - Up to 20% are asymptomatic with a normal neuro exam
  - ± Spinal cord injury: hyperreflexia with clonus, positive Babinski, abnormal sphincter tone
± Autonomic dysregulation, neurogenic shock
± Cerebrovascular injury, esp. vertebral dissection
- Definitive treatment
  ▪ Halo immobilization followed by internal occipitocervical fixation and fusion
  ▪ Cervical traction should be avoided

Jefferson Fracture (Type II Atlas Fracture)\textsuperscript{15}
- Vertical compression of the skull forces the atlas onto the axis
- Results in rupture (bilateral fractures) of the anterior and posterior arches with splitting of the lateral masses = Jefferson burst fracture (aka Type II atlas fracture)
  ▪ ± Rupture of the transverse ligament ➔ essential to prognosis
- Radiographic findings
  ▪ C1-C2 joint in frontal x-ray
    ▪ Loss of continuity of a vertical line traced on the lateral margins of the lateral masses of the atlas and of the joint masses of the axis
    ▪ >7 mm combined lateral mass displacement = rupture of the transverse ligament ➔ unstable injury

- Definitive treatment
  ▪ Stable
    ▪ Reduction by cranial traction + immobilization (hard cervical orthosis vs. halo) for 3-4 months
  ▪ Unstable
    ▪ Occipito-cervical arthrodesis (posterior C1-C2 fusion vs. occipitocervical fusion)
**Odontoid (Dens) Fractures**\(^{17,18}\)
- Typical mechanism – blow to the vertex of the skull
- Neurological injury is infrequent
- Classification
  - Type I: oblique avulsion fracture of the tip of the dens, avulsion of alar ligament
    - Inherently stable, rarely associated with atlantoaxial instability (assess Oc-C1 joints on CT scan, +/- evidence instability on flex-ext views)
  - Type II: fracture at base/body junction (“waist” of dens)
    - Potentially most unstable
    - Highest non-union rate (30-80% in literature)
  - Type III: fracture extends into cancellous body of axis
    - Usually stable
- Radiographic findings
  - AP, lateral, open mouth odontoid view
  - CT study of choice for fracture delineation, assessing stability of pattern
  - CT angiogram indicated if operative treatment required (location of vertebral arteries)
  - MR indicated if neurological symptoms present
- Treatment
  - Type I: collar immobilization
  - Type II:
    - Young patients: Halo immobilization vs. operative fixation
      - odontoid screw vs. posterior C1-2 fusion
    - Elderly patients: Cervical orthosis vs. operative fixation
  - Type III: collar immobilization

**Hangman’s Fracture**\(^{19}\)
- Traumatic spondylolisthesis of C2
- Mechanism usually hyperextension and axial loading
- Five injury patterns described
Illustrations demonstrating five injury patterns in traumatic spondylolisthesis.

A, Type I. B, Type II. C, Type III. D, Type IIA. E, Type III.

- Type I: minimally displaced pars interarticularis fracture, translocation <3 mm and no angulation (upright film in collar required)
  - Type IA: atypical, unstable; oblique fracture through one pars and anterior to the pars within the body of the contralateral side
  - Type II: similar to I but displacement >3 mm and/or >120 angulation (upright film required)
    - Type IIA: more horizontal fracture with no horizontal displacement and kyphosis greater than translation; associated with C2-C3 disk injury and PLL injury
  - Type III: similar to I + dislocation of C2/C3 facet joints; irreducible without surgery

- Definitive treatment
  - Type I: rigid cervical orthosis x 6 weeks
  - Type IA: same as Type I or halo vest
  - Type II: closed reduction followed by halo immobilization x 12 weeks
    - Surgery if severe displacement or angulation
  - Type IIA: same as Type II
    - Avoid axial traction in IIA, use hyperextension for reduction
  - Type III: surgical intervention
    - Options:
      - C2-3 ACDF
      - Posterior C1-3 fusion
      - Bilateral C2 pars ORIF
Clearing the C-spine with a Normal CT

Awake & cooperative patient with no C-spine pain or neurological symptoms and a normal CT c-spine:
- In an alert patient with a normal CT scan, clinical clearance is required to exclude ligamentous injury
  ▪ Absence of pain and neurological symptoms (e.g. numbness in extremities) on palpation and full range of C-spine movement (rotation, flexion, extension) = clinical clearance, immobilization may be discontinued

Obtunded or altered sensorium patient with a normal CT c-spine:20,21
- In an obtunded or unreliable patient, options include:
  ▪ Wait until clinical clearance can be performed
  ▪ Flexion-extension radiography
    ▪ All movements must be voluntary; the patient must move themselves
    ▪ Direct supervision by physician is required
    ▪ Imaging is to be aborted if pain or neurological symptoms arise
  ▪ MR of the c-spine
- Data is inconclusive on definitive clearance through CT c-spine alone
  ▪ One cohort study concluded safe c-spine clearance based on a normal multi-detector axial CT scan alone
    ▪ Must be multi-detector, axial from occiput to T1, with sagittal and coronal reconstructions
  ▪ Another systematic review revealed 0.7% of patients with a normal CT c-spine went on to have an unstable injury detected on MR c-spine requiring surgical intervention
    ▪ Conclude a continued role for MR c-spine with a normal CT was not necessary if a reliable clinical exam was able to demonstrate intact gross motor function

EAST Guidelines 2015:
- In obtunded blunt trauma patients cervical collar should be removed after a negative high-quality C-spine CT scan.
  ▪ Based on very low-quality evidence
- Places a strong emphasis on the high negative predictive value of CT imaging in excluding unstable C-spine injury.
  - This recommendation takes into account the high costs of MRI or other additional imaging.
  - Adjunctive imaging after a high-quality CT scan can:
    - Increases the number of low-value diagnoses.
    - Places patients at risk for unnecessary treatment plans.
    - Put patients with multiple injuries at risk by moving them out of the intensive care unit to the resource limited MRI suite.
    - Results in the same clinical action of collar removal.
(Please see Appendix for UofS C-spine Clearance Protocol)

**Thoracolumbar Injury**

**Screening Guidelines & Modalities**

- Imaging is proposed in any ONE of the following:
  - High-risk injury mechanism
    - MVC >70 kph, fall >3m, ejected from motor vehicle or motorcycle
  - Painful distracting injury
    - Torso, long bone
  - Cognitive impairment
    - GCS<15, any abnormal mentation or clinical intoxication
  - New neurological signs or symptoms/signs of vertebral fracture
    - Back pain, back tenderness, palpable step deformity, midline bruising
  - Known cervical fracture
- Alert & cooperative patient with reliable clinical exam:
  - Absence of back pain or midline tenderness has 95% negative predictive value for fracture
- Choice of modality
  - Standard = lateral, AP x-ray
    - If indeterminate, progress to additional modalities
    - If helical CT of chest, abdomen and pelvis are performed, reconstruct (sagittal and coronal) to visualize spine and forgo plain film
- Injuries described using three-column description
  - Anterior column: ALL; anterior half of vertebral body, disc & anulus
  - Middle column: posterior half of body, disc & anulus; PLL
  - Posterior column: pedicles, facet joints, ligamentum flavum, lamina, Spinous processes, inter/supraspinous ligament.

**Special Fracture Types**

Blunt Multi-Trauma Patient
High Force Mechanism

- Back Pain / Midline Tenderness
  - Local Signs of TL injury
  - Neurological Deficit
  - Cervical Spine Fracture
  - TL Imaging

- No Back Pain / Midline Tenderness
  - No Local Signs of TL injury
  - No Neurological Deficit
  - No Cervical Spine Fracture
  - GCS 15
  - Distracting Injury
    - Alcohol/Drug Intoxication
    - TL Imaging
  - No Distracting Injury
    - Alcohol/Drug Intoxication
    - TL Imaging
  - GCS < 15
  - Observe

Note: Maintain full spinal precautions until spine cleared

**Definitions:**
- Blunt Multi-Trauma Patient = victim of blunt trauma necessitating trauma team activation
- High Force Mechanism = Fall ≥ 3m, MVC or MBC of at least medium velocity, Pedestrian MVC at any velocity
- Local Signs of TL Injury = palpable step, back bruising/haematoma
- GCS = Glasgow Coma Score
- Distracting Injury = As decided by treating clinician
- TL Imaging = x-ray, CT, MRI as appropriate
- T-L spine fractures roughly categorized as:
  - “Major” injuries
    - Compression fractures
    - Burst fractures
    - Flexion-distraction injury (Chance fracture, seat belt-type injury)
    - Fracture-dislocations
  - “Minor” injuries
    - Transverse process fractures
    - Articular process fractures
    - Pars interarticularis fractures
    - Spinal process fractures

**The Thoraco-Lumbar Injury Classification and Severity Score (TLICS)**
- Depicts features important in predicting:
  - Spinal stability
  - Future deformity
  - Progressive neurologic compromise
- Facilitates appropriate treatment recommendations

<table>
<thead>
<tr>
<th>TLICS</th>
<th>3 Independent Predictors</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Morphology Immediate Stability</td>
</tr>
<tr>
<td>2</td>
<td>Integrity of PLC Longterm Stability</td>
</tr>
<tr>
<td>3</td>
<td>Neurological Status</td>
</tr>
<tr>
<td></td>
<td>Predicts</td>
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</table>

**Compression Fracture:**
- Involve one or both superior and/or inferior endplate(s)
- Rarely neurological compromise, generally stable
  - Potentially unstable: >50% body height loss, > 30° angulation, multiple adjacent compression fractures
- If asymptomatic, obtain upright films before final treatment decision e.g. to evaluate dynamic collapse
- Treatment
  - Stable: usually does not require bracing as inherently stable. If bracing used pain control, options include Jewett hyperextension brace or thoracolumbar spinal orthosis (TLSO).
  - Unstable: MRI to r/o posterior ligament complex disruption

**Burst Fracture:**
- Compression failure of anterior and middle columns (+/- sagittal split fracture of lamina due to pedicle splaying)
- Potentially unstable if:
  - Neurologic deficits
  - >50% loss of body height
  - >30° angulation
  - >50% canal compromise
- Treatment
  - Stable: Often stable burst fractures can be treated without bracing. If bracing used, options include Jewett brace or TLSO.
  - Unstable: early surgical stabilization

**Flexion-Distraction Injury (Chance Fracture):**
- Rarely neurological compromise
- Up to 50% have associated abdominal injury
- Can be purely osseous, ligamentous, or missed injury
- Treatment
  - Obtain MRI to evaluate for posterior ligamentous complex (PLC) injury and neural compression
  - Well aligned boney Chance Fractures – Jewett brace
  - Nearly all others – surgical stabilization, +/- decompression
Fracture-Dislocation:
- 3-column failure
- Highly unstable injury almost always requiring surgical intervention
  - Surgery can be performed when patient medically stabilized; neurologic deficit does not require urgent OR
- 3 types:
  - Type A: Flexion-rotation
    - 75% have neurological deficits, with 52% having complete SCI
  - Type B: Shear
    - All cases have complete SCI
  - Type C: Flexion-distraction
    - 75% have neurological deficits, all complete SCI

Incomplete Spinal Cord Injuries
Anterior cord syndrome:
- Blunt trauma to the anterior spinal cord and injury of anterior spinal artery (which supplies anterior 2/3 of spinal cord)
- Loss or impaired ability to sense pain, temperature and touch sensations below their level of injury.
- Patients retain proprioception, vibration sensation and deep pressure from preservation of the posterior columns.
- It is possible for some people with this injury to later recover some movement.

Chane Fracture (flexion-distraction injury)
Xray-Lumbar-Lat: Cross-table lateral radiograph of lumbar spine shows fanning of spinous processes (double-headed arrow) and fracture extending through pedicle (between arrowheads) and into L2 vertebral body (single-headed arrow).
**Posterior cord syndrome:**
- Rare syndrome
- Damage to the dorsal column, resulting in loss of proprioception and vibration sense
- Will typically remain with good muscle power, pain and temperature sensation.
- May experience difficulty in coordinating movement of their limbs.

**Brown-Sequard syndrome:**
- Hemitransection of the spinal cord with unilateral damage to the corticospinal tract, spinothalamic tract and dorsal columns.
- Ipsilateral deficit:
  - Corticospinal tract
    - Motor function
  - Dorsal columns
    - Proprioception
    - Vibration
- Contralateral Deficit:
  - Spinothalamic tract
    - Pain
    - Temperature
- Generally very good prognosis.

**Central Cord Syndrome:**
- Most common in complete SCI
- Hyperextension injury
  - Typically in elderly patients with preexisting cervical spondylosis.
  - Motor deficit worse in UE than LE; and in UE hand is affected more than proximal hand
  - Believed to be caused by spinal cord compression and central cord edema with selective destruction of lateral corticospinal tract white matter.
• It is possible for some recovery from this type of injury, usually starting in the legs, gradually progressing upwards (i.e. bowel/bladder -> proximal UE -> hand function)
References


Every pregnant trauma patient should be questioned regarding domestic/intimate partner violence (SOGC)

7% of pregnancies are complicated by trauma. Trauma is the leading cause of maternal death 46%\(^5\).

The leading causes of obstetric trauma are:
- Motor vehicle crash (49%)
- Falls (25%)
- Assaults (18%)
- Guns (4%)
- Burns (1%)

The American Congress of Obstetricians and Gynecologists (ACOG) subdivides trauma in pregnancy into three different types:
- Blunt abdominal trauma
- Pelvic fractures
- Penetrating trauma\(^2\).

Incidence of trauma increases as pregnancy progresses:
- 8% in first trimester
- 40% in second trimester
- 52% in third trimester

Most maternal deaths are due to head trauma or hemorrhagic shock.

Although many of the assessment and management aspects of obstetric trauma are unique to pregnancy, initial assessment and resuscitation should always be directed at the mother. The main principle guiding therapy must be that resuscitating the mother will resuscitate the fetus. Once maternal stability is established, evaluation of fetal well-being is conducted.

The effect of trauma on pregnancy depends on:
- Gestational age
- Type and severity of the trauma
- Extent of disruption of normal uterine and fetal physiology. Survival of the fetus depends on adequate uterine perfusion and effective delivery of oxygen through the placenta.

- Uterine circulation has no autoregulation:
  - This therefore implies that uterine blood flow is directly related to maternal systemic blood pressure, until the mother approaches hypovolemic shock.
  - Once the mother shows signs of hypovolemic shock, peripheral vasoconstriction will further compromise uterine perfusion.
  - Once obvious shock develops in the mother, survival rate of the fetus is 20%.

A multidisciplinary team approach is key to optimize outcome in severe trauma.

**Normal Anatomic & Physiologic changes in Pregnancy**

*Fundal Height is measured in centimeters from the pubic symphysis to the top most portion of the uterus.*

Changes in Blood Volume and Composition:
- 40% increase in blood volume
- 25% increase in red cell mass Relative anemia (Hct 31-35)
  - ‘Physiologic anemia of pregnancy’
- The mother may lose up to 1500 cc of blood without hemodynamic instability
• However, the fetus may be in shock.
  • White Blood Count elevated in pregnancy (15,000)
  • Fibrinogen and clotting factors increased
  • Decreased albumin level (2.2-2.8)
  • D-dimer often positive, therefore limited use

Hemodynamic changes:
  • In the pregnant patient, maternal vitals and perfusion may be preserved at the expense of utero/placental perfusion
    • This delays the signs of hypovolemic shock
  • Cardiac output is increased by 1.0-1.5 liters/minute after the 10th week of pregnancy
  • Hypotension may be due to vena caval compression by the uterus
    • Can cause up to 30% reduction in cardiac output
    • Wedge under right hip can facilitate
  • Heart rate increases 10-15 beats/minute
  • Blood pressure should remain relatively normal compared to a non-pregnant patient.
  • CVP variable
  • Venous hypertension in lower extremities

Respiratory changes:
  • Increased oxygen consumption
  • Elevated diaphragm
  • 30-40% increase in tidal volume and minute ventilation
  • Decreased functional residual capacity
  • Decrease respiratory system compliance
  • Increased airway resistance
  • PaCO2 = 30-35 mm Hg
  • Intubation may be challenging
    • Due to airway edema, increased breast mass, weight gain
    • In these cases, failed intubation is 8X more likely (SOGC)
  • Relaxed LES + delayed gastric emptying
- Increased risk of aspiration
  - Consider early intubation, placement of NG tube, cricoid pressure

The fetus is sensitive to maternal hypoxia, therefore maintain maternal O2 sats > 95% (SOGC)

Renal changes:
- Glomerular Filtration Rate increased
- BUN and creatinine decrease
- Glycosuria can be common
- Mild hydronephrosis is a physiologic response to uterine compression of the ureters

Thrombotic Disease and Pregnancy:
- Pregnancy can induce a hypercoagulable state:
  - Increased activity of clotting factors
  - Decreased fibrinolysis
  - Venous hypertension due to uterine pressure on the inferior vena cava
- Incidence of DVT of 0.1-0.2%
- Lower extremity Sequential Compression Devices recommended
- Heparin and Low Molecular Weight Heparin ok in pregnancy
- Coumadin contraindicated due to risk of severe fetal malformations

Pre-eclampsia/Eclampsia/HELLP Syndrome:
- Reduced intravascular volume -> more sensitive to anemia and hypovolemia
- Eclampsia = Seizures
- Hypertension, proteinuria, hyperreflexia, peripheral edema
- End organ dysfunction – elevated liver enzymes, hemolysis, thrombocytopenia, stroke, liver capsule hematoma or rupture
- Eclampsia may mimic head injury in the trauma patient

Musculoskeletal:
- Symphysis pubis widens by 7th month
Sacroiliac joint spaces increase
This may cause confusion in interpretation of pelvic x-rays.

**Imaging the Pregnant Trauma Patient**

Even though there is much concern about radiation exposure, a diagnostic modality which is necessary for maternal evaluation should not be withheld on the basis of its potential hazard to the fetus.

In this population of patients, ultrasound is easily accessible in the emergency department and can provide vital information such as:

- Approximation of gestational age
- Placental location
- Fetal presentation
- Fetal cardiac rate/rhythm
- Assessment of amniotic fluid volume
- Confirmation of fetal demise

Placental abruption remains a clinical diagnosis. Ultrasound has been proposed as a method of diagnosis, however the sensitivity is only 24%\(^6\).

Ultrasound is a safe and efficient method for detecting intraperitoneal free fluid and intraabdominal injuries.

**Radiation Exposure**: Mettler et al, 2000

- Measurement
  - Rad (radiation absorbed dose)
  - Grey (1 rad = 1 centiGy; 100 rads = 1 Gy)
- Greatest effects of radiation exposure occur between conception and week 25
- Radiation injury during weeks 1-3 results in death of the implant or embryo
- Radiation during weeks 8-25 is more likely to produce CNS effects or growth restrictions:
  - 10 rads may result in decreased IQ
  - 100 rads may result in severe mental retardation
After 25 weeks, greatest risk is childhood hematologic malignancy
- Background incidence is 0.2-0.3%
- Risk increases to 0.3-0.4% if exposure > 1 Gy
- Risk increases by 0.06% per 1 Gy of fetal exposure
- Risk negligible < 5 rads exposure
- Risk increases > 10-15 rads exposure
- Most diagnostic procedures have no measurable risk
- Therapeutic procedures have greatest risk

Benefit of judiciously chosen x-rays far outweighs risks in pregnant trauma patients.

Intermediate exposure (50-100 mGy) roughly equivalent to 3 years of natural background radiation exposure and is associated with no increase in anomalies or growth restriction (Mettler et al, 2000).

A chest x-ray is the equivalent of < 0.01 rads

Abdominal CT scan causes a fetal radiation exposure of up to 3.5 rads (0.035 Gy) per study.

Radiation doses < 5 rads (0.05 Gy) are not associated with an increased risk of anomalies, pregnancy loss, or growth restriction. ACOG Guidelines, 2004

**Fetal Monitoring**

When the fetus is deemed viable (> 23 weeks GA), continuous fetal monitoring should be initiated as soon as possible, as long as it does not interfere with maternal diagnostic tests or therapy. The ideal duration for monitoring has not been established, with recommendations ranging from 4-48 hours. The American Congress of Obstetricians and Gynecologists recommends a minimum of 2-6 hours of electronic fetal monitoring post trauma, in viable pregnancies.

A longer duration of monitoring may detect delayed fetal compromise from a concealed abruption.

Fetal monitoring can be discontinued after 4 hours if:
- Uterine contractions occur less frequently than every 10 minutes.
- Fetal heart tracing is reassuring.
- No maternal abdominal pain or vaginal bleeding.

Pregnant trauma patients > 23 weeks with signs of labor or abruption such as abdominal/uterine pain, contractions, rupture of membranes, vaginal bleeding or abnormal fetal monitoring, should be admitted for observation for 24 hrs. SOGC

Since placental perfusion and oxygenation depend on maternal cardiopulmonary function, fetal monitoring should continue in cases of:
- Adult respiratory distress syndrome.
- Continuous lung injury.
- Trauma causing maternal cardiac arrhythmia

An abnormality of the fetal heart rate pattern may be the first sign of hemodynamic shock in the mother.

**Kleihauer-Betke test (KB)**

When maternal injury is present, a complete blood cell count, coagulation profile, KB test, and type and screen should be obtained. In Rh-negative mothers, the KB test also allows for calculation of the total required dose of Rh immune globulin needed to prevent alloimmunity. One vial of 300 μg protects against 30 mL of fetal blood (15 mL of fetal red blood cells)².

The KB test is used in many institutions as a routine component of trauma evaluation.

- However, the KB test is insensitive and poorly predictive of adverse perinatal outcomes, preterm birth, placental abruption, or fetal distress in minor trauma or in trauma with absent maternal injury⁴,¹⁴. It’s utility in Rh positive women is unclear.

In addition to other labs, a coagulation panel including fibrinogen should be obtained.

**Emergency Cesarean Section**

Approximately 2.4-7.2% of maternal trauma patients need cesarean section shortly after trauma SOGC
Survival of both is dependent on multiple factors:\textsuperscript{15}
- Interval between maternal cardiac arrest and delivery.
- The underlying etiology of the arrest.
- Where the arrest takes place.
- The expertise of the team attending to the mother.
- Gestational age of the fetus

Perimortem cesarean section (PMCS):
- Cesarean section performed in the face of maternal cardiac arrest, can be life-saving for both mother and fetus.

Cesarean delivery may be appropriate in the setting of imminent maternal death or after 4 minutes of properly performed cardiopulmonary resuscitation that has failed to revive the mother, as both infant and maternal survival are increased when cesarean delivery is initiated within 4 minutes of maternal cardiac arrest\textsuperscript{12}.
- Start planning for it right away when the code is called.
- Start PMCS immediately if the diagnosis is catastrophic, prognosis dismal and maternal survival unlikely.
- Do not move the patient to do PMCS – only wastes time
- All that is needed is a scalpel

Although delivery should ideally occur within 4 minutes of failed maternal revival, this standard can rarely be met in actual practice even in ideal situations. Notably, resuscitation efforts may improve following delivery as a result of diminished aortocaval compression and improved volume return to the heart.

Gestational age is less than 24 weeks:
- Emergency cesarean delivery is usually not performed because the fetus is too small to survive and the birth is unlikely to have much effect on maternal hemodynamics.

Gestational age is greater than 24-25 weeks:
- Emergency cesarean birth most likely will favorably affect maternal or fetal outcome.

Gestational age of 26 to 32 weeks:
- External cardiac massage (ECM) is not effective, indicated by:
  - Failure to generate a carotid pulse
  - Inadequate end-tidal CO\textsubscript{2} levels
- Fetal bradycardia.
- Open cardiac massage (OCM) should be considered before an emergency cesarean section is performed:
  - If OCM proves successful, the delivery may be delayed so that chances of postnatal survival improve. Even slight prolongation of fetal intrauterine life may improve the chances of neonatal survival, especially when gestational age is less than 28 weeks.
  - If OCM proves ineffective, the fetus must be delivered immediately.

Gestation age greater than 32 weeks:
- ECM is not effective, an emergency cesarean section must be performed immediately.
- Delivering the infant improves maternal cardiac filling, thereby improving the success of CPR.
- The longer the delay between the onset of cardiac arrest and delivery, the less are the chances of fetal and maternal survival. If, however, the ECM appears to be effective, ECM may be continued for 5 minutes.
- If a spontaneous circulation is not restored within 4 minutes, an emergency cesarean delivery must be performed. If this fails to revive the mother, OCM may be considered.
- Ideally, personnel trained in neonatal resuscitation should be available to attend the infant.

If preterm labour or preterm prelabour rupture of membrane is suspected, medical management includes:
- Antibiotics:
  - If Group B streptococcus culture status of patient is unknown
  - Antenatal corticosteroids.
  - Tocolytic agents.
  - MgSO4 for fetal neuro-protection (< 32 weeks)
    - 4 hours of treatment is ideal
Unique Injury Patterns

Blunt Trauma

Although MVC are the most common cause of serious blunt trauma in pregnancy, assaults, abuse and falls are also frequent. In addition to maternal mortality from blunt trauma, the fetus is at significant risk, from:

- Placental abruption
- Uterine rupture
- Rupture of membranes

The major risk factor for adverse outcomes during MVC is improper seat belt use: in both front and rear collisions, the impact with the steering wheel can be avoided with proper belt use\(^2\).

Placental Abruption\(^{(Trauma.org)}\):

- Occurs in 2 to 4% of minor injuries.
- Occurs up to 50% of major traumas.
- Maternal mortality from abruption is less than 1%, but fetal death ranges from 20 to 35%.
- Separation results as the inelastic placenta shears away from the elastic uterus during sudden deformation of the uterus.
- Abruption can occur with little or no external signs of injury to the abdominal wall.
- Abruption is unpredictable on the basis of severity of maternal injury or placental position.
- Abruption may have associated vaginal bleeding or be concealed, with no external bleeding
- Clinical indications of abruption:
  - Vaginal bleeding
  - Abdominal pain
  - Uterine tenderness/contractions
  - Amniotic fluid leakage
  - Maternal hypovolemia
  - Uterus larger than normal for the gestational age
  - Change in the fetal heart rate
- When present after trauma, vaginal bleeding is an ominous sign often indicative of placental separation.
- Diagnostic tests:
  - Transabdominal ultrasound:
    - Less than 50% accurate.
  - Cardiotocographic (fetal) monitoring:
    - More sensitive in detecting placental abruption by fetal distress.
  - Ultimately remains a clinical diagnosis

Most cases of abruption become evident within several hours after trauma. Fetal monitoring should be started in the resuscitation room and continued for a minimum of 4 hours, from time of trauma.

Management of placental abruption should not be delayed from imaging if it is clinically suspected.

Uterine rupture
- Presence of a defect in the gravid uterine wall.
- 75% of cases involve the uterine fundus.
- May cause:
  - Serosal hemorrhage.
  - Avulsion of the uterine vasculature with hemorrhage.
  - Complete disruption of the myometrial wall with extrusion of the fetus, placenta, or umbilical cord into the abdominal cavity.
  - Complete uterine avulsion².

Clinical presentation:
- Uterine tenderness
- Vaginal bleeding
- Non-reassuring fetal heart rate patterns
- Rapid onset of maternal hypovolemic shock
- Easily palpable fetal parts on abdominal exam
- Typical signs of peritoneal irritation on physical examination:
  - Distention
  - Rebound tenderness
Guarding
- Rigidity

Management
- Urgent laparotomy to control bleeding and facilitate resuscitation

**Penetrating Trauma**

Management of penetrating injuries depend primarily on the entrance location and the gestational age. Fetal death has been reported in up to 60% of cases of penetrating trauma\(^1\). In terms of mortality, maternal outcome is more favorable during pregnancy than in non-pregnant victims\(^1\). This may be due to anatomic changes that take place during pregnancy, such as the superior displacement of the visceral organs by the growing uterus. Therefore, upper abdominal penetrating trauma will likely injure maternal bowel, where lower abdominal penetrating trauma will more likely injure the uterus/fetus.

Even though immediate surgical exploration is the most appropriate management approach in a non-pregnant patient, this approach is not universal in pregnant patients\(^1\):

- This decision to proceed with surgical exploration is dependent on:
  - Location of injury.
  - Uterine size.
  - Maternal and fetal vital signs.

- Location of possible entrance/exit wounds is key
- Visceral injuries are less likely when the entry site is anterior and below the uterine fundus
- Those that do not penetrate beyond the abdominal wall can be managed nonoperatively.
- Exploratory laparotomy is indicated with any evidence of peritoneal penetration, particularly if intraperitoneal hemorrhage or bowel perforation is suspected.
- Tetanus prophylaxis is safe in pregnancy, and its indications are similar in both pregnant and nonpregnant states\(^2\).
- Peritoneal lavage can be performed during pregnancy.
- An open technique is recommended after placement of a nasogastric tube and a Foley catheter\textsuperscript{13}.

Pelvic fractures are not an indication for cesarean delivery. Most women can safely attempt vaginal birth following a pelvic fracture, even those that occur during the third trimester\textsuperscript{8}.

**If a thoracostomy tube is required in a pregnancy, it is recommended that it be placed at least 1 or 2 intercostal spaces above the usual landmark of the fifth intercostal space to avoid inadvertent abdominal insertion\textsuperscript{3}.**
Reference


1. Pathophysiology
   - Local/systemic inflammatory reaction ➔
     Mediators disrupt normal capillary barrier ➔
     Increased vascular permeability ➔
     Fluid shift to interstitial space
   - Capillaries start to recover at 6 - 12 hrs
   - Without resuscitation, 15-20% TBSA burns = shock
   - “Burn Zones“:
     - Zone of coagulation
       • Nonviable area at epicenter of burn
     - Zone of ischemia/stasis
       • Surrounding coagulated areas
       • Progress to necrosis without resuscitation
     - Zone of hyperemia
       • Peripheral tissues that undergo vasodilatory changes
       • Not injured thermally and remain viable


- Degree of Burn
  - 1st degree:
    • Redness, tenderness, pain
    • Superficial damage to epidermis
    • No blistering
    • Sensation normal
    • Ex. sunburns
2nd degree:
- Partial-thickness
- Does not extend fully through the dermis
- Two types:
  - Superficial
    - Epidermis and superficial dermis
    - Blistering
    - Severe pain
  - Deep
    - Into reticular dermis
    - Thicker blisters
    - More pale

3rd degree:
- Through entire dermis
- Capillary blood supply destroyed
- Appears white
- No sensation

4th degree:
- Into underlying tissue

Estimating BSA:
- “Rule of 9s” in adults
- Person’s own palm = ~1% BSA
- Lund-Browder charts

** Illustration from Anatomy & Physiology, Connexions Web site. http://cnx.org/content/col11496/1.6/
1. First Aid
   - Remove patient from source of burn (if safe)
   - Remove charred clothing
   - For chemical burns – irrigate copiously with water
   - Immerse in water 1-5°C
     - Avoid ICE water (frostbite, tissue damage)
     - Use room temperature water - inhibits acidosis/inflammation/ischemia
     - Use COLD water on small burns
   - How long to cool?
     - Small burns (< 9% TBSA) up to 30 minutes or more
     - Large burns – prolonged cooling leads to hypothermia
   - Keep the patient warm, the burn cool

3. Trauma Bay Considerations
   - Airway
   - Fluid resuscitation
   - Large bore IVs
   - NG/foley placement
   - Carboxyhemoglobin levels
     - Elevated levels should get 100% oxygen
       - All patients should have a non-rebreather mask with high flow O2 on arrival to the trauma bay. This should help correct any elevation of carboxyhemoglobin levels before it become a problem.

4. Airway Management
   - Inhalation injury occurs 10 - 20%
     - Thermal injury usually supraglottic
     - With steam, upper and lower airway affected
   - Suspect inhalation injury when:
     - Facial burns
     - Singed nasal hairs
- Sooty sputum
- Tachypnea
- Hoarseness
- Stridor

Consider intubation early – evidence that airway edema progresses 12-24 hours post-injury

5. Fluid Resuscitation

- Formulas to guide initial fluids:

  - **Parkland**
    - First 24 h: RL at 4 ml/kg/% TBSA; give half in first 8 h and the remaining over next 16 h.
    - Second 24 h: colloid at 20 - 60% of calculated plasma volume to maintain adequate urinary output

  - **Modified Brooke**
    - First 24 h: RL at 2 ml/kg/% TBSA burn, one half in the first 8 h and half in the remaining 16 h.
    - Second 24 h: colloid at 0.3–0.5 ml/kg/% TBSA burn + D5W to maintain urine output

- Only include 2nd degree burns or greater in TBSA; 1st degree do not count
- No good evidence on which formula to choose

- Titrate fluids to urine output
  - Goal U/O – 0.5cc/kg/hr for thermal, 1cc/kg/hr for electrical burns

- Avoid over-resuscitation, may lead to:
  - Pulmonary edema
  - Abdominal compartment syndrome (ACS)
  - Conversion of superficial ➔ deep burns
  - Elevated intra-ocular pressure
  - Fasciotomies
  - Increased risk of ACS with IVF 300/hr x 24 hrs

6. Role of Antibiotics

- 2013 Cochrane review:
Systemic antibiotic prophylaxis in non-surgical patients evaluated in three trials (119 participants)
  • No evidence of an effect on rates of burn wound infection
  • Systemic antibiotics reduced PNA but not sepsis
  • Perioperative systemic antibiotic prophylaxis had no effect on outcomes
  • Conclusion: Re: systemic abx – effects unclear, limited by volume/quality of research

Silver sulfadiazine (Flamazine):
  • Use is surgeon-dependent – do not use without involvement of plastics
  • Some evidence it may increase wound infections

7. Wound Care (Saskatoon Health Region):
  • Wound and Blister management: Initial Visit (less than 24 hrs. after sustaining burns):
    • If the wound is dirty, clean with soap and tap water
    Chemical or caustic burns should be well irrigated with tap water or saline
    • Leave small (< 2 cm) blisters alone (serve as biological covering)
    • Open large blisters at one edge but leave otherwise intact
    • Blisters already broken but intact over skin should be left in place
  • Initial Dressing should be multilayer and consist of:
    • Polysporin and Bactigras: Trimmed to cover outside edge of 2nd and 3rd degree area
    • Dry Gauze
    • Kling
  • Subsequent Dressings
    • Remove all layers and on 1st follow up visit
    • Physician to debride all blisters left intact
    • Redress open areas with:
      • Polysporin and Bactigras
Dry gauze and kling to cover
- For facial burns, polysporin to face QID and PRN
- Follow up in ER q24hrs.
- Average superficial partial thickness burn will need to be dressed daily for 10 to 12 days
  Physician to reassess PRN or if signs of infection

8. Advanced care, specialist referral
- Plastic surgery referral for follow-up and further management (for all burns unless very minor)
  - Options include wound excision, autografting, human allografting, porcine xenografting, skin substitute, dermal analogue
- Circumferential burns may constrict edematous tissue → ischemia, respiratory distress
  Escharotomy indicated
- Criteria for referrals to Edmonton Burn Centre:
  1. Partial or full thickness burns > 20% TBSA in adults
  2. Partial or full thickness burns > 10% TBSA in children, or pediatric burns with other complicating factors
  3. Major burns associated with significant inhalation injury
  4. Complicated acid/alkali burns
  5. Complicated high voltage electrical burns

9. Electrical Burns
- Review:
  - Resistance – how difficult it is for electrons to pass through a material (ohm)
  - Ohm’s law – Current (I) = Voltage (E)/Resistance (R)
  - Dermis/most internal tissues except bone have low resistance
  - Heat produced proportional to resistance and square of the current
- Effects of electricity dependent upon:
- Type of current
- Amount of current
- Pathway of current
- Duration of contact
- Area of contact
- Resistance of the body
- Voltage

### Current:
- Alternating current more damaging
  - 3-4x more direct current needed for same effect
- For 1-second contact time:
  - 1 mA – threshold of perception
  - 10-15 mA – sustained muscular contraction
  - 50-100 mA – respiratory paralysis, ventricular fibrillation
  - 1000 mA – sustained myocardial contractions

### Arc vs. Internal Current
- Arc injuries
  - Current external to body
  - Injury more superficial
- Internal current
  - Path = source ➔ entry wound ➔ exit wound ➔ ground
  - Destruction of deep tissues
  - Low-voltage current – path of least resistance (nerves, blood vessels)
  - High-voltage current – direct path between entrance and ground
  - Most severe damage to tissue occurs at entrance/exit wounds

### Entry/Exit wounds:
- Entry = charred, leathery, depressed
- Exit = “exploded”
- Hand ➔ hand = 60% fatal
- Hand ➔ foot = 20% fatal
- Complications:
  - MSK – Fractures, dislocations, muscle injury, rhabdomyolysis, periosteal necrosis, limb necrosis, compartment syndrome
  - Vascular – Vascular wall necrosis, bleeding, thrombus
  - Neuro – Nerve injury
  - CVS – Vfib, afib, block, arrest
  - Resp – Arrest, effusions, pneumonitis
  - Skin – Burns
  - Nephro – Renal failure
  - GI – N/V, ileus, ulcers, visceral injury

10. Lightning Injuries
    - In Canada, 10 deaths/164 injuries per year
    - Three factors increase risk of strike:
      - Height, isolation, “pointiness”
    - < 5% “direct” strikes
    - < 50% survivors have burn marks
    - Shockwave component
    - Mechanisms of injury:
      - Direct strike (3-5%)
      - Side splash from another object (30%)
      - Contact voltage from object that is struck, ex. plumbing (1-2%)
      - Ground current effect (40-50%)
      - Energy not connected to main lightning channel (15-20%)
      - Blunt trauma/barotraumas
    - Versus electrical burns:
      - Brief contact (4-6 ms), usually no significant tissue damage along path of current
      - Majority of lightning energy flashes around body, vaporizing sweat or rainwater ➔ secondary steam burns
      - Rhabdomyolysis, compartment syndromes less likely
- Blunt, concussive, shrapnel-related injuries
- Most deaths by cardiac arrest
- Rupture of the tympanic membranes
- Minor burns and eye injuries
- Chronic sequelae – brain injury, chronic pain, neuropsychological
- Lichtenberg Figure pathognomonic

** From “Lichtenberg Figures Due to a Lighting Strike” by Yves Domart, M.D., Emmanuel Garet, M.D., New England Journal of Medicine, Volume 343:1536, November 23, 2000, Number 21, Images in Clinical Medicine
Reference

Hemorrhage Control and Balanced Transfusion in Trauma

Chris Pastor
Oksana Prokopchuk-Gauk
Alena Stirling

Please see Appendix for SHR Massive Transfusion Protocol

Introduction

Massive hemorrhage requiring massive transfusion is a significant cause of mortality in trauma. Although the phrases massive hemorrhage and massive transfusion impy a degree of bleeding that is life-threatening, a single standard definition has not been established in the literature. Definitions include:

- Transfusion of blood components equal to, or greater than, one blood volume in 24h
- Replacement of 50% blood volume in 3h
- Blood loss >150 ml/min
- Transfusion of 4 U PRBC in 4h, in the setting of major bleeding
- Transfusion of 10 or more RBC in 24h or time from ER presentation to ICU transfer

Physiological Coagulation

An understanding of the physiological mechanisms of hemostasis is essential for the application of a balanced resuscitation of the massively bleeding patient. The cellular component of coagulation involves platelets, which are localized to the damaged area and linked via fibrinogen (Figure 1). The enzymatic component involves a serine protease cascade that serves to convert fibrinogen to fibrin and stabilize the clot (Figure 2).

Figure 1: The cellular component or coagulation in the initial response to tissue damage. Von Willebrand Factor (vWF) localizes platelets to exposed collagen. The localization of platelets results in activation and release of platelet contents including ADP, serotonin, platelet activating factor, vWF, platelet factor 4 and thromboxane A2. The result is recruitment and activation of more platelets and activation of the enzymatic clotting cascade.
Trauma Induced Coagulopathy and the Lethal Triad

The lethal triad is coagulopathy, acidosis, and hypothermia, which is the result of significant blood loss. Volume loss decreases hemoglobin resulting in decreased perfusion and a loss of coagulation factors. Lactic acidosis occurs as cells rely on anaerobic respiration to meet their energy demands. The impaired energy metabolism causes thermal dysregulation and hypothermia, which increases oxygen demand further exacerbating the problem.

Control of massive hemorrhage is the obvious goal to prevent or reverse the aspects of the lethal triad. While this may not be immediately possible, it is critical that the resuscitation team takes measures to prevent exacerbation of the lethal triad in the resuscitation bay.

Avoiding exacerbation of trauma induced coagulopathy:

- TXA should be administered within the 1st hour of injury. There is generally no role for TXA beyond 3H post injury (Roberts et al., 2013). An exception to this generalization would be if TXA is indicated on thromboelastography (TEG) analysis. The dosage is: 1 gram loading dose over 10 minutes followed by a 2nd gram over 8 hours.

Figure 2: Enzymatic Component of Coagulation. Several serine proteases form a cascade for definitive clot stabilization. Intrinsc and extrinsic pathways lead to activation of factor X, which catalyzes the activation of thrombin resulting in the conversion of fibrinogen to fibrin.
Send a blood group and antibody screen on arrival, together with a “Trauma Panel”. This panel should be drawn every 30 minutes in a trauma patient, and used to help guide therapy. The panel includes:

- CBC – maintain Hb > 80 g/L
- PTT, PT/INR – goal to normalize
- Fibrinogen level – goal > 1.5 g/L
- Ionized Calcium

If there is a high suspicion of hypocalcemia, replace it early. Calcium is a clotting factor (Factor IV), and an essential component of the coagulation cascade.

Avoid excessive crystalloid/colloid resuscitation. Crystalloid can act a volume expander, but the cost is dilutional coagulopathy of clotting factors. In an actively bleeding patient, the role of crystalloid/colloid fluids should be limited to temporizing until blood products are available. There has been no demonstrated benefit of colloid infusion over crystalloid use in the trauma setting. Use of crystalloid with a near physiologic pH is preferred (ex. plasmalyte), and has been shown to have superior outcomes over normal saline.

Replace losses with a balanced approach that approximates whole blood, and which is based on results of the “Trauma Panel”.

- Blood components (red blood cells, platelets, plasma, cryoprecipitate) or blood products (fibrinogen concentrate) can be requested as-needed to manage a bleeding patient.
- The clinical team should consider providing notification to the transfusion medicine lab to begin thawing plasma in anticipation of a potential MTP activation. (They can prepare plasma ‘just in case’.)
- Activation of the massive transfusion protocol (MTP) should be considered if there is a concern of severe and ongoing blood loss. There are multiple scoring systems to aid in the decision...
process for activating a MTP.

Prevent Hypothermia:

- Ask for warm blankets and/or a Bair Hugger. Warm the patient immediately after completion of the primary survey. Be cognizant that patient will lose significant body temperature during the primary survey.
- Minimize uncovering of patient for adjuncts and secondary survey. X-rays penetrate warm blankets and the patient only needs small areas uncovered for FAST assessment.
- All fluids should be warmed during administration
  - Rapid infusers have an incorporated warming mechanism
  - Exception: platelets are stored at room temperature, and do not need to be warmed (the cells are damaged if exposed to a warmer).
- Keep the trauma bay warm.

Prevent Acidosis:

- If possible, avoid large volumes of normal saline (pH 5.5) as it can cause metabolic acidosis. A pH balanced fluid like Plasmalyte (pH 7.4) is preferred.
- Ensure patient can ventilate adequately. There are many reasons for decreased minute volume in a trauma patient, including iatrogenic due to administration of opioids. If significant respiratory depression results in respiratory acidosis, consider airway control and mechanical ventilation.
- Bicarbonate infusion increases CO2, as such a concomitant increase in minute ventilation is required.
- Furthermore, its use will decrease calcium concentrations lowering myocardial contractility as well as resulting in impaired coagulation. Bicarbonate in trauma resuscitation should only be considered by experienced clinicians.
Balanced Transfusion Strategy:

Use of a balanced transfusion strategy relies on clinical gestalt supplemented with objective laboratory information. Massive transfusion protocols should not be viewed as a binary concept of all or nothing. Laboratory data and thromboelastography (TEG) can guide which blood components and adjuncts are transfused.

When to use MTP:

- Upon patient arrival, it is critical to send the blood group, antibody screen and “Trauma Panel” (CBC, aPTT, PT/INR, Fibrinogen, and ionized calcium).
- Complete a clinical assessment and determine if the patient is rapidly exsanguinating (this may be visible external hemorrhage or massive internal hemorrhage). It is appropriate to activate the MTP if it is determined that:
  - The patient has an estimated volume loss of >4.5 L in 30 minutes, OR
  - There is ongoing uncontrolled bleeding (estimated at least 150 mL per minute) and loss of over half the circulating blood volume
- **ONE person** should be assigned as the clinical “Team Contact” with Transfusion Medicine, to communicate MTP activation, and ensure clear and coordinated communication with the blood bank throughout the duration of the MTP.

Upon MTP activation, 4 units of RBC and 1 platelet unit will arrive in advance of the plasma. It will take up to 30 minutes to thaw plasma and deliver it to the bedside. Throughout the MTP, communication is essential with the blood bank. Components and products may be requested over and above the contents of the MTP boxes, based on the needs of the patient.
**Adjuncts**

The purpose of a MTP is to replace whole blood in a massively bleeding patient. Adjunctive clotting factors, on the other hand, can be used for goal directed therapy.

Fibrinogen (Factor I) is the first clotting factor depleted in massive bleeding. Its concentration can be rapidly reduced due to acidosis, dilution, bleeding losses, and reduced synthesis. Fibrinogen sources include fibrinogen concentrate (FC), FFP, and cryoprecipitate. FCs have 2 advantages over FFP and cryoprecipitate in that, although a blood product derived from plasma, no crossmatch is required.

When FFP is centrifuged it separates into precipitate and supernatant fractions. The precipitate is called cryoprecipitate and contains fibrinogen, Factor VIII, vWF and Factor XIII. The role of cryoprecipitate in trauma has been limited in favor of FFP. Although the concentration of coagulation factors is higher in cryoprecipitate, several are missing.

Prothrombin complex concentrates (PCC) such as octaplex contain vitamin K dependent factors II, VII, IX, & X. PCCs can rapidly replace coagulation factors as they are typically low volume and do not require crossmatch. These are relatively new therapies and their use in trauma is still emerging. Involving Hematology early for help is strongly advised.

Recombinant factor VII has been the mainstay of treatment for hemophilia patients. There is no role for Factor VII in the treatment of trauma patients. In the event a patient with a coagulopathy such as hemophilia is involved in a trauma, consult Hematology.

**Further Reading**

This manual is by no means a comprehensive review. The following selections are strongly recommended reading.

Bloody Easy 4 – Essential reading for every medical student, resident, and attending physician who orders blood & blood products and obtains consent for their administration. An electronic copy is available at saskblood.ca
The following is the web address of the SHR MTP clinical procedure:

https://www.saskatoonhealthregion.ca/locations_services/Services/Pathology-Laboratory-Med/healthpractitioners/Pages/mtpadultstransfusionmedicine.aspx

Risks of Blood Transfusion

Table 1: Infectious Complications (per unit) (Callum, 2016)

<table>
<thead>
<tr>
<th>Complication</th>
<th>Risk per Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Immunodeficiency Virus (HIV)</td>
<td>1/21,000,000</td>
</tr>
<tr>
<td>Human T-Cell Lymphotrophic Virus (HTLV)</td>
<td>1/7,600,000</td>
</tr>
<tr>
<td>Hepatitis C Virus (HCV)</td>
<td>1/13,000,000</td>
</tr>
<tr>
<td>Hepatitis B Virus (HBV)</td>
<td>1/7,500,000</td>
</tr>
<tr>
<td>West Nile Virus (WNV)</td>
<td>&lt; 1/1,000,000</td>
</tr>
<tr>
<td>Chagas Disease</td>
<td>1/4,000,000 per Unit of Component</td>
</tr>
<tr>
<td>Bacterial Contamination of Red Blood Cell Unit</td>
<td>1/250,000 (symptomatic)</td>
</tr>
<tr>
<td></td>
<td>1/500,000 (death)</td>
</tr>
<tr>
<td>Bacterial Contamination of Platelet Pools</td>
<td>1/10,000 (symptomatic)</td>
</tr>
<tr>
<td></td>
<td>1/200,000 (death)</td>
</tr>
</tbody>
</table>

Table 2: Non-infectious Complications (per unit) (Callum, 2016)

<table>
<thead>
<tr>
<th>Complication</th>
<th>Risk per Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABO – incompatible transfusion*</td>
<td>1/40,000</td>
</tr>
<tr>
<td>Anaphylaxis</td>
<td>1/40,000</td>
</tr>
<tr>
<td>Transfusion-related acute lung injury (TRALI)</td>
<td>1/10,000</td>
</tr>
<tr>
<td>Delayed Hemolytic Transfusion Reaction</td>
<td>1/7000</td>
</tr>
<tr>
<td>Transfusion-associated circulatory overload (TACO)</td>
<td>1/100</td>
</tr>
<tr>
<td>Febrile Non-Hemolytic Reaction</td>
<td>1/300 (RBC units)</td>
</tr>
<tr>
<td></td>
<td>1/20 (Platelet units)</td>
</tr>
<tr>
<td>Allergic Reaction (minor)</td>
<td>1/100</td>
</tr>
</tbody>
</table>

* In the trauma bay there is increased risk of an incompatible transfusion as it can be noisy and crowded. When there are multiple casualties ensure that the wristbands have been placed on the appropriate patients. Be careful when there are two patients with the same name, eg. A father and son involved in the same MVC, unidentified casualties Jane Doe 1, Jane Doe 2, etc.
References


2. Callum, J. P., PH; Lima, A; Lin, Y; Karkouti, K; Lieberman, L; Pendergrast, JM; Robitaille. N; Tinmouth. AT; Webert. KE. (2016). Bloody Easy 4. Ontario, Canada: Library and Archives Canada Cataloguing in Publication


VTE Prophylaxis

Cause of death amongst trauma patients:
- Immediate (within the first hour): Blood loss, Traumatic brain injury (TBI)
- Later: Multi-organ failure, CNS injury, VTE

Trauma patients are at increased risk for VTE
- General trauma patients 3-5% risk (Chest Guidelines)
  - Higher with spinal trauma, acute spinal cord injury (SCI), and TBI - 8-10%
  - Other risk factors: lower extremity and pelvic fractures, older patient age, prolonged immobility, and increased hospital stay
- Incidence of DVT 11.8-65% and PE 1.5-20% amongst trauma patients (Cochrane Review)

Pathophysiology of VTE Risk in Trauma Patients (Cochrane Review)
- Virchow’s Triad:
  - Stasis
    - Hypercoagulability
    - Endothelial Injury
  - Injured ➔ immobilized ➔ reduction in venous return ➔ decreased oxygen and nutrients to endothelial cells
  - Direct endothelial injury to vessels ➔ procoagulation factor amplification ➔ thrombosis
Assessment of VTE risk:
Modified Caprini Risk Assessment

<table>
<thead>
<tr>
<th>Points</th>
<th>Risk Factor</th>
<th>Risk Category Score</th>
<th>Estimated VE Risk in Absence of Prophylaxis (%)</th>
<th>Recommendation</th>
</tr>
</thead>
</table>
| 1 point| - Age 41-60  
- Acute MI (<1m)  
- BMI>25  
- CHF exacerbation (<1m)  
- Hx of IBD  
- Procedure with local anesthesia  
- Swollen legs of varicose veins  
- Sepsis (<1m)  | 0                   | < 0.5              | Early and frequent ambulation                   |
| 2 point| - Age 61-74  
- Arthroscopic sx  
- Major open surgery (>45 mins)  
- Laparoscopic surgery (>45 mins) | 1                   | 1.5                                           | Mechanical Prophylaxis                                  |
| 3 point| - Age > 75 years  
- Hx of CTE  
- FMHx of VTE (1st degree relative)  
- F5 Leiden  
- Prothrombin 20210A | 2                   | 3.0                                           | Pharmacologic Prophylaxis                               |
| 5 point| - Stroke (<1m)  
- Elective arthroplasty  
- Hip, pelvis, or leg fracture (<1 m) | 4                   | 6.0                                           | Mechanical and pharmacologic prophylaxis                 |

Risk Category Score

- Very Low: 0
- Low: 1-2
- Moderate: 3-4
- High: > 5

Options:
- Pharmacological
  - LDUH – Low-dose unfractionated heparin
    - Heparin 5,000 units subq BID
  - LMWH – Low molecular weight heparin
    - Enoxaparin 40 mg subq daily
      - Renal impairment:
        - Enoxaparin 30 mg subq daily if CrCl<30cc/min
      - Bariatric (BMI > 40):
        - Enoxaparin 40 mg subq BID
    - Tinzaparin 4500 units subq daily
- Mechanical
  - IPC – Intermittent pneumatic compression
  - Graduated compression stockings
- Other
  - Inferior vena cava filter

**Examining the Literature**

**Cochrane Library:**
- “Prophylaxis was more effective than no prophylaxis, pharmacological prophylaxis than mechanical prophylaxis, and LMWH than UH”.
  - Higher risk of minor bleeding in pharmacological thromboprophylaxis compared to mechanical therapy.
- Limitations: Small trials, few events, questionable methodology quality.

**EAST Guidelines:**

**LDUH**
- Level II: Little evidence to support the benefit of LDUH as sole agent for prophylaxis in trauma patient at high-risk for VTE.
- Level III: For patients in whom bleeding could exacerbate injuries (e.g. intracranial hemorrhage, incomplete SCI, intraocular injuries, severe pelvic or lower extremity injuries with traumatic hemorrhage, and intra-abdominal solid organ injuries being managed non-operatively), the safety of LDUH has not been established, and an individual decision should be made when considering anticoagulant prophylaxis.

**LMWH**
- Level II: LMWH can be used for VTE prophylaxis in trauma pts with the following injuries:
  - 1. Pelvic #s requiring operative fixation or prolonged bed rest (5 days).
  - 2. Complex lower extremity #s (open fractures or multiple #s in 1 extremity) requiring operative fixation or prolonged bed rest (5 days).
- 3. SCI with complete or incomplete motor paralysis.

  ▪ Level III:
  - 1. Trauma patients with an ISS 9, who can receive anticoagulants, should receive LMWH as their primary mode of VTE prophylaxis.
  - 2. LMWH has not been sufficiently studied in the head-injured patient with intracranial bleeding to justify its use.
  - 3. LMWH should not be used when epidural catheters are placed or removed.

IVC Filters

  ▪ Please see Appendix for IVC Filter Protocol
  ▪ Level III: Should be considered in very high-risk trauma pts:
    - Those that cannot receive anticoagulation be cause of increased bleeding risk, AND
    - Injury pattern rendering them immobilized for a prolonged period of time, including the following:
      • GCS <8 – severe closed head injury.
      • Incomplete spinal cord injury with paraplegia or quadriplegia.
      • Complex pelvic fractures with associated long bone fractures.
      • Multiple long bone fractures.

CHEST Guidelines:

<table>
<thead>
<tr>
<th>Summary of CHEST Guidelines for VTE Prevention in Non-orthopedic Surgical Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>For major trauma patients:</strong></td>
</tr>
<tr>
<td>• Use LDUH, LMWH, or mechanical prophylaxis (IPC) over no prophylaxis.</td>
</tr>
<tr>
<td>• If high risk of VTE (acute SCI, TBI, spinal surgery), add mechanical prophylaxis to pharmacologic prophylaxis if not contraindicated by lower extremity injury.</td>
</tr>
<tr>
<td>• If LMWH and LDUH contraindicated, use mechanical prophylaxis (IPC) over none when not otherwise contraindicated. Add LMWH and LDUH when contraindications no longer present.</td>
</tr>
<tr>
<td>• Do not use an IVC filter for primary VTE prevention.</td>
</tr>
</tbody>
</table>
Summary of CHEST Guidelines for VTE Prevention in Non-orthopedic Surgical Patients

<table>
<thead>
<tr>
<th>Special Situation:</th>
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<tbody>
<tr>
<td><strong>TBI and SCI</strong></td>
</tr>
</tbody>
</table>

- Incidence of DVT among TBI population 54% without prophylaxis (mechanical and pharmacological) (Koehler et al).
- Assess the risk of on-going intracranial bleeding/haemorrhage.
- Generally, initiated at 72h.
  - Balance risks of delaying and starting prophylaxis
    - Discuss with your friendly local neurosurgeon.
  - Various studies suggest that early initiation is likely safe:
    - No progression in neurological exam or CT head findings after 24h means that it is likely safe to initiate prophylaxis (Schaible et al).
    - Early initiation (<72h) associated with lower rates of PE and DVT with no increased risk of neurosurgical intervention or death. Byrne et al
Early VTE prophylaxis (<72h) with enoxaparin not associated with increased progression of intracranial hemorrhagic injury in hemodynamically stable patients. Koehler et al.

Summary:

**VTE is a major source of morbidity in trauma patients.**
- Prophylaxis should be initiated on all trauma patients, unless otherwise contraindicated. Daily reassessment thereafter should be performed in order to start as soon as possible.

**Tracheostomy**

**Indications**
- Airway obstruction
- Anticipation of prolonged mechanical ventilation requirements from respiratory failure
- Need for improved pulmonary toilet
- Inability to protect the airway

**Benefits**
- Prevention of laryngeal and upper airway damage secondary to prolonged intubation
  - E.g. Vocal cord edema and damage, laryngeal erosions/scarring/stenosis, recurrent laryngeal nerve damage
- Allows for easy and frequent access to lower airway for suctioning and secretion removal
- Improved patient comfort and increased patient safety
- Promotion of oral feeding
- Facilitation of patient mobilization and nursing care
  - Less sedation requirements
- Decreased risk for ventilator-associated pneumonia
  - Data mixed on this point. Theory: Micro aspiration of oral secretions past the tube cuff may contribute to pneumonia (PNA).
Timing

- “Prolonged mechanical ventilation anticipated”
  - Definition of prolonged?
    - Beyond 10-14 days*
    - In severe multi-trauma or head injury with low GCS, tracheostomy within 3-4d of intubation may have some benefit. Durbin et al 2010
  - Cochrane
    - 8 RCTs: early tracheostomy < 10d & late > 10d
    - Moderate quality evidence showing lower mortality and decreased time spent on ventilation with early tracheostomy
    - Divergent results on PNA and probability of timing of ICU discharge

- EAST Guidelines
  - Level I: No mortality difference between patients receiving early tracheostomy (3-7d) vs late (>7d).
  - Level II: Early tracheostomy decreases total days of mechanical ventilation and ICU length of stay (LOS) in patients with head injuries. Patients with severe head injuries should receive early tracheostomy.
  - Level III: Early tracheostomy may decrease total days of mechanical ventilation and ICU LOS in trauma patients without head injuries. Early tracheostomy may decrease rate of PNA in trauma pts. Early tracheostomy should be considered in all trauma patients anticipated to require mechanical ventilation >7d.

Risks

- Morbidity 4-10%, Mortality <1%. Paul et al
### Short-term
- Airway loss
- Bleeding
- Damage to nearby anatomical structures
- Tracheal ring rupture
- Pneumothorax

### Long-term
- Infection
- Tracheoinnominate fistula (<1%)
  May be heralded by minor “sentinel” bleed that later turns to massive haemorrhage.
- Tracheomalacia
- Tracheal stenosis
- Swallowing dysfunction

---

**Method**

- **Option for percutaneous or surgical placement**
  - Dependent on patient factors as well as operator comfort and preference
  - Prior to performing tracheostomy, optimize conditions when possible:
    - PEEP < 10-15
    - Correction of coagulopathies and thrombocytopenia
      - INR < 1.5
      - Platelets > 50,000

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Surgical</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Percutaneous</strong></td>
<td><strong>Surgical</strong></td>
</tr>
<tr>
<td>- Decreased: Cost, wound infection rates, scarring</td>
<td></td>
</tr>
<tr>
<td>- No patient transportation required</td>
<td></td>
</tr>
<tr>
<td>- Minimal disruption of tissue planes</td>
<td></td>
</tr>
<tr>
<td>- Avoidance of GA</td>
<td></td>
</tr>
<tr>
<td>- Need for bronchoscopy</td>
<td></td>
</tr>
<tr>
<td>- Lack direct visualization of tissue</td>
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<td>- More appropriate for difficult cases (e.g. anatomy)</td>
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<tr>
<td>- Direct and better visualization of tissue during dissection</td>
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<tr>
<td>- Ability to place stay sutures</td>
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<tr>
<td>- Increased cost</td>
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<tr>
<td>- Transportation of patient</td>
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<tr>
<td>- Increased time</td>
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- **Cochrane**
  - No evidence of different rates in mortality and morbidity related to procedure, major bleeding, tube occlusion/obstruction, accidental decannulation, or difficulty in tube change.
  - Percutaneous tracheostomy showed reduced rates of wound infection and major scarring.
  - 20 trials examined, low quality of evidence.
  - Examining the evidence for percutaneous dilatational tracheostomy (PDT)
    - Freeman et al.
      - 5 RCTs, 236 patients
• Results:
  • No difference between PDT and open with respect to overall complication rates, days intubated, or death.
  • PDT associated with…
    - less perioperative bleeding (OR 0.14).
    - less postoperative bleeding (OR 0.39).
    - lower infection rate (OR 0.02).
    - shorter procedure time by 9.84 mins.

• Bachetta et al.
  ▪ Retrospective study over 3 years with 59 open tracheostomies and 27 PDT
  ▪ Results
    • No significant difference in demographics, medical histories, operations, or complications (excepting more postoperative arrhythmias in open) between both groups.
    • PDT estimated to save $304,000 during a 5-year period.
      • OR time = $$
        - Room set up, procedural time, anesthesia cost, room clean up.

• Delaney et al.
  ▪ 17 RCTs with 1,212 patients
  ▪ Results
    • Reduced wound infections in PDT
      • OR = 0.28, 95% CI, p<0.0005
      • Minimization of local tissue damage
    • No significant difference in bleeding
    • No significant difference in overall mortality but possible trend favoring PDT
- Fewer infections
- Undue risk of transportation to OR
- No significant difference in incidence of major complications (pneumothorax, tube malplacement, airway loss)
- Shorter duration to placement of PDT
  - Decreased duration of sedation
  - Earlier weaning from mechanical ventilation
- Conclusion: “PDT technique, performed in the ICU, should be considered the technique of choice for critically ill patients who require a tracheostomy”.
  - Further studies supporting use of PDT
    Higgins et al.
    Kornblith et al.

**Summary:**

<table>
<thead>
<tr>
<th>Tracheostomies should generally be considered in patients where intubation is expected beyond 10-14d.</th>
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<tbody>
<tr>
<td>- Tracheostomies aid in prevention of upper airway and laryngeal damage from prolonged intubation and increase patient comfort.</td>
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<tr>
<td>- Method selection depends on a variety of factors (patient and operator). Both have similar complication rates but PDT is associated with less scarring and fewer wound infections.</td>
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</table>

**Enteral Nutrition**

**Metabolic Response to Trauma**

Postinjury Hypermetabolism
- **Ebb** (within first 48h): Hyperglycemia, increased vascular tone, and changes in O2 consumption.
- **Flow**: Increased oxygen consumption and delivery, hyperdynamic circulation, and development of insulin resistance. Mobilization of amino acids from lean tissues to support wound healing, immunologic response, and accelerated protein synthesis.
Enteral nutrition (EN)

- Early – Delivery of nutrients into GI lumen within 24-48h of admission/injury.

- Benefits

  Nutritional:
  - Fulfill energy requirements via delivery of adequate calories and protein.

  Non-nutritional:
  - Maintenance of structure and functional integrity of GI tract.
  - Modulation of metabolic response to catabolic stimulus.
  - Support immune system by maintaining GALT.
  - Reduce oxidative stress. Martindale et al

<table>
<thead>
<tr>
<th>GI Response</th>
<th>Immune Response</th>
<th>Metabolic Response</th>
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<tbody>
<tr>
<td>- GI integrity maintenance</td>
<td>- Regular cell modulation to enhance systemic immune function</td>
<td>- Promotion of insulin sensitivity</td>
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<tr>
<td>- Enhance motility</td>
<td>- Promotes anti-inflammatory response</td>
<td>- Reduction of hyperglycemia, muscle and tissue glycosylation</td>
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<tr>
<td>- Improve absorptive capacity</td>
<td>- Maintains mucosa associated lymph tissue</td>
<td>- Reduces stress metabolism to enhance more physiologic fuel utilization</td>
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<tr>
<td>- Support and maintain commensal bacteria</td>
<td>- Modulates adhesion molecules to decrease migration of macrophages and neutrophils</td>
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</tr>
<tr>
<td>- Reduce virulence of endogenous pathogenic organisms</td>
<td>- Promote production of secretory IgA</td>
<td></td>
</tr>
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<td>- Promote production of secretory IgA</td>
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</tbody>
</table>

Martindale et al.

McClave et al.
Examining the Literature

Cochrane Library

- **Burn Injuries**
  - Insufficient evidence to support or refute effectiveness of early vs. late initiation.
    - Promising evidence that early blunts the hypermetabolic response but insufficient to provide guidelines.

- **Head Injuries**
  - Trend towards improved survival and reduced disability and decreased infections with early nutritional support but small trials and unable to come to consensus statement.

EAST Guidelines

- **re. Route**
  - **Level I:** Feed pts with blunt and penetrating abdo injuries enterally when feasible.
  - **Level II:** Feed pts with head injuries preferentially with EN as outcomes similar to parenteral nutrition (PN) but lower cost and complications in EN. PN feeds if EN not possible.
  - **Level III:**
    - TPN to be started by day 7 if EN not successful in severely injured patients.
    - Pts who do not tolerate 50% of their EN goals by day 7 should have TPN started. Wean TPN once >50% of EN feeds tolerated.

- **re. Early vs Late**
  - **Level I:** In severely injured blunt/penetrating trauma pts, no outcome advantage to initiating enteral feedings within 24h as compared to 72h.
  - **Level II:**
    - Burn patients: Enteric feeds should be started ASAP. Delay over 18h associated with gastroparesis and need for PN. Severe head injury: Those that do not tolerate gastric feeds within 48h should be
switched to postpyloric feeds if feasible and safe.

- **Level III:**
  - Pts incompletely resuscitated should not have direct small bowel feedings. If severely injured and undergoing laparotomy for blunt and penetrating trauma, direct small bowel access should be obtained and enteral feedings begun ASAP.

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**Summary:**

Enteral nutrition should be initiated when possible to fulfill the patient’s energy requirements and maintain integrity of GI tract, support the immune system, and modulate the metabolic response after trauma.
The Tertiary Survey (TS)  

“The W’s”

- **What:** A repeat comprehensive physical examination with cataloguing of all injuries and a complete review of the mechanism of injury with all pertinent investigations and imaging (films and reports).
- **When:** Typically occurs within 24-48 hours after the initial injury. This may vary from site to site.
  - An additional survey may be required at a later time if patient remains unconscious, uncooperative, and immobile.
- **Why:**
  - Goal to decrease incidence of missed injuries in trauma patients.
    - Decreased morbidity and avoidance of long-term disability
    - Improved prognosis
    - Medico-legal consequences (Thomson et al)
  - ATLS primary and secondary surveys, although proven to be effective in recognizing life-threatening injuries, has been shown to miss some injuries.
    - Missed injury incidence in literature 1-40% (Hajibandeh et al).
    - Implementation of tertiary surveys decreases this rate.
  - Missed injury rate: injuries that are not identified by tertiary survey.
    - TS vs. non-TS
      » Biffl et al. 1.51% vs. 2.37% (p=0.0123)
      » Keijzers et al. 1.5% vs. 2.4% (p=0.01)
  - Missed injury detection rate: injuries that are not identified by primary and secondary surveys but are diagnosed by tertiary survey.
- TS vs. non-TS
  » Keijzers et al. 7% vs. 3% (p<0.01)
  » Resler et al. 2.6% vs. 0.34% (p<0.0001)
  » Ursic et al. 6.16% vs 3.57% (p=0.00999)

Contributing factors to missed injuries:
  • Remember the **D's**
    - Decreased level of consciousness
      - Drugs and sedatives
      - Alcohol
      - CNS injuries – head trauma
    - Distracting injuries
    - Direct to OR (emergent surgery)
  • Factors with greatest risk of diagnostic delay
    - Altered mental status
    - Severity of trauma (Polytrauma vs. single injury trauma)
      - Vles et al.
        » ISS>15 in 57.1% of pts with missed injuries, (9.8% without).
      - Buduhan et al.
        » Higher ISS (25) and lower GCS (< 8)

Evidence
  • Zamboni et al.
    • Prospective observational study (n=526)
      - 81 = polytraumas, 445 = low-energy trauma
      - 57 new injuries diagnosed in 40 patients (7.6%)
        » Most commonly located in lower limb (62%) and up per limb (19%)
- 11 new injuries resulted in changes in procedure

• Biffi et al.
  • Retrospective study (n=6,854)
    - Missed injury rates pre- and post-implementation of tertiary survey
    - Missed injuries decreased from 2.4% to 1.5% overall after implementation
      » Most commonly extremity # (53%) and abdominal injuries (17%)

• Who:
  □ A physician familiar with the patient and another individual unfamiliar with the case

Summary:

**Tertiary surveys should be performed on all trauma patients.**
- Primary and secondary surveys are excellent at identifying life-threatening injuries but missed injuries thereafter contribute to patient morbidity.
- Consequently, tertiary surveys should be completed 24-48h after the initial injury.
- Contributors to missed injuries are decreased LOCs, distracting injuries, and injury severity that requires direct transfer to OR.
References

DVT Prophylaxis:

Tracheostomy:

**Enteral Nutrition:**

**Tertiary Survey:**


TRAUMA MANUAL

APPENDIX

Trauma Activation Criteria i
Massive Transfusion Protocol ii
Canadian CT Head Rules iii
U of S C-Spine Clearance iv
IVC Filter Protocol v
Level I
(any of the following)

Physiologic
GCS 12 or less with visible evidence of trauma
OR clear history of significant trauma*
SBP < 90, SBP < 80 (age <5), SBP < 70 (age <1)
RR < 10 or > 29 or requiring intubation

Anatomic
Penetrating Trauma to Head, Neck or Torso
Significant burns to the airway, face OR . 20% TBSA burn)
Severe Facial Injury with potential for airway compromise
Suspected spinal CORD injury (neurological deficits
2 or more long bone fractures)

Mechanism
Pedestrian or Cyclist vs Car > 30 km/hr
ATV or motorcycle vs Car >30 km/hr
Ejection from vehicle
Large Animal Trauma (non-MVC)
Falls >20 ft

Special Populations MEETING Level II CRITERIA, get upgraded to Level I
Pregnant patient >20 weeks gestation
Geriatric (Age > 65)

Response
Transfer to Royal University Hospital
Full Trauma Team Activation
MRP = Trauma Team Leader

*Patients who are found unresponsive with no history of trauma and no visible trauma will NOT be considered trauma patients. Simple falls while intoxicated do not qualify as significant trauma.

** For unannounced Level I Trauma, the Emergency Physician or Pediatric Emergency Physician (age <17) on shift is the MRP until the TTL arrives and there is an appropriate time to hand over.

Level II
(any of the following)

Mechanism
Falls of 10-20 feet
Highway speed crash
Rearward displacement of front axle
Significant passenger compartment intrusion
Rollover
Death of same car occupant

Response
Transfer to Royal University Hospital
MRP = Emergency Physician or Pediatric Emergency Physician (age < 17) on shift ***

***The Emergency Physician may upgrade any Level II Trauma to a Level I at their discretion, at any point during the care of the patient. This includes patient who are enroute from another facility who have a change in their clinical status.

Mass Casualty
If three or more Level II trauma patients arrive at the same time, the Emergency Physician or Pediatric Emergency Physician on shift may call in the TTL (not the full trauma team) to help manage these patients, at their discretion.
Clinical 'Team Contact' Role

One bedside individual assigned by the physician lead activation the MTP to communicate with the transfusion Medicine ab (TML) who:

- Notifies TML (#2179) of the MTP activation.
- Provides patient identification (name, PHN, sex), care team location, contact phone # and name of physician lead.
- Records TML technologist contact name and time of MTP activation.
- Confirms type, screen & crossmatch sent to TML.
- Ensures MTP Panel sent every 30 minutes.
- Informs TML of any change in patient location, contact phone #, team contact individual or physician lead.
- Calls TML as soon as the MTP is discontinued by the physician lead.
- Ensures coolers returned to TML ASAP

Treatment considerations:

- If INR >1.5 or aPTT >40 and hemoglobin stabilizes, prioritize plasma transfusion over red cells.
- If fibrinogen <1.5 g/L consider cryoprecipitate 10 units of fibrinogen concentrate
- If platelets <75x10^9/L consider an additional dose of platelets
- If ionized Ca++ <1 mmol/L give 2 g calcium gluconate (slowly)
- TEG Results by Perfusion to assess coagulation and guide component choice
- Based on results, MTP box contents may be customized upon request
- If patient is on anticoagulants, or other transfusion advice is required, consult the on-call Transfusion Medicine Physician (#1000 - switchboard).

Massive bleeding criteria met:

>4.5 L of blood loss in 30 minutes OR
>150 ml/minute bleeding with loss of over half the circulating blood volume

NOTIFY TML OF MASSIVE TRANSFUSION PROTOCOL ACTIVATION (#2179)

Tranexamic acid 1 gram IV over 10 minutes in all patients within 3 hours of injury, followed by 1 gram IV infusion over 8 hours in trauma patients

Pick up MTO Boxes and Transfuse warm red blood cells and plasma with Level 1 Rapid infuser (do NOT warm platelets)

MTP BOX 1*

- 4 units red cells
- 4 units plasma
- 1 adult dose platelets

Alternate MTP Box 1 and 2 until clinical situation is resolved

MTP BOX 2

- 4 units red cells
- 4 units plasma

*Box 1 may arrive without plasma at MTP initiation (~25 min delay to allow for thaw, unless liquid units available)

Contents of MTP Boxes must be transfused within 4 hours of issue. Transfusional Medicine WILL CONTINUE preparing boxes unless notified that MTP is discontinued.
Canadian CT Head Guidelines

Sensitivity: 99%. Specificity: 47%.

CT head is required for minor head injury patients with any one of the following findings:

1. Age ≥ 65 years
2. Vomiting > 2 times
3. Suspected open or depressed skull fractures
4. Signs suggesting basal skull fracture:
   1. Hemotympanum
   2. Raccoon eyes
   3. CSF otorrhea or rhinorrhea
   4. Battle’s sign (bruising around mastoid process)
5. GCS < 15 at 2 hours post injury
6. Retrograde Amnesia > 30 min
7. Dangerous mechanism
   1. Pedestrian struck by vehicle
   2. Ejection from motor vehicle
   3. Fall from elevation >3 feet or 5 stairs

Inclusion Criteria

- GCS 13-15
- Age ≥ 16 yr.
- No coagulopathy or on anti-coagulation
- No obvious open skull fractures
All patients who meet pre-hospital criteria for a cervical collar placement should undergo cervical spine clearance on arrival at the trauma center. If possible, the cervical spine should be cleared and the collar removed within 24 hours of collar placement.

If cervical collar is required to stay in place for more than 24 hours, stiff extrication collars should be replaced with collars designed for long-term immobilization – ones that provide greater padding and pressure ulcer prevention.

1. Asymptomatic patients
The cervical spine may be cleared clinically with no need for X-ray films or CT if ALL of the following preconditions are met:
   • Fully alert and orientated
   • No head injury
   • No drugs or alcohol
   • No neck pain
   • No midline tenderness, bruising or deformity
   • No abnormal neurology (e.g. numbness, weakness, radicular pain)
   • No significant other 'painful distracting' injury (i.e. another injury which may 'distract' the patient from complaining about a possible spinal injury).

2. Symptomatic patients
Patients who do not meet the “asymptomatic” criteria outlined above should be suspected of having a cervical spine injury. Apply Canadian C-spine rules to determine if radiography is necessary (Canadian C-spine rules include additional criteria, including the mechanism of injury, to determine if imaging is indicated).
It is appropriate to consult the spine surgeon on-call if there is clinical evidence neurological deficit prior to obtaining spine imaging.

For patients in whom C-spine injury is suspected based on clinical criteria, or plain radiographs:

- The primary screening modality is axial CT from the occiput to T1 with sagittal and coronal reconstructions.

- Plain radiographs contribute no additional information and should not be obtained in addition to CT, unless recommended by the spine surgeon (e.g. flexion-extension view, in the appropriate clinical circumstances).
- If CT of the C-spine demonstrates injury: Obtain spine consultation.
- If there is neurologic deficit (with or without evidence of C-spine injury on x-ray or CT): Obtain spine consultation.
- For the neurologically intact awake and alert patient complaining of neck pain with a negative CT: C-spine is considered cleared. Patients should have follow up with a physician (GP, trauma clinic, etc) in 10-14 days. If still having pain during the follow up visit, consider spine consult.
- For the obtunded patient with a negative CT c-spine (No injury or degenerative changes) read by a staff radiologist, c-spine can be cleared without further imaging or clinical correlation.
Trauma patients are at high risk of development of venous thromboembolism (VTE) including deep venous thrombosis and pulmonary embolism (PE). PE is thought to be the third major cause of death after trauma in those patients who survive longer than 24 hours after onset of injury.

Placement of a prophylactic IVC filter in a trauma patient could be considered if there are absolute contraindications to prophylactic anticoagulation.

If the ACS/Trauma surgeon feels a patient may benefit from an IVC filter, please consider Hematology Consultation for formal advice and long term follow up.

If the Hematology service agrees that the patient would benefit from a prophylactic IVC filter, then Interventional Radiology will be consulted for placement of the filter.

In ICU patients who are not being followed by the ACS/Trauma surgeon, it is at the discretion of the ICU attending to arrange Hematology Consultation.

In summary, IVC filter placement is a reasonable consideration to mitigate the risk of VTE in the trauma setting. Optimally, IVC filters should be removed as soon as possible as they represent a significant independent risk factor for the development of lower extremity and IVC venous thrombosis. The Hematology Consultation Service is willing and available to inform decisions regarding indications for IVC filter placement and their subsequent removal.