

PERIPHERAL VASCULAR INJURY

Injury to major arteries or veins is often life-threatening but invariably poses a threat to the viability of the affected limb. The extremities are the most common anatomic location of combat-associated trauma (50-75% of all combat injuries) & historically, because of rapid blood loss, injury to major vessels was often fatal in the field.

The aetiology of peripheral vascular injuries is divided into *blunt* & *penetrating* mechanisms.

Principles of Disease.

Blunt & penetrating types of trauma result in similar spectrum of vascular injuries, although the mechanisms differ. Blunt injuries (whilst less common), are more likely to result in amputation due to associated injuries to nerve, bone & soft tissue.

Penetrating Trauma.

Gunshot wounds.

- Result in the formation of a temporary cavity within distensible tissues with almost immediate recoil of these tissues.
- The size of the cavity & degree of soft tissue injury depend directly on the *velocity, tumble & yaw* of the bullet.
- Direct arterial laceration / transection
- Distant vessel injury --> intimal injury with subsequent thrombosis.

Stab wounds.

- Cause vascular injury by complete or partial transection of vessels.
- Partial laceration of arteries produce few immediate symptoms (often associated with delayed complications)
- The injuries can usually be predicted reliably from the anatomical location, depth & direction of the wound (as well as the implement used).

Shotgun wounds.

- Injuries vary from minor soft tissue wounds to massive destruction of soft tissue & bone (depend on the range from which it was fired).
- Multiple missiles (10 --> dozens) with many potential sites of vascular injury.
- Pellets can migrate proximally through the venous system (into heart or artery).

Blunt Trauma.

- Involves avulsion forces that can stretch vessels beyond their capacity, or crush the vessel wall.
- Fracture fragments can lacerate or entrap vessels.
- Injuries can range from *small intimal tears* to *complete avulsion* of arteries or nerves.

NB. skin is the final tissue to tear, therefore in avulsion injuries to limbs it is inevitable that vessels & nerves are torn too.

- Suspect vascular injury in massive soft tissue avulsion, crush injury, displaced long bone #s, electrical or lightning injuries & severe burns.
- Compartment syndromes in trauma, 'long-lies' & entrapment are all associated with vascular injury also.

Quick Pathogenesis:

Distal ischaemia results in anaerobic metabolism & accumulation of lactic acid. As ischaemia progresses, cellular integrity is lost and cell death occurs. Tissue injury leads to oedema which worsens and potentiates impairment of blood supply.

6 hours of complete warm ischaemia is generally considered the point at which irreversible nerve and muscle damage begins to occur. After 6 hours of warm ischaemia, 10% of patients will have irreversible damage; by 12 hours, 90% will have irreversible damage.

Two main types of vascular injury can result from trauma:

1. Occlusive injury
 - All effective perfusion distal to the occlusion is lost
2. Non-occlusive injury
 - Some arterial flow continue past the injury.

Complete Occlusive Injury.

Transection.

- The most common vascular injury.
- Distal flow is effectively eliminated.
- Cleanly transected arteries will often retract & undergo spasm (blood loss minimised).
- Longitudinal lacerations result in greater blood loss.

Thrombosis.

- Can occur in an acutely injured artery (within 24 hours), or may be delayed for many months.
- *Acute thrombosis* results from stasis from arterial compression or disruption of intima.
- *Delayed thrombosis* results from stricture formation & reduced blood flow distally.

Reversible Arterial Spasm.

- Cause & incidence in trauma is unknown.
- Results in *segmental narrowing of an artery*, producing distal ischaemia.
- Usually reverse with conservative management (warm saline, topical GTN), however occasionally needs infusions of GTN, CCBs, alpha-blockers, nitroprusside or prostaglandins.
- This should be a diagnosis of exclusion, and an injury should never be assumed to '*just be spasm*'.



Figure 45-1. Complete thrombosis of the distal brachial artery after reduction of a posterior elbow dislocation. (Courtesy of D. Demetreades, MD.)

Non-occlusive Injuries.

Intimal Flap.

- Occurs following breach of vessel intima (generally from excessive stretch or concussive forces).
- Intimal flap becomes a nidus for thrombosis which can occur hours to months after the initial injury.
- Most heal spontaneously.

Pseudoaneurysm.

- A true aneurysm contains *all three layers of the vessel wall*. [Intima, media, adventia].
- Pseudoaneurysm is formed following a tear in a vessel, where the haemorrhage was contained within the surrounding fascia & is then encased in a capsule of fibrous tissue.
- Thin walled; therefore rupture is possible.
- Expansion over time can lead to adjacent structure compression (esp. neuropathy).
- Embolisation of mural clots can lead to distal arterial occlusion.



Figure 45-2. Multiple small pseudoaneurysms of the axillary artery after penetrating injury. (Courtesy of D. Demetreades, MD.)

Arteriovenous Fistula.

- Formed when both an artery and adjacent vein are injured.
- Higher pressure arterial flow is directed into the lower pressure vein (thereby diverting blood away from distal tissues).
- Results in turbulent flow, a bruit & a palpable thrill.

Compartment Syndrome.

- Most commonly occurs after a crush injury or long bone fracture.
- Can be seen following reperfusion of an ischaemic limb.
- The original insult can be non-occlusive, however progressive oedema elevates tissue pressure above capillary pressure and ends arterial perfusion.
- Smaller calibre vessels are compressed first, therefore pulse may be palpated until late in the course.
- After restoration of arterial blood flow, a cascade of reperfusion injury results in release of oxygen free radicals, lipid peroxidation & influx of intracellular calcium.

Clinical Features.

Detection & treatment of vascular injuries must take place within the context of overall resuscitation. This includes the control of active bleeding. Many patients have no evidence of injury but are considered *at risk for vascular injury* because of penetrating wounds in close proximity to major neurovascular bundles or because they have sustained high-risk injuries such as posterior knee dislocation.

Peripheral vascular injury can be divided into three categories by physical examination: *hard findings*, *soft findings*, and *asymptomatic high-risk wounds* based on the mechanism of injury.

Hard Findings of Vascular Injury.

- Pulsatile bleeding
- Loss of distal pulses
- Audible bruit or palpable thrill (indicative of AVF)
- Expanding or pulsatile haematoma
- The 6 P's (overt distal ischaemia)

Incidence of arterial injury is > 90%
if any of these are present !!

Soft Findings of Vascular Injury.

- Palpable, but diminished pulse
- Isolated peripheral nerve injury (due to common proximity to vessels)
- History of severe haemorrhage in the field
- Unexplained hypotension
- Large, non-pulsatile haematoma
- ?delayed capillary refill (in combination with other signs).

Up to 35% of patients w/ 'soft' findings
have positive angiographic studies !!

High-Risk Injuries.

- Proximity of wound to a neurovascular bundle (< 1cm)
 - Includes axillary, brachial, common femoral & popliteal arteries.
- Bites from large dogs or other animals.
- Severely displaced fractures.
- Crush injuries.
- Major joint dislocations (especially knee).

History.

Appropriate for patients who achieve and maintain haemodynamic stability.

- Exact time & mechanism of injury
 - ?Mandatory reporting of injury
 - some mechanisms are more prone to complications (ie. crush or bite-wounds)
- Occupation, hand dominance.
- Comorbidities / Medications / ?immunosuppression

Physical Examination.

- Meticulous examination is requires looking for the above *hard & soft signs*.
 - *Relatively dependable* - Sn 92%, Sp 95%.
- Goals include discovering...:
 - Local wound complications & distal ischaemia
- Palpation of all peripheral pulses.
 - NB. distal pulses can occur in up to 42% of patients with significant arterial injury.
 - Assessment of overall perfusion (temperature, skin appearance etc).
- Comparison between *blood pressures* on injured & unaffected sides.
- *Two-point discrimination* on the injured & unaffected side.
- ?bruit

Diagnostic Strategies.

These must be tailored to the situation (ie. the obvious major arterial injury may require urgent emergency operative intervention without further workup).

Delaying definitive treatment of an obvious arterial injury that is approaching the *6-hour limit of warm ischaemia time* to obtain angiogram is ill advised.

Plain Radiography.

- Used to detect *fractures, joint penetration & foreign bodies*.
- Location of bullets (and correlation with number of wounds found clinically).

Pulse Oximetry.

- Simple, easy & non-invasive.
- Unfortunately, quite *insensitive*.

Hand-held Doppler.

- ?absence of a signal
- A change in signal from *triphasic* (to a biphasic or monophasic waveform, due to dampening) is more sensitive.

Ankle-Brachial Index / Arterial Pressure Index.

- Provides more information than just physical examination alone.
- Systolic pressure is measured using a manual cuff & hand-held Doppler.
 - Repeated on affected and uninjured limb.
- Can reduce the number of unnecessary angiograms.
- API of 0.90 - 0.99 = 12-24 hours of observation & repeated examination.
- Normal API & examination can be discharged home.
- Limited usefulness in
 - Deeper arteries (profunda femoris, profunda brachii) which do not produce palpable pulses.
 - Shot-gun wounds (due to multiple small arterial injuries).

A ratio of < 0.90

- Sn 95% & Sp 97%.
- PPV 100%
- NPV 95%

Ultrasound.

- Allows for direct visualisation of both arterial & venous flow.
 - Doppler or colour-flow. Duplex (combination of Doppler & B-Mode US)
 - Obstruction or thrombosis can also be seen on occasion.
- **Duplex:** Sn 83-100%, Sp 99-100%. Accuracy = 96-100%.
- **Colour-Flow:** Sn 50-90%, Sp 95-99%.

CT & MRI.

- CT-Angiography has largely replaced traditional catheter-based angiograms.
 - Sn 93-100%, Sp 87-100%.
- Non-invasive.
- Artifacts from bullets, orthopaedic hardware etc will degrade images and reduce sensitivity.
- Venous injuries often missed, depending on the phase of CT.

Arteriography.

- Its use dropped the negative exploration rate (from patients with 'soft' signs) down from 84% to just 2%.
- Sn 99%, Sp 97%.
- Approx 5% false-positive rate (?secondary to reversible vasospasm).
- Cannot exclude venous injuries.
- Whilst it may detect injuries in up to 21% of 'proximity' wounds, very few of these actually require surgical intervention.
- DSA increase accuracy (especially for extravasation) & requires administration of less contrast media.
- Can facilitate immediate repair of some lesions (embolisation of pseudoaneurysms, placement of endoluminal stents or thrombolytic injection).

Many centres now manage proximity wounds now with repeated examination and reserve CT-angiography for those with abnormal physical examination or an ABI < 0.90.

Treatment.

- As always, assessment of airway, cervical-spine and oxygenation/ventilation take precedence over circulation.
- Active haemorrhage is controlled by direct *digital pressure*.
 - Blind clamping is never indicated.
- Military literature suggests that tourniquet application for up to 6 hours is safe & effective.
- Insertion of a Foley-catheter into the wound (with inflation of balloon) can temporarily tamponade bleeding.
- Avoid IV line placement on the affected limb.
- Crossmatch and blood transfusion, as indicated by haemodynamic markers and haemoglobin.
 - "*Permissive-hypotension*" - aim for systolic BP ~ 90mmHg if the arterial injury is inaccessible for occlusion by direct pressure.

Major Vascular Injuries.

- Must be repaired within 6 hours to avoid irreversible ischaemic neuropathy & myonecrosis.
- Treatment decisions made by Trauma or Vascular Surgeons.
 - Endovascular stents (self-expanding), embolisation etc.
 - Open repair, following placement of temporary vascular shunt.
 - End-to-end reanastomosis for transections.
 - Saphenous vein grafts (for large defects)
- Broad-spectrum ABx use is recommended prior to all vascular repairs.

Late complications include thrombosis, claudication, chronic pain or oedema & aneurysm formation in the graft.

Venous injuries can be primarily ligated or definitively repaired (reduces risk of compartment syndrome, thrombosis & PE). Generally, vascular repair is prioritised over orthopaedic repair (usually with shunt insertion, during fracture repair).

Minor Vascular Injuries.

- Minor, non-occlusive injuries are being treated expectantly.
- Eg. associated with low-velocity missile wounds, intact distal circulation, no active haemorrhage and minimal disruption on angiography.
- Most of these injuries (85%) will resolve spontaneously.
- Almost all pseudoaneurysms will be repaired.

Specific Injuries.

Upper Extremity.

Subclavian Artery & Vein.

- Uncommon. Isolated venous injury is more common, than isolated arterial injury.
- Usually penetrating mechanism and result in massive haemorrhage.
- 77% of cases will present in haemorrhagic shock.
 - Can present as massive haemothorax.
- Limb ischaemia may be present.
 - APIs are inaccurate due to collateral flow from thyrocervical trunk.
- Neurological deficits are common due to proximity to brachial plexus.
- Immediate proximal or distal control of bleeding is very difficult.
- Blunt injuries are often associated with clavicular fractures or dislocations.
 - Isolated 1st rib #'s are rarely complicated by vascular injury.
 - However, 1st rib injuries are associated with other major injuries.
- Subclavian vein injuries are more lethal.
 - High rate of massive haemorrhage
 - High risk of massive air embolism.

Axillary Artery & Vein.

- Common. Vein runs medial to artery.
- Forceful reduction of dislocated shoulder is a common iatrogenic cause of axillary artery injury.
- Good collateral flow, and pulse is generally palpable.
- Significant denervation of the upper extremity can occur due to proximity of the brachial plexus.
- High rate of amputation in setting of combination of neurovascular injuries.

Brachial Artery.

- The most common major vascular injury of upper limb.
 - 75% will have absent radial pulse.
- Median & ulnar nerves + basilic vein are in close proximity.
- Profunda brachii is major branch and provides good collateral flow.
- Often injured with penetrating trauma, humeral shaft #, elbow dislocation or animal bites.

Forearm Arteries.

- Usually repair is not indicated (distal to ulnar-radial bifurcation) unless there is evidence of ischaemia of the hand, expanding haematoma, AVF or pseudoaneurysm (OR) if both arteries are injured.
- Compartment syndrome to forearm is common.

Lower Extremity.

Iliac Artery & Vein.

- Virtually all these injuries have associated trauma to bowel, bladder, solid viscera or bony pelvis.
- “Damage control” laparotomy with temporary shunting may be required in moribund patients.

Femoral Artery & Vein.

- There are extensive proximal collateral arteries around the hip joint.
- Very commonly seen, mostly resulting from penetrating injuries.
- Ligation of common femoral artery = 80% amputation rate.
 - Repair should be attempted in all cases.

Popliteal Artery & Vein.

- The most common cause of arterial injury is a *posterior knee dislocation*.
 - 25-33% of cases
 - Results from direct laceration of artery, or resulting thrombosis.
 - Up to 40% can be occult in presentation
 - Commonly associated with injury to either *peroneal or posterior tibial nerves*.
- Also common in pedestrian vs car mechanism.
- Debilitating injury (~66% = persistent deficits).
- Diagnostic approach remains controversial.
 - Routine angiography
 - Selected angiography (w/ +ve physical signs, abnormal ABI or abnormal US, CT or Duplex).
 - Reliance only on examination & ABI.
 - If both are normal = 100% negative predictive value.
- Penetrating trauma & 1 hard-sign = operating theatre.

Lower Leg Arteries.

- Anterior & posterior tibials + Peroneal arteries.
- Injuries below the trifurcation may need repair if there is evidence of hard signs or if two of the three vessels are occluded on angiography.
- Notorious for causing compartment syndrome.
- Amputation is common with combination of orthopaedic & vascular trauma, especially with a crush injury.

Disposition.

Patients with *confirmed injury to major vessels, equivocal findings on diagnostic tests or symptoms from limb ischaemia* must be admitted for further investigation or observation.

Vascular surgical consultation is indicated as soon as injury is suspected.

Do not delay transfers to definitive care for angiography or other tests.