MAJOR EXTREMITY TRAUMA MODULE

INTRODUCTION

Extremity trauma in general is extremely common, and may be characterised by the following:

- Occur in isolation, or in the multiply injured patient;
- Be limb threatening and occasionally life threatening
- Occur secondary to blunt or penetrating trauma
- Present with degrees of severity from a closed, neurovasculargy intact simple fracture through to a mangled extremity or traumatic amputation
- Involve skeletal, soft tissue, vascular and neurological structures in various combinations

While the principles of assessment are consistent irrespective of the severity of the injury, this module does not specifically address simple closed fractures. Rather, this module focuses on the assessment and management of more severe limb trauma and its complications.

The most common mechanisms for major extremity trauma are open fractures, crush injuries and major soft tissue injury from motor vehicle crashes, pedestrian injuries, falls from heights and industrial accidents.\(^1\) The lower limb is more frequently involved than the upper limb. Penetrating trauma resulting in vascular injuries is increasing in frequency and most commonly involves the brachial, femoral and popliteal arteries.

Assessment and management of major extremity trauma must occur in the context of assessing and managing the patient as a whole. Life-threatening injuries, which should be identified as part of the primary survey, will always take precedence over limb-threatening injuries, which may not be identified until the secondary survey.

**Life threatening extremity injuries include:**

- Pelvic disruption with massive haemorrhage – see the Pelvic Injury Module
- Severe arterial haemorrhage irrespective of mechanism
- Haemorrhagic shock from multiple long bone fractures (blood loss into the compartments)
- Crush syndrome

**Limb-threatening injuries include:**

- Mangled extremity
- Complex open fractures and / or dislocations
- Degloving injuries
- Severe vascular injury
- Traumatic amputation
- Compartment syndrome (as a consequence of the injury)
- Neurological compromise of the limb

Major extremity injury is best managed in a trauma centre with a multi-disciplinary team approach given the extensive resource requirement from initial management through to rehab.\(^2\) The ultimate goal of management is to optimise the potential for functional outcome.\(^3\)
PATTERNS OF INJURY

Open Fracture
Where the fracture is in communication with an overlying disruption of the skin. This may be subtle. If in doubt, consider the fracture to be compound. Open fractures may be associated with a mangled limb (see below).

The **Gustilo-Anderson classification system** is commonly used to describe and classify open fractures. It classifies according to the extent of soft tissue injury associated with the fracture.\(^2,3\) The higher the grade, the higher the risk of infection and the more likely amputation will be required.

**Type I:** Wound < 1cm, wound is clean without evidence of contamination; usually simple transverse / oblique fractures (infection risk 0-2%)

**Type II:** Wound > 1cm with moderate soft tissue injury and moderate contamination; (infection risk 2-5%)

**Type IIIA:** Severe soft tissue injury but bone adequately covered irrespective of the size of the wound; highly contaminated; usually more complex fractures - segmental or severely comminuted fractures (infection risk 5-10%)

**Type IIIB:** Extensive soft tissue loss, exposed bone, periosteal stripping, massive contamination (infection risk 10-50%)

**Type IIIC:** Extensive fracture associated with arterial injury requiring repair (infection risk 25-50%)

6 Hour Rule

Until recently, it was recommended that all compound fractures be taken to theatre for washout and debridement within 6 hours. Recent guidelines\(^2,4\) have identified no increased risk of infection where urgent theatre occurs within 24 hours, with appropriate antibiotics given early.

**Indications for immediate theatre include:**
- Gross contamination of the wound
- Compartment syndrome
- Devascularised limb
- A multiply injured patient

Antibiotics of choice are debated in the literature, but a generally accepted regime is:
- Type I/II wounds - 1\(^{st}\) generation cepaholsporin
- Type I/II – add an aminoglycoside
- For grossly contaminated wounds consider adding metronidazole to cover for clostridium (seek ID advice where appropriate)

The recent BOAST guidelines suggest wounds only be handled in the ED to remove gross contaminants, to photograph and to seal from the environment. Wounds are not to be provisionally cleaned by exploration or irrigation for risk of forcing contaminants deeper into the wound\(^2\).
Mangled Extremity

A mangled extremity exists where there is a severe injury involving a combination of skeletal, soft tissue and / or nerve structures resulting in a concern for the viability of the limb. Mangled extremities are not common injuries.

There are many scoring systems available to attempt to predict the likelihood of amputation of the mangled extremity (for example, Mangled Extremity Severity Score, Predictive Salvage Index to name a few). Ultimately the decision to amputate is a surgical one. Rather than memorise severity scores, it is useful to be aware of predictors that are associated with need for amputation of a mangled extremity:

- **Systemic Factors**
  - Age > 50 years
  - High energy transfer mechanism
  - Persistent hypotension (< 90mmHg)

- **Skeletal factors**
  - Gustilo Type III fractures
  - Severe open injury to the hind or midfoot

- **Soft tissue factors**
  - Large, circumferential tissue loss
  - Extensive closed soft tissue loss (degloving type injury)
  - Compartment syndrome

- **Vascular factors**
  - Prolonged warm ischaemic time (> 6 hours)
  - Degree of vascular segment loss
  - Proximal vascular injury (femoral > popliteal)
  - Absence of viable distal anastomotic site

- **Neurological factors**
  - Confirmed nerve disruption

Vascular Injury

Arterial injury may occur in the setting of penetrating injury or blunt trauma (fractures, dislocation, crush injury, traction injury). In the USA, 75-80% of peripheral vascular injuries are caused by penetrating trauma, while blunt trauma accounts for only 5-25%. Axillobrachial and branches in the upper extremity and femoropopliteal and branches in the lower limb account for 40-75% of all vascular injuries treated in civilian trauma centres. The long tracks of named arteries and veins in the extremities make them susceptible to injury although their location, narrow diameter, and compressibility result in a low incidence of death in the field. The exception to this rule is the axillary artery and the proximal femoral artery as it disappears under the inguinal ligament as penetrating injuries in these areas are considered injuries to the torso rather than limbs. They are considered non-compressible injuries, requiring immediate surgical intervention.

Based on physical examination findings arterial injury can be separated into hard signs requiring immediate transfer to theatre, and soft signs requiring further investigation. Patients with no signs do not require further investigation for vascular injury.
Crush Injury / Crush Syndrome

Crush injury occurs when a limb is compressed between two hard surfaces to the point where vascular supply is impaired, resulting in ischaemia and potential necrosis of tissue distal to the injury. The severity of the crush injury depends on the degree and duration of compression. Crush syndrome is the complication of a crush injury, occurring when the trapped limb is freed and reperfused. It is characterised by:

- **Electrolyte disturbances** - hyperkalaemia, hypocalcaemia, hyperphosphataemia, hyperuricaemia.
- **Rhabdomyolysis** which may result in myoglobinuria and acute renal impairment
- **Lactic acidosis** from anaerobic metabolism of ischaemic tissue and hypovolaemia
- Potential shock from third space losses into the soft tissue of the injured limb

Compartment Syndrome

Extremity compartments, bordered by inelastic fascia and bone contain compressible structures such as blood vessels, muscle and nerves. Compartment syndrome occurs when the pressure in a compartment rises, secondary to oedema, haemorrhage / haematoma or external compression (compressive dressings, casts). Veins and venules are compressed first, reducing outflow. Arterial flow continues, resulting in increased oedema. Eventually the increased pressure disrupts capillary flow and arterial perfusion.
Long bone fractures are the most common cause (75%), particularly tibial (anterior compartment) and forearm (volar compartment) fractures. Compartment syndrome can also occur elsewhere e.g. thigh, foot, buttocks, back, abdomen.

Normal compartment pressure is 0-10 mmHg. Compartment pressure of > 20 mmHg may disrupt capillary flow; compartment pressures of 30-40 mmHg place nerve and muscle fibres at risk. This is also dependent on systemic pressure, as ischaemia may occur at a lower compartment pressure in the setting of hypotension. For this reason, it may be more accurate to measure the delta pressure (\( \Delta P \))\(^4\) - a \( \Delta P \) of < 30 mmHg is concerning for compartment syndrome.

\[ \Delta P = \text{diastolic BP} - \text{compartment pressure} \]

Muscle and nerves can tolerate 4-6 hours of warm ischaemic time. Some necrosis will have occurred at 6 hours; after 8 hours most nerve and muscle fibres will have undergone necrosis.

Pain on passive stretch, delayed onset of pain, or increasing severity of pain despite reduction of the limb are the most reliable signs of compartment syndrome. Paraesthesia and paralysis are late signs. The compartment is usually swollen and tense. Arterial pulses may be present as the syndrome occurs before compartment pressure rises above systolic pressure\(^4\).

Acute complications of compartment syndrome are similar to crush syndrome as above, with contractures and impaired function occurring in the long term.

**Traumatic Amputation**

Traumatic amputations do not usually result in massive haemorrhage, as the arteries recoil and spasm in the first instance. Patients are at risk of massive haemorrhage as the arterial spasm subsides.

Re-implantation is a surgical decision, but may be considered for the following\(^5\):

- Upper limb more so than lower limbs, given the effectiveness of lower limb prostheses
- Amputations involving whole limbs, the thumb or index finger
- Dominant limb
- Short ischaemic time (< 6 hours warm, 12 hours cold)
- Multiple amputations
- Children

Contra-indications to re-implantation include\(^5\):

- Prolonged warm ischaemic time
- Crushed or avulsed parts
- Multiple levels of amputation
- Significant peripheral vascular disease, diabetes
- Haemodynamically unstable patients
Degloving Injury

These injuries occur when the overlying skin / subcutaneous tissue is separated from the underlying fascia as a result of shearing forces applied to the limb. They are usually open wounds, but not always (e.g. Morel-Lavellee injury). Closed injuries are often missed on initial assessment.

Neurological Injury

Nerve injury should be suspected when there is concomitant vascular injury (they run close together), crush injury or evidence of compartment syndrome. All fractured limbs should have a comprehensive neurological exam performed to identify neurological issues.

ASSESSMENT

HISTORY

Handover from the pre-hospital team with particular consideration of mechanism (e.g. blunt vs penetrating). The mechanism is an important aid when trying to determine possible patterns of injury.

- Evidence of major external haemorrhage including how much blood was lost on scene / ongoing bleeding
- Evidence of airway injury
- Evidence of ventilatory impairment
- Evidence of circulatory impairment
- GCS (important confounder of clinical examination in trauma)
- Injury profile
- Management to date
- Specific history e.g. timing of amputation, timing of tourniquet application

EXAMINATION

Life threats always take precedence over limb threats. In the setting of an extremity injury with major haemorrhage, the traditional ABC dogma of assessment and management should change to CABC with the initial C being haemorrhage control.

Immediate priority is to identify life threats:

Control Haemorrhage

Airway Associated injuries, altered level of consciousness
Breathing Associated injuries, ventilatory distress or impending failure
Circulation Global makers of hypoperfusion: altered level of consciousness, tachycardia, hypotension, cool peripheries. Assess the abdomen, pelvis and chest as potential source of circulatory compromise. Note that a significant amount of blood can be lost into the compartments when multiple long bones are fractured.


**Extremities**

Assess extremities as part of the secondary survey to identify limb threatening injuries. Mangled extremities, degloving injuries and amputations are visually distracting injuries that can potentially draw attention away from the primary survey.

Irrespective of the nature of the injury, the general examination of the extremities includes:

**Inspection**

- **Deformity** – closed fracture, dislocation
- **Open fracture** – deformity, presence of an open wound, condition of the overlying skin defect, bony involvement, degree of soft tissue involvement, contamination
- **Mangled extremity**
- **Active bleeding, expansile haematoma**
- **Location of wound** – proximity to an artery, location with regards to the clavicle and inguinal canal (transition points where proximal control of extremity vascular injury becomes difficult)
- **Degloving injury**
- **Amputation** – site(s), condition of skin, soft tissue and bone of stump and amputated appendage

**Palpation**

- **Crepitus**
- **Haematoma** – pulsatile, palpable thrill
- **Swelling / firmness of the compartment involved, response to passive movement if compartment syndrome suspected**

** Neurovascular status**

- **Pulses**
- **Warmth of periphery**
- **Paraesthesia**
- **Paralysis**

**INVESTIGATIONS**

**Bedside:**

**ECG:** Evidence of hyperkalaemia / arrhythmia

**VBG:** rapid pH status, electrolytes (K, Ca++), Hb, lactate

**Arterial Pressure Index (API) or Ankle Brachial Index (ABI):**

Performed when vascular injury is suspected in the absence of hard signs. The ratio of the systolic blood pressure in the injured extremity distal to the injury (ankle or forearm) to the systolic blood pressure in an uninjured extremity (usually the brachial artery)

\[
API = \frac{\text{Injured SBP}}{\text{Uninjured SBP}}
\]
Lower limb:
The dorsalis pedis or posterior tibial pulse is found with Doppler. A BP cuff is placed below the site of the injury and inflated to 20mmHg higher than the pressure at which the Doppler sound disappears. The cuff is released until the Doppler sound is clearly heard and the BP is recorded (SBP). The process is repeated on either the uninjured lower extremity or the brachial artery of an uninjured upper extremity.

Upper limb:
The same technique is used except that the two upper limbs are compared. Note, the cuff needs to be placed below the site of the wound on the injured limb.

A ratio of ≥ 0.9 is used to rule out the need for diagnostic imaging with a sensitivity and specificity as high as 95%. Patients with soft signs and an API ≥ 0.9 may be observed (although ultimately there will be a delayed operative rate of 1-4%).

Patients with soft signs and a ratio of < 0.9 require further investigation as the prevalence of vascular injury requiring surgery is 3-25% depending.

**Compartment Pressure Measurement:**

Commercial devices are available (Stryker STIC) device. A video of this device being used can be seen on LITFL.

Compartment pressure may also be measured by setting up a central venous or arterial pressure monitor and attaching it to a needle that is then inserted into the compartment that you want to measure. All compartments at the level of the injury should be measured.

**Laboratory:**

- CK – rhabdomyolysis
- Creatinine – renal insult secondary to hypoperfusion, rhabdomyolysis
- Electrolytes – K, calcium, uric acid, phosphate – Crush / Compartment Syndrome
- Haemoglobin (normal Hb does not exclude haemorrhage)
- Urine – myoglobinuria – marker of rhabdomyolysis
- G&H and CXM - transfusion

**Imaging:**

It is important that imaging does not delay transfer to theatre for life-threatening conditions.

**Plain films of extremities**

- Identifies fractures, skeletal deficits, foreign bodies, soft tissue defects, subcutaneous emphysema
- Amputation – x-ray stump and amputated appendage
**CTA**
- Up to 100% sensitive and specific in detecting all clinically significant arterial injuries
- Allow for interrogation of the vascular system as well as surrounding skeletal and soft tissue structures
- Standard teaching is that CTA should only be performed in patients who are haemodynamically stable to stratify injuries in patients with soft signs of vascular injury. At PAH, we may CT unstable patients in consultant with inpatient seniors

**MANAGEMENT**

Goals of management:

1. Integrated Trauma team approach
   - Initiate trauma activation system: ALERT or RESPOND depending on mechanism and physiological parameters. If RESPOND, notify Surgical Consultant as a part of the RESPOND
   - May need to notify orthopaedic and vascular teams depending on nature of the injury
   - Manage in a trauma resuscitation bay with comprehensive non-invasive monitoring

2. Address Life threatening injuries – CABC approach if massive external haemorrhage

3. Address limb threatening injuries
   - **Senior orthopaedic cover is required for mangled extremities / grade III open fractures**
   - **Senior vascular / ortho cover is required for arterial injuries**
   - **Senior orthopaedic cover is required for compartment syndrome**

4. Expedite definite care i.e. surgery as indicated

**Resuscitation**

**Circulation**

Immediate cessation of arterial bleeding is paramount. This may be achieved by:

- **Direct pressure** applied to the wound. This is best achieved using fingers (or a fist in a large wound) applied directly to the source of bleeding. Simply applying more bandages on top of an arterial bleed will disperse the pressure of the bandages and not stem bleeding. If there is active bleeding, take down the dressing and apply pressure directly.
- **Indirect pressure over the artery proximal** to the wound
- In smaller wounds, inserting a **Foley catheter** and inflating the balloon
- **Pressure bandage** over a “nugget” of gauze applied to the wound. This technique is well described in a blog in LITFL.\(^8\)
- **Tourniquet** applied proximal to the wound. Kragh et al\(^8,9\) demonstrated the survival benefit of tourniquets in the military environment, particularly when they were applied before the onset of shock (survival rate of 90% vs
10%); and where tourniquets were placed pre-hospital rather than in ED (11% mortality vs 24%). This study identified a complication rate of 1.7%, limited to transient nerve palsy. **Note the time of placement, and place the tourniquet as close to the wound as possible.** Tourniquets may be commercial brands (CAT), or blood pressure cuff / Biers Block cuff inflated above SBP (clamp BP cuff so that won’t leak).

**Airway & Breathing**

- Manage the airway and breathing along standard lines. Keep in mind that performing a RSI and mechanically ventilating patients in haemorrhagic shock is perilous. Consider delaying RSI if possible until the patient is in theatre with a surgeon present to control haemorrhage.

**Circulation**

- Identify and manage other causes of shock
- Pull fractured long bones to length and splint

Resuscitate patient with principles of **damage control resuscitation** if evidence of haemorrhage while expediting surgical control of bleeding.

- **Expedite surgical care to control haemorrhage**
- Activate Massive Transfusion Protocol where applicable
- Haemostatic Resuscitation - 1:1:1 red cells:FFP:platelets to correct acute coagulopathy of trauma / prevent development of coagulopathy
- Aim to restore radial pulse or SBP ~ 80
- Minimise crystalloid use – worsens acidosis
- Warm all fluids
- Consider Tranexamic Acid 1g bolus & 1g infusion over 8h if ≤ 3 hours of injury
- Minimise the period of permissive hypotension

**Specific therapy**

**Vascular Injury**

- Hard signs – surgical exploration
- Extravasation / pseudoaneurysm on CT may be amenable to Interventional Radiology rather than exploration in theatre\(^\text{5,6}\)
- Soft signs with CTA evidence of arterial injury – surgical exploration in theatre
- Soft signs with no CTA evidence of arterial injury and patients with no signs of vascular injury – manage wound(s) as required

**Open Fracture**

- Reduce fracture / dislocation(s)
- Splint and immobilise
- Minimise wound handling
  - Remove gross contamination
  - Cover with saline soaked dressing
  - If there is a delay to theatre, consider irrigating the wound
- Antibiotic therapy as outlined previously
- See previously for a review of indications for theatre and timing
Compartment Syndrome
- Remove all constrictive dressings and plasters
- Reduce the fracture if not already done. Expedite fasciotomy
- Elevate the limb to the level of the heart
- Crush injuries not going to theatre should be observed for ensuing compartment syndrome

Crush Syndrome
- IV fluids to target UO 1-2ml/kg/hr to correct hypoperfusion and to protect the kidneys
- Treat hyperkalaemia (calcium, sodium bicarbonate, insulin dextrose, haemodialysis if required) and monitor electrolytes and pH status
- Use of sodium bicarbonate to alkalinise the urine (theoretically limits uric acid crystallisation and the nephrotoxic effects of myoglobin) is controversial, as is the use of mannitol for forced diuresis, especially in the setting of trauma
- Treat other associated injuries

Traumatic Amputation
- Manage arterial haemorrhage as above
- See previous for indications / contra-indications for reimplantation
- Decontaminate and cover stump as for open fractures
- Irrigate amputated appendage, cover with saline soaked gauze, place in a thin plastic bag into an ice slurry
- Expedite surgical review
- Antibiotics as for open fracture above

Degloving Injury
- Reduce associated fracture
- Treat open degloving injuries as for open fracture above
- Expedite surgical review for open and closed degloving injuries

Supportive Care
- IV analgesia
- Regional anaesthesia
- Tetanus immunisation and Tetanus immunoglobulin (see table below)
- Keep NBM if awaiting surgical intervention
- IV fluid maintenance
- Antiemetics charted
- Keep warm
- Ensure normoglycaemia
- Ensure documentation completed
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From Therapeutic Guidelines, March 2013

**ADDITIONAL READING**

a. LITFL. Trauma! Extremity Arterial Haemorrhage (Chris Nickson, 2012)
b. LITFL Muscular Claustrophobia (Chris Nickson 2010)
c. LITFL Trauma! Extremity Injuries (Chris Nickson 2012)
d. LITFL Broken Open (Chris Nickson 2010)

**REFERENCES**