INTRODUCTION

This guideline has been formulated as an educational resource and means of standardising assessment and management of extremity vascular injuries in the Emergency Department.

BACKGROUND

Vascular injuries (particularly arterial injuries) are potentially limb and/or life-threatening injuries that can occur from both penetrating and blunt trauma. Vascular injuries are commonly associated with soft-tissue, skeletal and neurological injuries. They may be seen in isolation, or as a part of the multi-injured, often critically unwell, trauma patient.

Penetrating trauma resulting in vascular injury is increasing in frequency. The most commonly involved arteries are the brachial, femoral or popliteal arteries, with injuries to these vessels and their major branches accounting for up to 75% of all vascular injuries treated in civilian trauma centres. Whilst these vessels are most susceptible to injury, their location, narrow diameter, and inherent compressibility result in an overall low mortality rate. The exception to this are injuries to the axillary artery and the proximal femoral artery as it disappears under the inguinal ligament. These vessels are potentially non-compressible and injury usually requires immediate surgical intervention.

KEY PRINCIPLES

- Vascular Injuries (VI) can be both limb and life-threatening. They can result from both blunt and penetrating trauma. They are encountered on a spectrum from isolated limb injury through to the extremity vascular injury in a critically-injured multi-trauma patient.

- Assessment and management of major extremity vascular injury must occur in the context of assessing and managing the whole patient. Life-threatening injuries (which should be identified as part of the primary survey) always take priority over limb-threatening injuries.

- Specific assessment of vascular injury requires knowledge of, and assessment for ‘hard’ and ‘soft’ clinical signs of vascular injury. This clinical assessment differentiates between patients that require exploration in theatres and those appropriate for use of investigation strategies such as CT Angiography.

- Tourniquets are a potentially useful adjunct for haemorrhage control in patients with an arterial injury. Where a tourniquet has been placed pre-hospital, on arrival to the Emergency Department it must be assessed for its effectiveness and the existence of an ongoing indication for use of the tourniquet. Alternative haemorrhage control techniques should be considered with the goal of removing the tourniquet at the earliest appropriate opportunity. Alternative haemorrhage control techniques include;
  - Direct pressure to the bleeding vessel
  - Indirect pressure applied to the proximal artery
  - Compression bandage with limb elevation

- Indications for Emergency Department application of a tourniquet are:
  - In multi-trauma patient with active arterial bleeding in the context of other life threats that take priority
  - In haemodynamically unstable patients with peripheral arterial injury and ongoing haemorrhage requiring rapid control while resuscitation occurs
  - Where alternative haemorrhage control techniques have been ineffective
• Temporarily whilst assessing a site of haemorrhage to provide a bloodless field

• Timely involvement of appropriate in-patient teams is essential. In general, at Princess Alexandra Hospital, inpatient team allocation is as follows:
  o Upper limb arterial injuries distal to the anterior cubital fossa (ACF): Orthopaedics (or Plastics if they are on call)
  o Upper limb arterial injuries including and above the ACF: Vascular and Orthopaedics, particularly if there is associated soft tissue / skeletal injury requiring orthopaedic intervention
  o Lower limb arterial injuries: Vascular and orthopaedics, if there is associated soft tissue / skeletal injury requiring orthopaedic intervention

ASSESSMENT OF EXTREMITY VASCULAR INJURY

HANDBACK:
The key aspects of handover for patients with extremity vascular injury include:
  • Mechanism (e.g. blunt vs penetrating). The mechanism is an important aid when trying to determine possible patterns of injury.
  • Presence of other life threats (airway, breathing, circulatory impairment) and GCS
  • Evidence of major external haemorrhage including how much blood was lost on scene / ongoing bleeding
  • Location and type of wound (e.g. fracture, dislocation, degloving, amputation, mangled extremity)
  • If a tourniquet has been placed pre-hospital note the following:
    o Tourniquet time
    o Indications
    o Adequacy of tourniquet in preventing active haemorrhage in amputated limbs and active haemorrhage and no pulse in non-amputated limbs
    o Use and effectiveness of other haemorrhage control techniques prior to tourniquet placement
  • Management initiated in the field-to-date

EXAMINATION:
In the setting of an extremity injury with major haemorrhage, the traditional ABC approach of assessment and management should be modified to CABC with the initial C being haemorrhage Control. Mangled extremities, degloving injuries and amputations are visually distracting injuries that can potentially draw attention away from the primary survey.

Based on physical examination findings arterial injury can be separated into:
  • Hard signs: These require immediate involvement of appropriate in-patient team and generally require immediate transfer to theatre
  • Soft signs: Requiring further investigation, usually via CT Angiography.

Where patients have no signs, the need for further investigation is not supported by the medical literature.

### Clinical Signs of Arterial Injury

#### Hard Signs:
- External or pulsatile haemorrhage
- Rapidly expanding or pulsatile haematoma
- Palpable thrill / audible bruit
- Ischaemic limb (absent pulses, pallor, paraesthesia, pain, paralysis, poikilothermia)

#### Soft Signs:
- History of arterial bleeding at the scene / in transit, now ceased
- Proximity of penetrating wound / blunt injury to an artery
- Small non-pulsatile and non-expanding haematoma over an artery
- Neurologic deficit originating in a nerve adjacent to a named artery
- Reduced pulses (compared to the contralateral limb)
- Mechanism (posterior dislocation of knee, anterior dislocation of elbow)
- Ankle Brachial Index (ABI) or Arterial Pressure Index (API) ≤ 0.9
Irrespective of the nature of the injury, the general examination of the extremities includes:

**Inspection**
- Type of wound: Penetrating vs blunt
- 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)
- Active bleeding: Visible bleeding or presence of an expanding haematoma
- 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
- Amputation: Site(s), condition of skin, soft tissue and bone of stump and amputated appendage
- Mangled extremity
- Degloving injury

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

**Neurovascular status**
- Pulses (compare to uninjured limb where possible)
- Warmth of periphery
- Paraesthesia
- Paralysis

**MANAGEMENT OF VASCULAR INJURY**

Initial management of Extremity Vascular injury includes use of the following haemorrhage control techniques:
- **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, consider inserting a **Foley catheter** and inflating the balloon
- **Pressure bandage** over a “nugget” of gauze applied to the wound
- **Pneumatic Tourniquet** (Image 1)

**USE OF TOURNIQUET FOR HAEMORRHAGE CONTROL:**

1. **EMERGENCY DEPARTMENT PLACEMENT**

**INDICATIONS**
Indications for application of a tourniquet in the Emergency Department are:
- Where alternative haemorrhage control techniques have been ineffective
- In haemodynamically unstable patients with peripheral arterial injury and ongoing haemorrhage requiring rapid control while resuscitation occurs
- In multi-trauma patient with active arterial bleeding in the context of other life threats that take priority

These patients should have the tourniquet remain in place for review and definitive haemorrhage control in theatre.

**EQUIPMENT:**
A pneumatic tourniquet should be used. A Blood Pressure cuff should never be used due to high risk of failure. If no dedicated pneumatic cuff is available, then a Biers Block cuff can be utilised.
PROCEDURE FOR TOURNIQUET APPLICATION:
The tourniquet should be applied as follows:

1. Apply the tourniquet proximal to the wound directly to skin as close to the wound as feasible. Do not apply over the wound or over a joint. The tourniquet is applied as distal as possible to minimise potential tissue damage from ischaemia.
2. On the pneumatic tourniquet set a cuff pressure to 100 mmHg above the patient’s systolic blood pressure
3. Inflate the cuff
4. **Assess adequacy:** The tourniquet must prevent distal arterial flow to control arterial haemorrhage AND to prevent venous congestion which will contribute to ongoing blood loss and increased compartment pressure.
   a. For *amputated* limbs, ensure no active bleed and no soft tissue ooze.
   b. For *non-amputated* limbs, ensure no active bleeding and no distal pulse – this may require confirmation with doppler. There may be dark residual blood that continues to ooze from the wound along with ongoing medullary bone ooze.
5. Mark the location of the tourniquet on the skin and monitor for slippage. Do not cover the tourniquet or the limb involved – this impairs the ability to monitor tourniquet status and efficacy.
6. Record the time of application as well as the indication
7. Monitor the cuff pressure regularly for accidental deflation
8. Notify appropriate in-patient team of the application of a tourniquet.
9. **Analgesia:** A correctly applied tourniquet will be very painful for an awake patient. Parenteral analgesia will be required

Re-assess the ongoing need for tourniquet regularly.

2. **TOURNIQUETS PLACED IN THE PRE-HOSPITAL SETTING**

The flowchart for Guide to Removal of a Tourniquet can be found in Appendix A and should be referenced when assessing a tourniquet placed in the pre-hospital environment.

For patients with tourniquets placed pre-hospital, the following are important considerations:

- The tourniquet should not be removed if the patient remains haemodynamically unstable or has other life threats that are being addressed.
• The tourniquet should be assessed to ensure adequacy (see Assess adequacy above). If the tourniquet is ineffective, options to optimise include:
  o Tightening the existing tourniquet,
  o Replacing with an ED pneumatic tourniquet or,
  o Adding a second tourniquet adjacent to the pre-hospital tourniquet.
• A partially effective tourniquet should NOT be removed until there is an alternative effective haemorrhage control strategy in place.
• The ongoing need for a tourniquet should be reassessed

PROCEDURE FOR REMOVAL OF PRE-HOSPITAL TOURNIQUET:
The flowchart for Guide to Removal of a Tourniquet can be found in Appendix A and should be referenced when considering removing a tourniquet in the Emergency Department.

If the patient is haemodynamically stable without competing priorities then a graduated process to removal of the tourniquet can be initiated as per the flowchart.

The prerequisites for removal include:
• Pneumatic Tourniquet: Prior to releasing a field-placed tourniquet a pneumatic tourniquet should be placed above the injury
• Adequate lighting
• A compliant or sedated patient
• Equipment for Haemorrhage Control prepared: Examples of appropriate equipment include compression bandage(s), saline soaked gauze to apply to the wound, sutures and suture equipment, local anaesthetic with adrenaline
• Presence of appropriate in-patient team such that the wound(s) can be reviewed by relevant parties prior to placement of a compression bandage to prevent the need to repeat examination

If the wound actively bleeds again, haemorrhage control with alternative strategies can be attempted (eg. direct pressure, indirect pressure to the feeding artery, compression bandage and elevation). If these fail and / or the patient becomes unstable then inflate the pneumatic tourniquet to achieve control.

REPERFUSION INJURY:
On removal of a tourniquet you should monitor for signs of Reperfusion Injury. Reperfusion injury may occur if the tourniquet has been applied for 2 hours or more.

The implications of reperfusing an ischaemic limb include:
• Electrolyte disturbances: Hyperkalaemia, hypocalcaemia and potential for bradycardia followed by asystolic cardiac arrest
• 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

Prior to removal of the tourniquet ensure that the patient is in an appropriate resuscitation area and has appropriate intravenous access and cardiac monitoring. Consider preloading with calcium, bicarbonate and fluid. To minimise the risk associated with rapid reperfusion and washout of metabolites (particularly potassium), options to release the tourniquet that has been on for 2 hours or more include:
  a. Release the tourniquet gradually over several minutes, or
  b. Release the tourniquet for 30 seconds and then reapply for 3 minutes. Repeat for 3 cycles and then leave down.

COMPLICATIONS
The use of a tourniquet for an extended period of time is associated with the following complications:
• Limb ischaemia
• Muscle damage
• Nerve damage
• Compartment syndrome associated with ischaemia, oedema or venous congestion due to inadequate arterial compression and ongoing arterial flow
• Amputation

The risk of complications increases as the duration for which the tourniquet is left in place increases. 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.
IMAGING MODALITIES IN EXTREMITY VASCULAR INJURIES

Role of CT Angiogram:
Ct Angiograms are up to 100% sensitive and specific in detecting all clinically significant arterial injuries. They allow for interrogation of the vascular system as well as surrounding skeletal and soft tissue structures. However, they are not indicated in patients with hard signs of arterial injury unless the patient is haemodynamically stable, bleeding is controlled and the patient is requiring a CT to assess for additional injuries.

Tourniquets and CT Angiogram
The flow-chart in Appendix A should be referenced for guidance.

In general:
- Hemodynamically unstable patients: In most situations, unstable patients should not have the tourniquet released prior to CTA. Deviation from this plan should only occur at the discretion of senior decision makers (ED Consultant or Surgeon)
- Haemodynamically stable patients should have the tourniquet released as per the flowchart in Appendix A and undergo CTA with the tourniquet down if there is no active bleeding or where the bleeding has been controlled through alternative techniques

INVOLVING IN-PATIENT TEAMS

The trauma activation pathway (trauma alert or respond) should be utilised in patients with extremity vascular injuries. Arterial injuries are seldom isolated injuries.

The in-patient teams should be notified early. It is often appropriate to notify the appropriate in-patient team based on pre-hospital information, particularly if a tourniquet has been placed pre-hospital, there is active bleeding or the patient is haemodynamically unstable. This will allow in-patient teams early involvement in decision making and prevent the need for repeat examination of the wound.

In general, vascular surgery and orthopaedics are split as follows:
- Upper limb arterial injuries distal to the anterior cubital fossa (ACF) – Orthopaedics (or Plastics if they are on call)
- Upper limb arterial injuries including and above the ACF – Vascular and Orthopaedics particularly if there is associated soft tissue / skeletal injury requiring orthopaedic intervention
- Lower limb arterial injuries – Vascular and orthopaedics if there is associated soft tissue / skeletal injury requiring orthopaedic intervention

SPECIFIC INJURY MANAGEMENT GUIDELINE

The following vascular injury patterns are generally most appropriately managed as follows:
- Hard signs of Arterial Injury present: Surgical exploration in theatre
- Extravasation / pseudoaneurysm on CT: May be amenable to Interventional Radiology rather than exploration in theatre
- 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

REFERENCES
- Inaba K et al. Prospective Evaluation of Multidetector Computed Tomography for Extremity Vascular Trauma. J Trauma 2011; 70: 808-815