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# Diagnosis and management of arterial injuries associated with limb fracture or dislocation

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## Abstract

An arterial injury is a time-critical emergency and, when associated with a fracture or dislocation, its management requires joint specialist input from orthopaedic and vascular or plastic surgeons. Initial management involves haemorrhage control and stabilisation of the patient, reduction and splinting of the limb and careful reassessment. With ongoing vascular compromise, urgent surgery is indicated to restore arterial flow and stabilise the skeleton, and this should be performed at a centre with appropriate expertise. This article provides an evidence-based review of the British Orthopaedic Association Standards for Trauma for the diagnosis and management of arterial injuries associated with extremity fractures and dislocations.

Key words: Arterial injury; BOAST guideline; Orthopaedics; Trauma; Vascular

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## Introduction

Arterial injury associated with a fracture or dislocation can be limb- or life-threatening, and delay in detecting such injuries is associated with considerable morbidity. If arterial continuity is not restored promptly, outcomes can range from loss of the limb distal to the point of injury, through to systemic complications of tissue necrosis and death.

Only 1–2% of all injuries reported in trauma patients involve vascular injury, but these patients account for over 20% of all trauma-related deaths (Huber and Manna, 2021). The majority of blunt limb injuries with arterial compromise occur as a result of motor vehicle accidents (as much as 93% in one study; Shakeri et al, 2006), and when compared to penetrating trauma, patients with vascular injuries secondary to blunt trauma are often more severely injured (Perkins et al, 2012). Vascular compromise is more common with certain types of injury, such as open tibial fractures.

The British Orthopaedic Association's Standards for Trauma (2021) offer specific guidance for the management of arterial injuries associated with extremity fractures and dislocations, to help reduce morbidity and mortality in this group of patients. These guidelines serve as an evidence-based national standard against which all centres should develop their practices in preparation for these injuries when they present (British Orthopaedic Association, 2021). This article discusses these standards with a focus on the evidence.

## Initial management

Bleeding from any source can lead to haemodynamic compromise, and the patient should be assessed and resuscitated in accordance with Advanced Trauma Life Support principles. Initial neurovascular examination should comprise careful assessment of neurological status (movement and sensation) and vascular status (see below) distal to the injury, and documentation of the findings. For external haemorrhage, direct pressure should initially be applied for at least 5 minutes and the limb re-examined. Particularly in the pre-hospital setting, compressive bandaging may be useful, and haemostatic products can be applied topically to the wound (Geeraedts et al, 2009). Embedded foreign bodies should not be removed in the first instance, and blind clamping should be avoided as this can exacerbate soft tissue trauma. As a last resort, an arterial tourniquet may be applied, with judicious documentation and handover of the time of application (Geeraedts et al, 2009). Fractures and

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dislocations should undergo reduction and realignment with splinting as soon as possible, followed by repeat neurovascular examination and documentation (British Orthopaedic Association's Standards for Trauma, 2021). Assessment for compartment syndrome is also mandatory and should be managed concurrently according to established guidelines.

The classic signs of an acutely ischaemic limb are 'the 6 Ps' (pain, pallor, pulselessness, paraesthesia, paralysis and poikilothermia), although these are not always present, especially in the context of trauma. Signs of traumatic vascular injury have been described as 'hard' and 'soft' signs (Table 1) (Redmond et al, 2008; Monazzam et al, 2017), and the key aspects of clinical examination include evaluation of pulses (Figure 1), skin warmth and colour, and capillary refill time. Diminished or absent pulses are strongly associated with vascular injury (Monazzam et al, 2017), whereas capillary refill time can be unreliable as it is subjective, and pooling of blood may give the false impression of normal capillary refill time, and should not be relied on as a means of excluding vascular injury (National Institute for Health and Care Excellence, 2017). Furthermore, skin colour may be difficult to interpret in patients with dark skin or dermatological disease. The presence of clinical signs of vascular injury require intervention and/or further investigation (see below).

It may be necessary to arrange patient transfer to a centre with appropriate facilities and expertise (for example, to ensure the availability of surgeons skilled in performing vascular or microvascular repair, which may be vascular or plastic surgeons depending on

**Table 1. Hard and soft signs of vascular injury**

| | |
|---|---|
| Hard signs | Absent distal pulse |
| | Pulsatile haemorrhage |
| | Expanding haematoma |
| | Palpable thrill |
| | Audible bruit |
| Soft signs | Non-pulsatile haematoma |
| | Asymmetry of colour |
| | Asymmetry of temperature |
| | High risk injury pattern or a wound near an artery |
| | Peripheral nerve deficit |

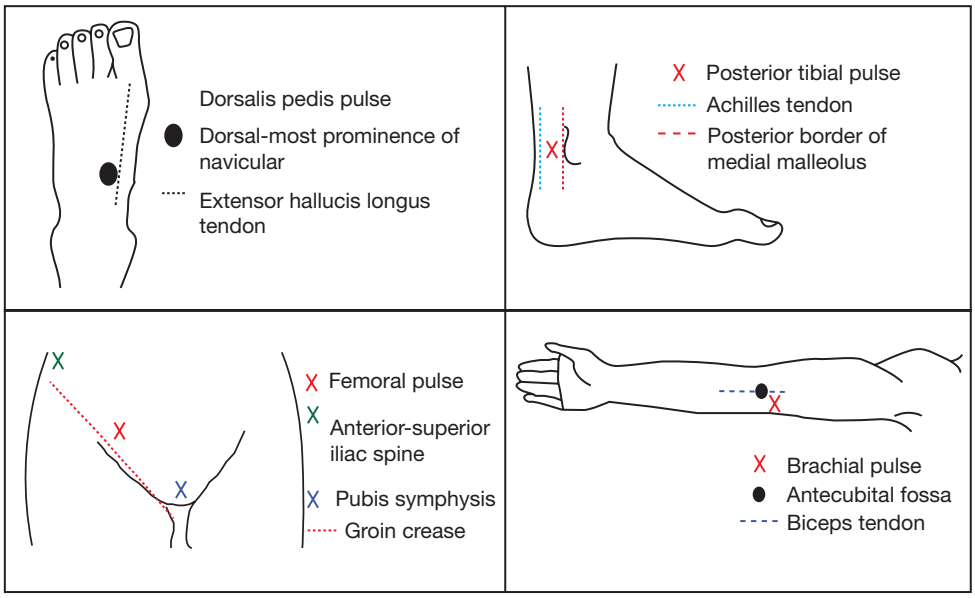


**Figure 1.** Pulse locations.

local arrangements), and all emergency departments should have clear referral and transfer protocols. Centres providing definitive care must have a standard management algorithm for these injuries and early decision making must be undertaken in collaboration between consultant orthopaedic and vascular or plastic surgeons, as this results in better outcomes (Leclerc et al, 2018). In the case of any disagreement, further senior clinicians must be involved (British Orthopaedic Association, 2021). Initial management is summarised in Figure 2.

## Investigations

Available vascular investigations include duplex ultrasonography, arterial pressure index measurement, arteriography and computed tomography angiography.

- Duplex ultrasonography can be performed at the bedside and has a high sensitivity and specificity for identifying arterial disruption, although it is very user-dependent (Fry et al, 1993)
- Arterial pressure index is calculated by measuring the systolic blood pressure in the injured limb distal to the site of injury, and dividing it by the systolic blood pressure in an uninjured limb. A measurement of <0.9 can indicate arterial injury (Johansen et al, 1991). This method may not identify deep arterial injuries (eg profunda femoris), or

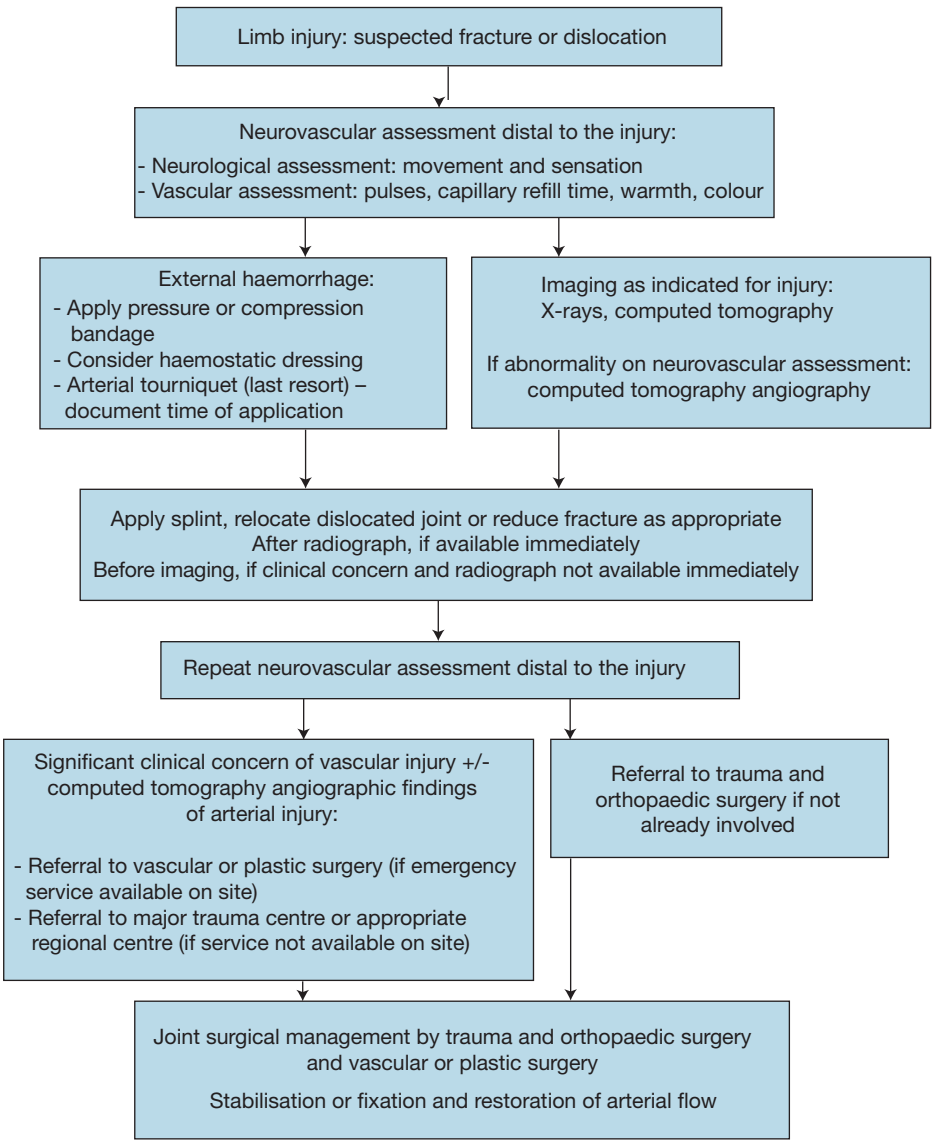


**Figure 2.** Management of fracture or dislocation with suspected arterial injury.

lesions which do not reduce blood flow (eg minor intimal tear), and cuff placement may be impractical for the injured limb
- Arteriography allows visual assessment of arterial injury, but it is associated with risks including puncture site complications, haematoma formation and thrombosis (Redmond et al, 2008), and requires additional skills for arterial cannulation
- In practice, the above modalities are now rarely performed as they have been superseded by computed tomography angiography.

Computed tomography angiography is the gold standard diagnostic technique used in the emergency setting to evaluate a potential vascular injury. It is less invasive than arteriography and remains highly accurate, with studies reporting 100% sensitivity and specificity for detecting clinically significant arterial injuries (Busquéts et al, 2004). British Orthopaedic Association Standards for Trauma (2021) recommend that the major trauma patient undergoing a computed tomography scan should have a head-to-toe scanogram, and in patients where clinical assessment has identified a vascular deficit, computed tomography angiography of the affected limb should proceed immediately afterwards, without repositioning. Computed tomography angiography involves rapid intravenous injection of contrast followed by a computed tomography scan. Potential signs of arterial injury include contrast extravasation, widening, narrowing or loss of opacification of an arterial segment, pseudoaneurysm formation, or arteriovenous fistula formation (Figure 3) (Miller-Thomas et al, 2005; O'Malley et al, 2019). A low threshold for performing investigation for these is encouraged, particularly in patients who have high energy injuries, and it also helps with planning for vascular and soft tissue reconstruction (O'Malley et al, 2019).

Blood tests including full blood count, urea and electrolytes, coagulation screen and blood group form part of the routine assessment for these patients in the emergency department. Fibrinogen levels are routinely measured and predict contrast extravasation on computed tomography angiography (Notani et al, 2021). Many centres now measure real-time coagulation parameters, such as rotational thromboelastometry or thromboelastography, to guide transfusion (Brill et al, 2021).

## Revascularisation and skeletal stabilisation

The time from injury to reperfusion ('ischaemic time') is critical in determining the outcome (Hossny, 2004). A systematic review demonstrated that limb salvage rates in patients with an ischaemic time of less than 6 hours were 87%, compared to 61% when it exceeded 6 hours (Glass et al, 2009). While 6 hours has historically been used as the cut-off for warm ischaemic time of the limb, significant necrosis of soft tissue may occur earlier (Forrest et al, 1989), and the British Orthopaedic Association Standards for Trauma (2021)

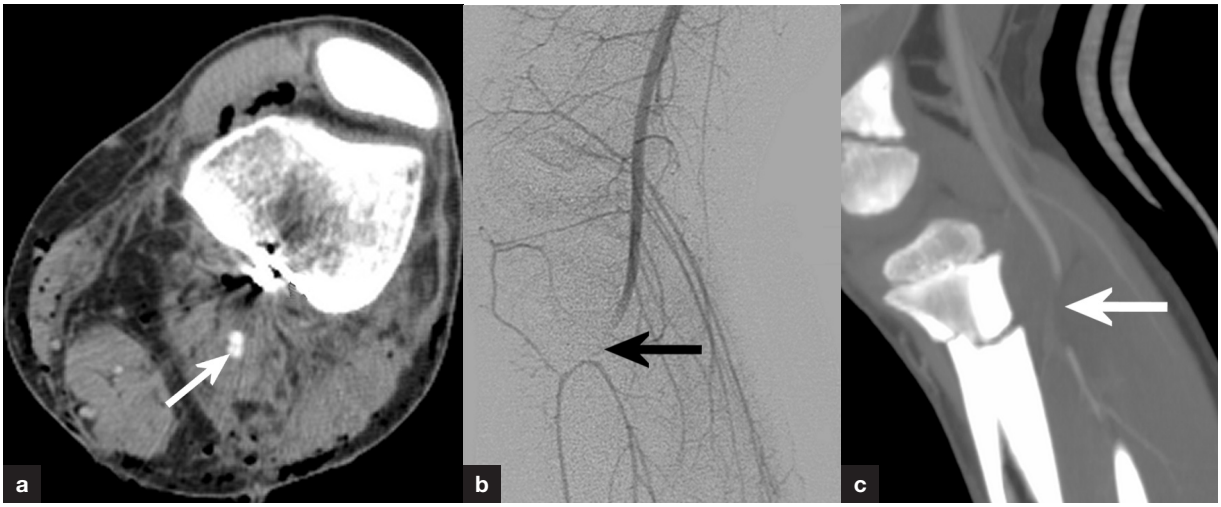


**Figure 3.** Computed tomography angiogram and conventional arteriogram demonstrating radiological signs of arterial injury. a. Computed tomography angiogram displaying loss of opacification of the popliteal artery in association with proximal tibial fracture. b. Conventional arteriogram of the same limb as **Figure 3a** demonstrating distal filling defect. c. Computed tomography angiogram showing contrast extravasation from the axillary artery, no bony injury demonstrated here.

guideline recommends revascularisation within 4 hours of injury. Given the time-critical nature, documentation of examination must include time of assessment, and the patient should be taken to theatre urgently for surgery if there are ongoing signs of distal vascular injury after realignment and splinting in the emergency department.

There is debate regarding the optimal surgical sequence (Glass et al, 2009), with some authors recommending arterial repair before skeletal stabilisation to reduce ischaemic time, while others advocate for the opposite, concerned about the risk of iatrogenic disruption to the vascular repair. The National Institute for Health and Care Excellence (2017) guidance and British Orthopaedic Association Standards for Trauma (2021) advocate that if arterial continuity cannot be restored rapidly, then temporary shunts should be used to re-establish arterial flow. Placement of a temporary vascular shunt may reduce ischaemic time, incidence of compartment syndrome and length of hospital stay (Hossny, 2004). After temporary shunt placement, skeletal stabilisation should be performed, which may be external fixation or definitive internal fixation, depending on factors such as the degree of soft tissue injury. Following this, definitive restoration of vascular supply should be achieved: the British Orthopaedic Association Standards for Trauma (2021) guideline recommends anatomical reconstruction in preference to bypass grafts. Options for vascular reconstruction include end-to-end anastomosis, simple stitches for wall defects, patch angioplasty, or interposition grafts, with primary patency generally achievable in most cases (Klocker et al, 2010).

## Amputation

In severely injured limbs with prolonged ischaemic time or irreparable damage, early amputation may be the most appropriate option. This decision should be made by two consultants and carefully documented, and discussed with the patient and their family if possible (National Institute for Health and Care Excellence, 2021).

Scoring systems have been developed to assess severely injured limbs, but these are unreliable (Loja et al, 2017), and the National Institute for Health and Care Excellence (2017) recommends not using an injury severity tool score when deciding between limb salvage and amputation. Emergency amputation is indicated when a limb is the source of uncontrollable life-threatening bleeding, limb salvage would cause unacceptable risk to the patient's life, or the limb is deemed unsalvageable after orthoplastic assessment (National Institute for Health and Care Excellence, 2017).

Amputation is a last resort if meaningful reconstruction is not possible, but patient-reported health measures and functional outcomes following amputation may not be dissimilar to those in patients that undergo limb reconstruction following severe injury (Bosse et al, 2002).

## Fasciotomy

A fasciotomy (emergency surgical decompression of a myofascial compartment) is performed to prevent or treat compartment syndrome. This occurs when pressure increases within a muscle compartment, leading to insufficient blood supply and causing irreversible ischaemic damage (Ahluwalia et al, 2020). In patients with arterial injury and revascularisation, there should be a low threshold for fasciotomies as there is a significant risk of compartment syndrome developing (Gourgiotis et al, 2007). The British Orthopaedic Association Standards for Trauma (2021) recommend clear senior documentation if fasciotomies are not being performed in this context.

Acute compartment syndrome may develop up to 48 hours after the initial injury, with the key clinical sign being pain out of proportion with the clinical picture and pain on passive stretch of the fascial compartment. It may not be possible to evaluate this in patients with altered consciousness or neurological deficit. Compartment pressures can be monitored, but if there is reasonable clinical suspicion, fasciotomies should be performed (Ahluwalia et al, 2020).

## Postoperative management

Postoperatively patients should be monitored closely by staff competent in the assessment of the critically injured limb, with regular assessment of neurological and vascular status,

## Key points

- Hospital protocols should be clear and easily accessible, and encourage stabilisation and urgent transfer of patients when required. A multidisciplinary approach is mandatory to provide optimum outcomes.
- Early recognition of vascular injury is essential, using clinical examination in conjunction with imaging, and all attempts should be made to minimise ischaemic time.
- Early restoration of arterial continuity is the first surgical priority, with a temporary shunt being placed if necessary, followed by stabilisation of the skeleton, before proceeding to the definitive vascular procedure.
- There should be a low threshold for fasciotomy, and in severe injuries where early amputation is indicated, this should be decided by at least two consultants in collaboration.
- Careful postoperative observations of the injured limb should be performed, in order to detect complications and react in a timely fashion.

function and pain. Vascular compromise may be a sign of failure of the repair or graft, and so circulation should be meticulously assessed, and any concerns of ischaemia escalated urgently to the surgical team. These observations should be performed hourly for the first 24 hours, and then 4-hourly for the next 24 hours (Lucas et al, 2014).

## Conclusions

Fractures and dislocations with associated arterial injuries present a complex and multifaceted challenge, which require a time-critical collaborative approach between orthopaedic and vascular or plastic surgeons to reduce complications and achieve the best possible outcomes.

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**Conflicts of interest**

A Trompeter is a member of the British Orthopaedic Association Trauma Committee, who are responsible for producing the British Orthopaedic Association Standards for Trauma guidelines, and was directly involved in the production of the latest version of the British Orthopaedic Association Standards for Trauma (2021) for arterial injuries. SA Hussain, S Walters and A Ahluwalia declare that they have no conflicts of interest.

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Figure 3 is reproduced with permission from The Radiological Society of North America from Miller-Thomas et al (2005).

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## Curriculum checklist

This article addresses the following requirements from the trauma and orthopaedic surgery curriculum:

- Promptly assesses acutely unwell and deteriorating patients, delivers resuscitative treatment and initial management
- Makes a full assessment of patients by taking a structured history and by performing a focused clinical examination, and requests, interprets and discusses appropriate investigations to synthesise findings into an appropriate overall impression, management plan and diagnosis
- Demonstrates effective communication with colleagues, patients and relatives.


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