

ARTERIAL INJURY (LIMB)



Confederate General Albert Sidney Johnston, (1803 - 1862)

"I realized our strongest pillar had been broken" - Jefferson Davis

.....In a peach orchid, the Federals lay flat beneath the blossoming trees, firing as the rebels came, soft pink petals raining down on the living and the dead. By late morning, thousands of untried Federal troops had seen enough. Most did not stop running until they reached the river, where almost 5,000 men cowered beneath the bluff. "We are sweeping the field", General Johnston told his second in command, Beauregard, "And I think we shall press them to the river" Grant's back was to the Tennessee. There was no sign of Buell and nowhere else to go, but a thin federal line held in the center, Illinois and Iowa farm boys mostly, prone along a sunken road. Their commander Benjamin Prentiss, understood the deadly seriousness of Grant's order to "Maintain that position at all costs". The Confederates launched a dozen massive assaults against what became known as the "Hornet's Nest". Albert Sidney Johnston himself led the last charge.

He came out of it with bits of his clothing nicked all up. One boot sole was shot in half and he flapped this on horseback there, and said, "They didn't trip me up that time!" And very soon after that, they saw him reel in the saddle and realized he was hurt, and someone said, "General are you wounded?" And he said "Yes, and I fear seriously" and he was shot behind the knee, in the femoral artery I suppose, and bled to death. They saw blood pouring out of his boot. He could have easily been saved with a tourniquet, but he had sent his surgeon off to take care of some federal prisoners. (Shelby Foote, Civil War Historian)

"Advancing a little further, we saw General Albert Sidney Johnston surrounded by his staff. We saw some little commotion among those who surrounded him, but we did not know at the time that he was dead. That fact was kept from the troops" (Sam Watkins, Confederate Private).

The command of the Western Army now passed to General Beauregard

Albert Sidney Johnston was looked on by many people at the time of Shiloh, and especially before Shiloh while he was holding that line up in Kentucky, as the South's number one field soldier. Jefferson Davis viewed him as that, and when he lost Albert Sidney Johnston, he said "I realized our strongest pillar had been broken" (Shelby Foote, Civil War Historian)

David McCullough and Shelby Foote in Ken Burns', "The Civil War", 1990.

One of the most intriguing exercises in the historian's oeuvre is to consider the great "what ifs" of critical junctures of history.

The Battle of Shiloh was the first big battle of the American Civil War. The Confederate general Albert Sidney Johnston had Ulysses S. Grant, on the ropes. Then a minié ball, hit him in the knee and exploded his popliteal artery. These monstrous bullets caused enormous tissue loss - blood positively hosed out of his boot, it was said, while his subordinates simply stood around gawking and did nothing - other than frantically sending for the help of Johnston's personal physician - who was off tending to Union wounded at the time! Albert Sidney Johnston died within 30 minutes at a critical stage of the battle. After that, confusion and uncertainty reigned within Confederate ranks. Grant grimly held on with his back to the Tennessee River until General Buell arrived the next day to rescue him, and then by sheer force of numbers he was able to swing the tide of battle. Ulysses S. Grant was the only Union

general of the American Civil war who could really match it with Robert E. Lee. Grant would eventually defeat Lee 4 years later to finally the end the terrible bloodshed. If Albert Sidney Johnston had not been killed at Shiloh at a most critical juncture, it is conceivable that he could have won and that in consequence, Grant may never have had the chance to do battle with Lee.

Could a simple tourniquet, applied at the battle of Shiloh, have ultimately led to a Confederate Victory in the American Civil War?



The sunken road through the Hornet's Nest, (Photograph, taken a few years after the end of the Civil War).

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This penetrating wound to the femoral triangle must be considered to have involved the femoral vessels and/ or nerve, until proven otherwise. The presence of pedal pulses, does not necessarily rule out an injury to the artery. Wound exploration and possibly imaging if doubt still remains will be required in this case.

Introduction

Arterial injury in a limb may be **revealed** or **concealed**

A variety of injury patterns may be seen.

Patients with traumatic limb amputation are at especially high risk of life-threatening haemorrhage.

The first priority in exsanguinating arterial haemorrhage will be control of the bleeding, via either direct compression or in more serious cases by arterial tourniquet or arterial clamping.

Arterial tourniquets are simple, portable, easy to apply, potentially life-saving devices

This is followed by fluid resuscitation, and blood product administration where required and then if required definitive surgical repair.

Vascular compromise may be delayed when there has been an arterial injury. The injury may for example result in delayed thrombosis or embolization of clot.

Skeletal muscle does not tolerate the absence of arterial blood flow for much longer than **6 hours**. Tissue necrosis will occur after this time frame.

See also separate documents on:

- **Haemorrhagic shock (in Trauma folder)**
- **Amputation (in Trauma folder)**
- **Wound packing (in Trauma folder)**
- **Arterial pressure index (in Trauma folder)**

Pathology

Arterial injury can be due to

1. Blunt injury
 - Revealed
 - Concealed
2. Penetrating injury
 - Revealed
 - Concealed

Transection of an artery is usually obvious on inspection, however in penetrating trauma (and blunt trauma to a lesser degree) there can be significant arterial damage that may be concealed from direct observation.

Injury *patterns* can include:

1. Transection:
 - Total
 - Partial
2. Dissection
3. A-V fistula
4. Thrombosis

5. False aneurysm
6. Spasm

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Clinical Assessment

Important points of history:

1. Estimated amount of blood loss
2. Time of injury
3. Treatment given before arrival to hospital
4. Type of implement used to inflict the injury.
5. Circumstances of injury:
 - For example, assault, accidental, self-inflicted.

Important points of examination:

1. Assess the circulatory status of the patient:
 - Are signs of circulatory shock present?
2. Assess the distal limb circulation:
 - Check the **peripheral pulses** and **perfusion status** of the limb.
 - ♥ **Direct evidence** of arterial injury is demonstrated by active pulsatile hemorrhage.

Compromised peripheral circulation is *suggested* by:

- ♥ Absent or reduced pulses, (a late sign).

Note however that the presence of a peripheral pulse does not necessarily rule out an arterial injury.

- ♥ Pale/ cyanosed periphery

- ♥ Cool periphery
- ♥ Reduced capillary return, (> 2 seconds).
- ♥ Pain (secondary to ischaemia)
- ♥ Loss of sensation in a glove or stocking distribution, (this can be an *early* sign of vascular impairment).
- ♥ A pulsatile or expanding hematoma:
 - ♥♥ A rapidly expanding hematoma, suggests a significant vascular injury. Note that major haemorrhaging may be concealed by bleeding into the soft tissues.

Note the characteristics of the pulse:

- Its **presence** or **absence**.
- Its **quality**, (strong versus “thready” or weak).
- Its **symmetry**, (i.e. compared to its opposite uninjured limb).
- The presence of a **bruit** on auscultation (and possibly a palpable thrill) may occasionally indicate an arterial injury.

Checking the peripheral circulation should be a *dynamic* process, as a change in the presence or even character of the pulse is an important sign.

A lost or reduced pulse with normal capillary return (< 2 seconds), indicates a viable extremity, but does not rule out the possibility of a significant arterial injury.

Lost pulses and no capillary refill indicates severe ischemia and a surgical emergency.

Penetrating wounds that are located near major neurovascular bundles, as shown above, must in particular be viewed with a high index of suspicion for a neurovascular injury.

3. Arterial pressure index (API):

- Also known as DPI (Doppler Pressure Index) or Arterial Brachial Index or Ankle - Brachial Index (ABI) - despite the last name, the procedure can be performed for upper extremity or lower limb injuries

This may be helpful in raising or lowering the index of suspicion for an arterial injury in less certain situations.

See separate document, Arterial pressure index (in Trauma folder).

4. Assess the wound:

Open wounds, (especially penetrating) and fractures in the *vicinity* of a major artery should always raise suspicion for an arterial injury.

A temporary **arterial** tourniquet may be required to control bleeding and allow adequate examination of the wound.

Arterial versus venous bleeding:

- **Arterial bleeding will be bright and pulsatile, whilst venous bleeding is relatively dark and non-pulsatile.**

Investigations

The degree of investigation necessary will depend on how unwell the patient is and the exact nature of the arterial injury.

The following may be required:

Blood tests:

1. FBE
2. U&Es/ glucose
3. Blood group and cross-match / massive transfusion protocol, as clinically indicated

Plain radiography:

To further assess a wound for associated bony injury or foreign bodies.

Vascular Imaging:

The presence of a peripheral pulse does not rule out the possibility of a significant arterial injury.

If clinical suspicion is high, eg penetrating injury near a major neurovascular bundle, then imaging investigations may be warranted to rule out more subtle arterial injury.

Imaging investigations should only occur once the patient has stabilized with fluid resuscitation and control of ongoing hemorrhaging - otherwise there should be urgent operative intervention.

Imaging investigations may include:

Doppler examination:

- A Doppler ultrasound device may assist in detection and quality of the peripheral pulses, especially when systemic hypotension makes palpation of peripheral pulses difficult.

CT angiograms:

- This is the best imaging modality to assess an arterial injury.

Catheter arteriography:

- Is the gold standard, but not usually required, due to the widespread availability of CT angiography.

Management

1. Control of hemorrhage:

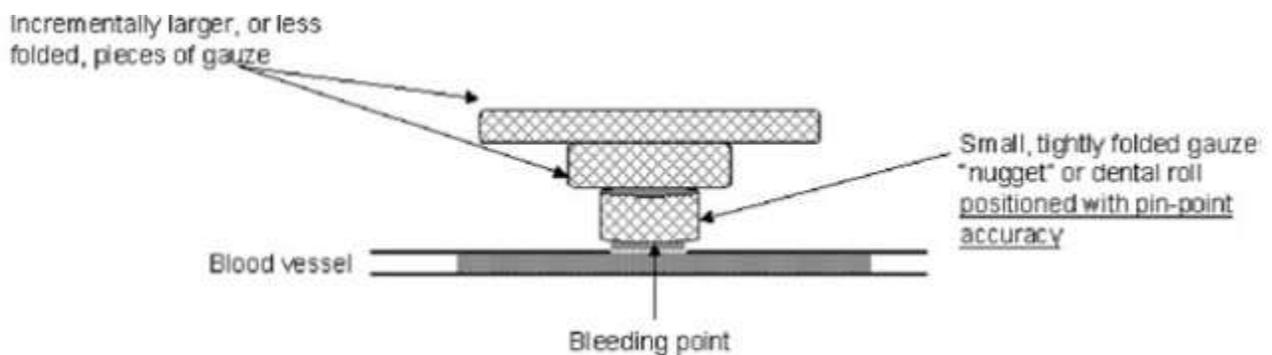
Options include:

Direct compression:

- **Direct compression** is the preferred method of initial control of more **minor** arterial bleeding.

This should primarily be with sterile saline moistened combines **compressed directly** over the wound with firmly bound crepe bandages.

One useful technique is the Shokrollahi or “**inverted pyramid**” series of cushions method, whereby a small tightly folded nugget of gauze is placed over the injury. then over this is placed a series of several larger less folded pieces of gauze. The whole is then secured with a loose crepe bandage. Relatively lighter pressure then needs be applied to the top layer of gauze to maintain haemostasis, as the pressure is “focused” down onto the bleeding point, due to the physics principle of **Pressure = Force/Area**.²



Inverted pyramid series of cushions (from Shokrollahi et al).

Wound Packing:

- Wound packing is especially useful in regions of the body that are not amenable to control with a tourniquet such as:
 - ♥ The neck, (obviously not with circumferential bandaging, however!)
 - ♥ The upper arm/ shoulder
 - ♥ The upper leg / groin

It may be used as an alternative to a tourniquet (provided good control is achieved)

It may be used as an adjunctive measure to a tourniquet.

See also separate document on wound packing (in Surgery Trauma folder).

Proximal Arterial Pressure:

- If direct pressure over the wound fails to control bleeding, then more proximal manual pressure to the artery should be applied - failing this an arterial tourniquet should be used.

Arterial tourniquet:

- **Arterial tourniquets** must be used for initial control of severe bleeding and to allow for initial wound assessment

Arterial tourniquets can be life-saving.

Dedicated arterial tourniquets devices are available, (see **Appendix 1 below**)

Alternatively:

A **blood pressure cuff** may be used in the absence of a dedicated device.

A **Biers device** is better than a normal blood pressure cuff (although a normal blood pressure cuff is still better than no cuff at all) as it is able to go to 100 mmHg above arterial pressures without “bursting” off the patient’s arm - these higher pressures are needed to *completely* stop blood flow to the limb.

Pneumatic tourniquets may require pressures as high as:

- 250 mmHg for an upper extremity
- 400 mmHg for a lower extremity.

Note that tourniquets must **occlude arterial inflow** as simply occluding the venous system may increase the degree of hemorrhage. The “end point” of **arterial tourniquet application** is **cessation of bleeding** and loss of **arterial pulse**.

Arterial tourniquets can be left on for several hours. At around 6 hours however, the limb will be at risk of ischaemic injury.

If an arterial tourniquet is required to be left on for a *prolonged* period in the “field” it is recognized that a choice of life over limb has been made.

Arterial vessel clamping:

- If **large bleeding artery** can be easily identified, then clamping is an acceptable treatment

2. IV fluid and blood product resuscitation:

- IV access should be obtained and IV fluid resuscitation (in general not more than around 2 litres in adults) should commence immediately, and **blood products** given as required.

Massive transfusion protocols may need to be activated in severe exsanguinating cases.

3. Elevation:

- Simple elevation will also assist in the ongoing management of arterial bleeding.
- In severe cases, once bleeding is controlled, the limb may be elevated in a sling attached to an IV pole, whilst the patient awaits further surgical assessment.

4. Analgesia:

- Give analgesia as clinically indicated.

5. Haemorrhaging associated with bony fractures:

- Femoral fractures and open long bone fractures in general are sources of potentially significant blood loss.
- Reduction and splinting of fractures can significantly decrease bleeding by reducing motion and assisting the tamponade effects of adjacent muscle and fascia.
- If the fracture is open a direct pressure should be applied with a sterile dressing.

6. Antibiotics:

- If there is obvious wound contamination, then IV antibiotics should be commenced.
- Antibiotics must also be given for any **open fractures**.

Delay of antibiotic administration > 3 hours is associated with increasing risk of infection. ¹

First generation cephalosporins, such as **cefazolin** are given to cover gram positive organisms.

Clindamycin is an alternative for those with severe beta-lactam allergy.

For more severe injuries, especially contaminated ones, there should be wider gram negative cover. an **aminoglycoside** can be *added* or **Tazocin** can be given in these cases

7. Tetanus Immunoprophylaxis:

- Give tetanus immunoprophylaxis, as clinically indicated.

8. Surgical repair:

- Early vascular surgical consultation should occur for all significant cases of arterial damage or suspected cases of arterial damage.

There should be no or minimal delay to definitive surgical control of haemorrhaging.

Surgical Options include:

- Direct repair:
 - ♥ Sutures / patch angioplasty / interposition graft or vein patches.
- Ligation:
 - ♥ Only for small, distal and redundant arteries.
- Damage control surgery:
 - ♥ This may involve using intravascular shunts to allow immediate restoration of distal blood flow, with later definitive repair once the patient has been resuscitated and normal physiology has resumed.

Disposition

Penetrating injuries near a major neurovascular bundle should always be referred for surgical opinion/ exploration.

Urgent referral to Surgical Units is essential

Appendix 1



Example of an arterial tourniquet device; CAT Tourniquet (Combat Application Tourniquet)



Examples of CAT tourniquets applied to severely injured lower and upper limbs. (Clinical Photographs, courtesy, Dr Arun Ilancheran).

References

1. ATLS 10th ed. 2017.
2. Kayvam Shokrollahi, a technique for temporary control of hemorrhage. The Journal of Emergency Medicine, Vol. 34, No. 3, pp. 319 - 320, 2008.
3. TACMED Australia:
 - <https://tacmedaustralia.com.au/>

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