Management of open fractures of the lower limb

This article gives a practical guide for the management of open lower limb fractures. It outlines the referral criteria and pathway for definitive care in a specialist centre, the initial management steps that should be taken in the emergency department, and the principles of fixation, soft tissue coverage and antibiotic therapy.

In the UK, a district general hospital serving a population of 250 000 people will treat around 30 tibial shaft fractures per year, of which 25% will be open (Court-Brown et al, 1998); if tibial plateau and pilon injuries are included, this gives around 60 cases per year, of which 15% are open. Evidence shows that the treatment of major lower limb trauma in designated specialist centres, where the expertise in managing such cases is greater, gives improved outcomes (MacKenzie et al, 2008). Early input from experienced orthopaedic and plastic surgical teams is available, and definitive fixation and soft tissue coverage of the wound can be coordinated. For this reason, the British Orthopaedic Association/British Association of Plastic, Reconstructive and Aesthetic Surgeons (BOA/BAPRAS) standards recommend the immediate transfer of all complex open fractures of the lower limb to a specialist centre (*Table 1*; Nanchahal et al, 2009), with the only indication for debridement outside of such units being when the patient cannot be transferred safely.

The creation of regional trauma networks in the UK, in which there is a designated 'major trauma centre' for population groups of 3–4 million people at which major trauma is managed, has facilitated the swift transfer of patients to specialist care and should lead to improved outcomes for patients with complex open fractures (Kanakaris and Giannoudis, 2011; Sleat and Willett, 2011).

Initial management in the emergency department

Open fractures of the lower limb are often associated with high-energy trauma such as road traffic collisions or falls from a height. In such cases, concomitant life-threatening injuries of the head, chest, abdomen or pelvis take priority, and assessment and management of the patient should be according to Advanced Trauma Life Support (ATLS) principles. With regards to the fracture itself, the first priority is to control external haemorrhage by direct pressure or, on rare occasions, by use of a tourniquet.

The wound should be handled as little as possible. Gross contaminants may be removed but there is no evidence that washout in the emergency department reduces infection rates. The neurovascular status of the limb must be clearly documented, including assessment of peripheral pulses and the presence or absence of pain on passive movement of the toes to assess for compartment syndrome. The wound should be photographed and covered with a dressing moistened with saline and an occlusive film dressing. If not already done before arrival at hospital, the limb should be splinted appropriately and the neurovascular status rechecked. Appropriate radiographs of the limb (orthogonal views and views including the adjacent joints) should be arranged and the orthopaedic team (and plastic surgery team if available) should be informed.

Intravenous antibiotics should be given as soon as possible but certainly within 3 hours of injury (co-amoxiclav 1.2 g intravenous or a cephalosporin, e.g. cefuroxime 1.5 g intravenous or clindamycin 600 mg intravenous if the patient is allergic to penicillin). The patient's tetanus

Table 1. Characteristics of open fractures of the lower limb requiring prompt referral to a specialist centre

Fracture patterns	Transverse or short oblique tibial fractures with fibular fractures at a similar level
	Tibial fractures with comminution or butterfly fragments with fibular fractures at a similar level
	Segmental tibial fractures
	Fractures with bone loss, either from extrusion at the time of injury or after debridement
Soft tissue injury patterns	Skin loss such that direct tension-free closure is not possible following wound excision
	Degloving
	Injury to the muscles which requires excision of devitalized muscle via wound extensions
	Injury to one or more of the major arteries of the leg

From Nanchahal et al (2009)

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status should be checked and immunization provided if required; in the case of tetanus-prone wounds, such as penetrating injuries or those contaminated with soil or manure, human tetanus immunoglobulin must also be given (Salisbury and Begg, 1996).

Although the initial management steps outlined apply irrespective of fracture severity, it is helpful to have a system for classifying open fractures both to alert clinicians to the type of surgery that may be required and to objectively gauge prognosis and the risk of infection. The most widely used classification system is the Gustilo and Anderson score (*Table 2*), although a range of other scoring systems that take into account patient characteristics and more subtle variations in structural damage have been developed with varying success (Gustilo et al, 1984; Durrant and Mackey, 2011).

Table 2. Gustilo–Anderson classification of open fractures

Classification	Description
Type I	Wound <1 cm with minimal soft tissue injury
Type II	Wound >1 cm with moderate soft tissue injury
Type IIIA	Extensive soft tissue laceration or flaps with adequate soft tissue cover of fractured bone, or high energy trauma irrespective of the size of the wound
Type IIIB	Extensive soft tissue injury with periosteal stripping and bone exposure, usually associated with massive contamination
Type IIIC	Associated arterial injury requiring repair

From Gustilo et al (1984)

Table 3. Recommended antibiotics in the British Orthopaedic Association/British Association of Plastic, Reconstructive and Aesthetic Surgeons standards

Indication	Antibiotic
Within 3 hours of injury and to be continued until the time of first debridement	Co-amoxiclav (1.2 g intravenous) or cephalosporin (e.g. cefuroxime 1.5 g intravenous)
At the time of first debridement	Co-amoxiclav (1.2 g intravenous) or cephalosporin (e.g. cefuroxime 1.5 g intravenous) and gentamicin (1.5 mg/kg intravenous)
	Co-amoxiclav or cephalosporin continued until soft tissue closure or for a maximum of 72 hours, whichever is sooner
At the time of definitive skeletal stabilization and definitive soft tissue closure	Gentamicin (1.5 mg/kg intravenous) and either vancomycin (1 g intravenous) or teicoplanin (800 mg intravenous) on induction of anaesthesia
	The vancomycin infusion should be started at least 90 minutes before surgery
In case of anaphylaxis to penicillin	Clindamycin (600 mg intravenous 6-hourly preoperatively) in place of co-amoxiclav or cephalosporin. For those with a lesser allergic reaction, a cephalosporin is preferred

From Nanchahal et al (2009)

Wound debridement and initial stabilization

Early, accurate wound debridement is the most important surgical procedure in the management of open fractures (Nanchahal et al, 2009). The BOA/BAPRAS standards stress that wound debridement should be performed in a specialist centre by senior orthopaedic and plastic surgeons working together on scheduled trauma operating lists within 24 hours of injury. The previously held rule that debridement should be performed within 6 hours of injury is not evidence-based, and the only indications for urgent debridement are gross contamination of the wound, compartment syndrome, a devascularized limb or a multiply injured patient.

All devitalized tissue (except neurovascular bundles) must be excised by systematic exploration using a tourniquet to allow adequate visualization. The wound is washed to remove gross contaminants and then explored from superficial to deep and from peripheral to central, with care being taken to make appropriate extensions of incisions so as not to miss any hidden damage. Devitalized muscle may be assessed using the four 'C's: colour, contraction, consistency and capacity to bleed (Sculley et al, 1956). If the damage is difficult to assess, a second look may be undertaken at 24–48 hours, although multiple serial debridements should be avoided as they have been shown to be associated with worse outcomes (Park et al, 2002). Debridement should be completed using low pressure lavage with large volumes of warm saline.

If definitive fixation and soft tissue cover is not carried out at the time of primary debridement, a negative pressure dressing (e.g. vacuum-assisted closure or VAC dressing) or antibiotic bead pouch is used to cover the wound and spanning external fixation may be applied to maintain bony alignment and minimize further disruption to the soft tissues. Antibiotics should be given up until and at the time of first debridement, in addition to a single dose of gentamicin on induction for each procedure; at the time of definitive fixation and soft tissue cover, vancomycin or teicoplanin is also required (*Table 3*).

Definitive fixation

The precise timing of conversion from external to internal fixation is under debate. Provisional external fixation is preferred in highly contaminated injuries and those where there is significant bone loss, but prolonged delay in conversion to internal fixation may increase the risk of external fixator pin track infection spreading to involve the intramedullary cavity (Clasper et al, 2001; Bhandari et al, 2005). The BOA/BAPRAS standards therefore recommend that definitive fixation is carried out within 72 hours of the primary debridement and provisional stabilization where possible, but that where there is significant contamination, bone loss or multilevel fractures of the tibia, multiplanar or circular fixators should be used for skeletal stabilization instead. When internal fixation is required, the type of fixation depends upon the fracture pattern, with

intramedullary nailing or plating offering advantages under different circumstances (Griffin et al, 2012).

Soft tissue cover

Soft tissue cover of an excised wound is critical in enabling infection-free fracture union (*Figure 1*). In low energy open fractures with minimal devitalized tissue, primary closure may be achieved after debridement. If soft tissue cover is deemed necessary in the form of a local flap or free flap, this should ideally be performed at the same sitting as definitive fixation – the 'fix and flap' approach – which aims to reduce the risk of infection by minimizing the length of time that metalwork is exposed (Gopal et al, 2000; Naique et al, 2006). The BOA/BAPRAS Standards for Trauma (BOAST 4) guidelines (British Orthopaedic Association and British Association of Plastic, Reconstructive and Aesthetic Surgeons, 2009) acknowledge that while this may not always be feasible in practice, the time from injury to soft tissue cover should be less than 72 hours and should certainly not exceed 7 days.

In cases where soft tissue cover is required, the nature of flap used is dependent upon a number of factors, including both fracture characteristics and patient factors (Chan et al, 2012). In cases where vascularity has not been compromised, local fasciocutaneous flaps offer a solution for reconstruction which avoids the need for microsurgical vascular anastomoses. Unless meticulously planned and executed, these flaps can suffer a high rate of tip necrosis, usually of the part of the flap which covers the fracture. However, free flaps can be used for more extensive defects and effectively minimize dead space in such cases, reducing the risk of seroma and/or haematoma formation and hence infection. Free muscle flaps are often harvested from the gracilis or latissimus dorsi muscles whose single pedicle vascular supply facilitates removal of part of the muscle and survival of the flap once implanted over the fracture site. Following free flap reconstruction, careful monitoring of flap viability is required over the subsequent days by clinical examination and adjuncts such as implantable Doppler probes inserted at the time of surgery (*Figures 2* and *3*).

Indications for primary amputation

The BOA/BAPRAS guidelines give clear indications for amputation including avascular limbs with a warm ischaemic time exceeding 4–6 hours, segmental muscle loss affecting more than two compartments, segmental bone loss greater than one-third of the length of the tibia and incomplete traumatic amputations where the distal remnant is significantly injured. Furthermore, the decision to perform an amputation must be made by two consultant surgeons, if possible after consultation with the patient and his/her family. Plastic surgery input at this stage may allow salvage of amputated parts to aid stump cover or for 'spare part' surgery (tendon, nerve, vessel, bone or skin grafts or flaps) in multiply injured patients.

Figure 1. Open fractures of the lower limb are often associated with significant soft tissue damage. Following definitive fracture fixation, it is important that soft tissue cover is achieved as soon as possible to minimize the risk of infection.

Figure 2. a. An open tibial fracture which has been covered using a gracilis free muscle flap.

Figure 3. A hand-held Doppler probe is a non-invasive means of assessing arterial inflow into the flap and may be used in conjunction with or as a replacement to venous Doppler monitoring.

Conclusions

Open fractures of the lower limb require a multidisciplinary approach to their management, with involvement from emergency department staff, orthopaedic, plastic and occasionally vascular surgical teams, and occupational therapists and physiotherapists. While initial management of the fracture should occur on arrival at any hospital, evidence shows that transferring patients to a specialist centre for surgery leads to better outcomes, and the recent formation of regional trauma networks in the UK should facilitate this. BJHM

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KEY POINTS

- Open fractures of the lower limb require early input from senior orthopaedic and plastic surgeons.
- All complex open lower limb fractures should be managed in a specialist centre.
- The time between definitive fixation and soft tissue cover should be minimized.
- The time from injury to soft tissue cover should be less than 72 hours.
- The joint British Orthopaedic Association/British Association of Plastic, Reconstructive and Aesthetic Surgeons standards give details of the type and timing of antibiotics required.