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Assessing and managing open fractures: a systematic approach

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Abstract

Open fractures are complex injuries strongly associated with high-energy trauma. Assessment should include the mechanism and place of injury, timing, associated injuries and comorbidities. The initial management of these fractures, whether in the prehospital setting or emergency department, must include the following in a prompt manner: administration of antibiotics and tetanus prophylaxis, photography, reduction or re-alignment, wound coverage and splintage.

Imaging includes plain X-rays and a computed tomography trauma scan, as well as an angiogram if vessel damage is suspected. Collectively, the energy of the mechanism of injury, with the level of contamination, potential for compartment syndrome and vascular damage, determines the operative urgency.

Operative management can be a one- or two-stage procedure, because definitive internal skeletal fixation should only be attempted if soft tissue coverage can occur during the same operation. Ideally, all open fractures should be closed within 72 hours. This article explores the evidence for current best practice.

Key words: Compartment syndrome; External fixator; Infection; Open fractures; Trauma

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Introduction

Open fractures are complicated musculoskeletal injuries, in which a skeletal fracture site is in direct communication with the external environment as a result of disruption of the overlying soft tissue (Ahn et al, 2021). Injuries of this nature are strongly associated with high-energy trauma (Ahn et al, 2021). They may occur in high-risk environments (eg farmyards), leading to wound and fracture contamination. Anatomical disruption, inherent contamination and increased risk of concurrent major trauma injuries can lead to substantial morbidity and mortality. The confluence of these risk factors requires a prompt, multidisciplinary orthopaedic and plastic surgical ('orthoplastic') approach to reduce infection and optimise patient recovery. The orthoplastic approach aims to minimise the likelihood of severe complications including, but not limited to, non-union, deep infection, chronic osteomyelitis, tissue devitalisation, ischaemic necrosis and amputation.

Successful management of open fractures requires an in-depth appreciation of the relevant anatomy, as well as the mechanism and timing of injury, patient physiology and surgical techniques. The heterogeneity of these components invariably influences management, ranging from initial wound decontamination and/or debridement, early or delayed definitive fixation, to soft tissue repair and/or reconstruction.

This article outlines the basic concepts of open fracture management for the surgical trainee. It is based on the British Orthopaedic Association Standards for Trauma and Orthopaedics (British Orthopaedic Association, 2017) guidelines. The concepts are mainly time-orientated. Intravenous antibiotics and tetanus prophylaxis should ideally be given within 1 hour of the injury; imaging by the radiology department, photography, wound coverage and splinting should occur in the emergency department; and highly contaminated or vascular compromised limbs should be operated on 'immediately' (British Orthopaedic Association, 2017).

The most significant change to UK trauma management came with the introduction of the major trauma centre network (MacKenzie et al, 2006). Pre-hospital pathways now streamline patients with serious injuries directly to major trauma units that offer on-site

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trauma subspecialities (MacKenzie et al, 2006); in the case of open fractures, orthopaedic and plastic surgery consultants. This allows the 'timely multidisciplinary' approach set out in the BOAST guidelines. An orthoplastic centre offers operating lists with consultants from both orthopaedics and plastic surgery, combined clinics for postoperative management, and specialist nursing for fractures and flaps (British Orthopaedic Association, 2017).

Patients with open fractures are not always taken directly to a major trauma centre (Townley et al, 2010), for reasons such as reduced bed availability, poor weather conditions, extensive distances from rural hospitals and inadequate triage. There can be significant delays before a patient taken to a peripheral hospital is accepted and transferred to a major trauma centre (Townley et al, 2010). Although the network attempts to mitigate this and triage patients appropriately, some patients will present to a peripheral hospital in the first instance.

So, what should happen to a patient with an open fracture who is not at a major trauma centre? Administration of intravenous antibiotics and tetanus vaccination within 1 hour is still achievable, and it should be possible to photograph and cover the wound, reduce the fracture, and obtain radiographs (in at least two planes) and a computed tomography or computed tomography angiography in most UK hospitals. These initial steps can be performed regardless of orthoplastic input, and delaying initial treatment by seeking an orthoplastic input first would be likely mean that antibiotics are not given in a timely manner, resulting in higher infection rates (Pollak, 2006). Once immediate management is complete, transfer to the major trauma centre can be arranged. In cases of delayed transfer, peripheral orthopaedic units can be directed by major trauma centre consultants to perform the initial surgical debridement and apply an external fixator. The patient can then be transferred to a major trauma centre less urgently, to provide internal fixation and soft tissue coverage. Regardless of which hospital a patient presents to, robust assessment, triage and senior orthopaedic review is needed in the early post-injury phase to reduce complication rates (Townley et al, 2010).

Clinical anatomy

A fracture is considered open when there is disruption to the soft tissue overlying or near to the site of a fractured bone. The wound can either be 'inside-out', caused by a broken bone fragment puncturing through the skin, or 'outside-in' caused by a penetrating injury (Ahn et al, 2021). Theoretically, any broken bone can become an open fracture. Unlike other orthopaedic injuries, classification of open fractures can only be completed in the operating theatre when the wound has been adequately irrigated, explored and debrided.

Prehospital care and initial management

A junior member of the orthopaedic team will often be the first to assess the patient from an orthopaedic perspective. The information gathered and immediate action taken is important in appropriately managing the patient and helping to plan surgical management (Table 1).

Five key management actions should happen immediately, either in the emergency department or in the pre-hospital setting (Table 2).

After the immediate management steps are completed, surgical plans can be made (Table 3).

Surgical management

Classification of open fractures

The Gustilo and Anderson classification system (Table 4) can be used to grade open fractures and guide management. The classification should be made in the operating room once initial irrigation and debridement of the wound is completed (Cross and Swiontkowski, 2008; Ahn et al, 2021).

In some cases, the decision needs to be made whether to salvage or amputate a severely traumatised limb. Use of the nerve injury, ischaemia, soft tissue injury, skeletal injury, shock and age (NISSSA) scoring system can help (McNamara et al, 1994). It predicts the

Table 1. The initial assessment and examination of a patient who has sustained an open fracture

ATLS	Open fractures are often a result of a major trauma, so an Advanced Trauma Life Support (ATLS) primary survey approach must be adopted first. This ensures that acute serious life- and limb-threatening injuries are identified, and the patient is appropriately stabilised		
Basic history	In these obvious emergency situations, basic history taking should not be neglected Past medical and medication history will help determine the patient's surgical risk, allergy status and tetanus status, and will identify immunocompromised patients, and those on anticoagulation therapy that may need reversal before surgery. A venous thromboembolism risk assessment should be conducted in line with local guidelines Social history should be recorded, including smoking status, nutrition status, drug and alcohol use, occupation, living situation, and mobility. In patients with upper limb fractures, hand dominance should be recorded		
Focused history	Open fracture diagnoses, by their nature and severity, are usually apparent on observation alone, although this should not omit the need for a focused history A focused history can provide vital information for determining the timing and the method of surgical fixation When taking a focused open fracture history, specific questions directly influence management	Sources	Ideally the patient will be able to describe the circumstances of the injury, but in many cases a collateral history is required Multiple sources, including paramedics, helicopter emergency medical service staff, police officers, relatives, and witnesses, can help recreate the timeline of events
		Location of injury	Owing to the break in the skin, knowing the environment in which the injury took place is paramount. High-risk environments for wound contamination include, but are not limited to, marine, freshwater, farmyard and sewage (Ahn et al, 2021). Bowel contamination must be considered if there are pelvic fractures with associated bowel injury
		Timing of injury	Timing of the injury influences both the method and urgency of open fracture management, through the consideration of length of wound exposure, possible bleeding time, vascular compromise and 'cold time' of the affected limb When the patient last ate or drank can influence operating times and associated anaesthetic risk
		Pre-hospital	Status: Pre-hospital neurological and vascular status should be documented, to act as a comparator for repeat examinations Interventions: Details of any pre-hospital medications (including antibiotics, tetanus prophylaxis, analgesia) and/or interventions (eg application of tourniquets, pelvic binder) should be obtained from paramedics or helicopter emergency medical service staff
Examination	Priority is given to the primary survey and ATLS approach, after which, a focused examination of the affected limb or limbs should take place	Neurology and vascular status	The neurological and vascular status of the affected limb distal to the injury site must be assessed. It is important to examine and clearly document the specific nerves (motor power and sensation) and vessels tested. Marking the palpable site of pulses can allow easier identification and comparison later. If a reliable pulse cannot be felt on palpation, the pulse can be assessed with a hand-held Doppler, or the vessel can be formally assessed with a computed tomography angiogram (British Orthopaedic Association, 2017) Initial neurological and vascular status should be clearly documented for use as a reference point for subsequent reassessments, such as post-manipulation and post-surgery
		To note	Other important things to note in documentation include active bleeding, bone protrusion, obvious injuries to tendons, vasculature, ligaments or muscles, size and location of the wound, obvious contaminants and foreign bodies Swelling, effusions and tenderness should be assessed and documented, as should any concern regarding compartment syndrome
Senior support	If there is any concern regarding active bleeding, neurological and/or vascular compromise or compartment syndrome, a senior colleague should be promptly informed		

Table 2. Five key immediate steps for the management of a patient with an open fracture

Immediate management		Checklist
Administration of prophylactic intravenous antibiotics	The risk of infection is high and early administration of intravenous antibiotics is recommended (British Orthopaedic Association, 2017). The rate of infection is increased if antibiotics are given >3 hours from the time of injury (Ahn et al, 2021), and BOAST recommends that they should be given within 1 hour of injury The choice of antibiotic regimen should be as per local or hospital microbiology guidelines (British Orthopaedic Association, 2017) Prophylactic antibiotics should only continue for 2–3 days, corresponding with the 72-hour window in which definitive closure of the wound should be achieved (British Orthopaedic Association, 2017). This may vary in some cases and be guided by medical teams and microbiology input	■ Timing – within 1 hour ■ Route – intravenous ■ Appropriate – local or trust guidelines ■ Allergies ■ Contamination risk considered
Administration of tetanus prophylaxis	Clostridium tetani is a concern for wounds that have been contaminated, so prophylaxis and treatment should be considered in a patient with an open wound. The following are recommended based on a patient's tetanus immunisation status (Cross and Swiontkowski, 2008): 1. Tetanus booster within last 5 years = no further treatment required 2. Over 5 years since booster or incomplete childhood immunisation = give tetanus toxoid 3. Over 10 years since booster or immune system compromised = tetanus toxoid and human tetanus immune globulin	■ Immunisation status ■ Tetanus toxoid or human tetanus immune globulin
Photographing the wound	A multidisciplinary team approach is required for the management of open fractures. Imaging the wound in the emergency department allows different members of the multidisciplinary team to view the wound without repeated exposure or disturbance of the injury. Photography also allows remote review, discussion and treatment planning between staff members at different hospital sites. Both close-up and zoomed-out photographs should be taken, to clearly demonstrate the wound's location and size in its surroundings When taking clinical photographs, consent should be obtained from the patient where possible (General Medical Council, 2013). If consent cannot be gained, the reasons why this is not possible and why photography is in the best interest of the patient must be clearly documented Obtaining the images must follow local and trust policy, for example using an allocated camera. Sharing images with other members of the multidisciplinary team should follow good medical practice guidance (General Medical Council, 2013)	■ Consent ■ Legal – in accordance with local guidelines ■ Perspective
Re-alignment or reduction of the fracture	The aim of reduction is to restore anatomical alignment as much as possible. This can reduce traction and pressure on the surrounding soft tissue and neurovascular structures, improve pain control, reduce swelling and tamponade bleeding at the fracture site (British Orthopaedic Association, 2017) In open fractures, an attempt should be made to cover any exposed bone with soft tissue Sufficient analgesia is required to realign or reduce an injury, and some cases may require procedural sedation. Therefore reductions should take place in the emergency department with assistance from emergency physicians and/or anaesthetists After reduction it is vital to reassess the neurological and vascular status of the limb and clearly document the findings, including any changes	■ If indicated and appropriate ■ Aims to reduce exposed bone with soft tissue coverage ■ Plaster if needed
Covering the wound	British Orthopaedic Association (2017) guidelines recommend that there should be minimal handling of an open fracture outside of theatre. Only gross contaminants should be removed, before dressing the wound with saline-soaked gauze and an occlusive dressing Wound washout must not be attempted outside of theatre. Plaster-cast or skin traction may be appropriate, depending on the fracture pattern and type	■ Remove gross contaminant ■ Saline gauze ■ Occlusive dressing ■ No washout in the emergency department

Table 3. Preoperative planning for open fractures

Departmental imaging (X-rays)	As well as photographing the open wound, departmental radiological imaging should be obtained. A minimum of two perpendicular views must be imaged, as well as the bones and joints involved A trauma computed tomography scan may also be indicated, depending on the mechanism of injury British Orthopaedic Association (2017) recommends that hospitals should have a clear policy regarding the inclusion of computed tomography angiography for patients with any limb or extremity that has sustained an open fracture			
Theatre plan	The plan for debridement and fixation of an open wound should be jointly discussed between orthopaedic and plastic surgery consultants (British Orthopaedic Association, 2017). The risk of infection and soft tissue management need to be carefully considered as well as the fracture management British Orthopaedic Association (2017) recommends that definitive closure or coverage of all open fractures should be achieved within 72 hours, but definitive internal bone fixation should only be performed if it can be immediately followed by definitive soft tissue cover. In cases where this is not possible external fixation must be considered It is imperative that junior members of the team (or those involved in initial management) address any factors that could prevent or delay a patient's transfer to surgery, eg reversal of anticoagulation in accordance with local haematology guidance			
	Timeline for debridement	The timeline is dictated by the level of contamination and energy type of the mechanism (British Orthopaedic Association, 2017)	Immediate surgery	Highly contaminated wound, vascular compromise, compartment syndrome
			Within 12 hours of injury	Isolated high-energy open fracture
			Within 24 hours of injury	Low-energy open fracture

Table 4. Gustilo and Anderson classification used in the operating theatre

	I	II	IIIA	IIIB	IIIC
Energy	Low	Moderate	High	High	High
Wound size	<1 cm	1–10 cm	>10 cm	>10 cm	>10 cm
Soft tissue damage	Minimal	Moderate	Extensive	Extensive	Extensive
Contamination	Clean	Moderate	Extensive	Extensive	Extensive
Fracture pattern	Simple transverse or short oblique	Simple transverse or short oblique	Gunshot injuries or segmental fractures	As per IIIA but very contaminated	As per IIIB but with vascular injury
Periosteal stripping	No	No	Yes	Yes	Yes
Skin coverage	Local coverage	Local coverage	Local coverage	Requires free tissue flap or rotational flap coverage	Requires flap coverage
Neurovascular status	Normal	Normal	Normal	Normal	Exposed fracture with arterial damage

From Gustilo and Anderson (1976)

likelihood of successful limb salvage vs amputation, with higher scores suggesting that successful limb salvage is less likely.

Wound irrigation and debridement

Accurate assessment of the fracture site and visualisation of soft tissue damage will likely require wound extension (Nanchahal et al, 2009), which should be performed along standard fasciotomy incision lines. Subsequently, fracture ends can be delivered and exposed, provided that care is taken to avoid periosteal stripping.

Debridement aims to remove as much debris, devitalised soft and bone tissue from the contaminated wound as possible, while preserving maximal amounts of viable tissue to

facilitate wound healing and fracture fixation (Nanchahal et al, 2009). Once all devitalised tissue has been carefully removed, a normal saline 'wash-out' should be performed. Although copious lavage is an important step, it should not act as a substitute for debridement (Nanchahal et al, 2009). To avoid ongoing contamination, surgical instruments should be exchanged for a clean set after the wash-out and the fracture site should be re-draped and prepared, as the wound is now considered clean.

Fracture fixation and soft tissue cover

Depending on the physiological response of the patient and the soft tissue loss after debridement, fracture fixation and soft tissue cover may occur in one or two stages. At the time of primary debridement, fracture reduction should occur to restore anatomical alignment and reduce soft tissue dead space (Nanchahal et al, 2009). Soft tissue dead space can be reduced by restoring osseous anatomical alignment and via the use of flaps. Elimination of dead space reduces the risk of haematoma or seroma formation, which helps reduce deep infection rates (Nanchahal et al, 2009).

The decision to perform definitive surgery with either internal or external fixation of the fracture depends on the level of soft tissue cover, as this is the greatest determinant of subsequent infection risk (National Institute for Health and Care Excellence, 2018). Internal fixation is preferred when adequate soft tissue cover can be achieved, either by the availability of soft tissue (ie Gustilo I and II fractures) or via local or free flap reconstruction, which can be performed immediately after fixation (National Institute for Health and Care Excellence, 2018). Soft tissue cover should ideally take place within 72 hours of injury with concurrent fracture stabilisation to mitigate further infection (National Institute for Health and Care Excellence, 2018).

Shunts and revascularisation

Open fractures can also result in vascular injuries. In these cases, direct surgical exploration of the vessel is recommended (National Institute for Health and Care Excellence, 2018) with the aim of re-establishing circulation within 3–4 hours of injury (Glass et al, 2009). Care should be taken when making incisions during exploration to avoid iatrogenic compromise to potential reconstructive flap options (Nanchahal et al, 2009).

Vascular shunts allow prompt revascularisation, with prior application of external fixation to prevent dislodgement of the shunt (Nanchahal et al, 2009). Immediate limb revascularisation via temporary shunts quickly restores circulation and relieves some of the urgency associated with skeletal fixation and soft tissue debridement (Johansen et al, 1982). Once the fracture is stabilised, reversed vein grafts can replace the shunt – these are preferred over prosthetic materials in the definitive reconstruction of vascular defects (Nanchahal et al, 2009).

Limb salvage

Successful limb salvage is linked to a reduced ischaemic time. Often more central injuries are easier to salvage, compared to distal injuries, because of the vessel size and availability of soft tissue for coverage (Shahien et al, 2021). It is suggested that, before formal vascular repair, shunting and bone stabilisation (with an external fixator) will help reduce salvage rates (Shahien et al, 2021). Infection, compartment syndrome and failed vessel repair are all major contributors to failed limb salvage attempts (Culliford et al, 2007).

Common problems with open fractures

The major complications of these injuries are infection and ischaemia secondary to vascular injury.

Infection

Infection can present obviously or insidiously (eg non-union) following an open fracture, and is most often complicated by deep infection, which itself is likely a result of inadequate soft tissue cover. Failure of local or free muscle flaps can be as high as 3.7%, even in ideal conditions, and drastically increases the incidence of deep infection (Culliford et al, 2007).

Temporary bone fixation at the primary debridement is not associated with an increased risk of infection (Nanchahal et al, 2009). However, time between definitive internal fixation and flap coverage, if required, is predictive of subsequent infection (Malhotra et al, 2014). This reinforces the BOAST guidance of definitive internal bone fixation only in cases that allow for immediate definitive soft tissue cover (British Orthopaedic Association, 2017). Higher infection rates in both upper and lower limb open fractures correlate with more severe Gustilo-type injuries (Malhotra et al, 2014). However, infections of open fractures in the lower limb are also influenced by delay in initial debridement and irrigation (Malhotra et al, 2014). The use of local antibiotics may provide better outcomes, but their use on implants or in the wound itself needs evaluating.

Gold standard care in fracture management involves the use of systemic antibiotic prophylaxis and good surgical management. However, despite the use of systemic antibiotics, biofilms can form at the level of implant (De Meo et al, 2020). A number of trials propose that increased local antibiotic concentration at the site of fracture can reduce rates of fracture-related infections, while avoiding the side effects of increased or prolonged systemic antibiotic use (De Meo et al, 2020). Antibiotic-coated nails allow for simultaneous fracture stability and infection control (De Meo et al, 2020). Residual dead space can increase risk of infection (Kotrych et al, 2018). Bone graft substitutes containing antibiotics can reduce infection by minimising dead space and promote cancellous bone healing. Similarly, antibiotics can be incorporated into synthetic vascular conduits, to provide local level resistance to infection during revascularisation procedures (Fischer et al, 2009).

Ischaemic necrosis and tissue damage

The aim is to identify any arterial compromise and re-establish vascularisation of a limb within 3–4 hours of injury (Glass et al, 2009). If ischaemic time is prolonged, muscle will become irreversibly damaged. Dead muscle can cause both local and systemic complications. Debridement aims to prevent systemic catastrophes, including myoglobinuria, renal failure and death (Glass et al, 2009).

Amputation

While it can be considered a complication, amputation can also be a primary definitive treatment. Primary amputation of a severely traumatised limb, which cannot feasibly be salvaged, should be attempted within 72 hours of injury (Nanchahal et al, 2009). Unavoidable factors such as severe crush injury, incomplete amputation or prolonged critical limb ischaemia might render a limb unsalvageable (Nanchahal et al, 2009). These clinical decisions include at least two consultant surgeons, following intensive multidisciplinary discussions involving the patient at all times (Nanchahal et al, 2009). In severe circumstances, amputation may be the only option for controlling major haemorrhage and resuscitating the patient (Nanchahal et al, 2009).

Open fractures in the frail or older patients

The severity of soft tissue insult in older patients with low-energy open fractures is comparable to that in high-energy open fractures in young patients. A retrospective major trauma centre study of open tibia-fibula fractures found that there was no statistical difference in the rate of non-union or amputation, despite the increase in comorbidities in the older subgroup (>65 years) (Lee et al, 2021). However, preoperative optimisation, comprehensive anaesthetic review and management of comorbidities meant that the timeline set by BOAST was met less often in the older group, mainly because there was a prolonged time before initial debridement (Lee et al, 2021).

Long-term outcomes

Successful surgical management is only the first step on the path to rehabilitation and resumption of normal activities. This should be communicated early to the patient, highlighting the importance of physiotherapy-guided exercises in regaining function post-injury and the need for psychological support. Long-term functional outcomes following open fracture management can be measured using the Sickness Impact Profile and Medical

Outcomes Study Short Form-36 (SF-36) (Ware and Sherbourne, 1992). Definitive studies are awaited to assess outcomes, but the heterogeneity of this group may make these difficult to undertake.

Conclusions

Open fracture care incorporates senior clinical decision making, good surgical management and antimicrobial use within a major trauma centre setting. Immediate steps need to be taken to ensure that prompt and appropriate surgical intervention can be provided for all patients. Achieving fracture realignment and stabilisation promotes bone healing and reduces the rate of fracture-related infections. Stabilisation can be temporary or definitive, depending on the soft tissue coverage that can be achieved. Temporary fixation of open fractures is not associated with an increased rate of infection but does allow soft tissue management and placement of intraluminal shunts.

The introduction of the major trauma centre network has clear benefits for care, allowing severely injured patients to be taken directly to hospitals with surgical subspeciality expertise. The BOAST guidelines insist that a multidisciplinary team approach should be standardised across the UK, regardless of classification severity. Infection remains an important complication of open fractures, and there has been a move towards the use of local antibiotics at the fracture site. However, lower limb open fractures remain at a higher risk of becoming infected, giving scope to improve outcomes in the future.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

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Key points

- Immediate management of open fractures can be divided into five key steps: administration of intravenous antibiotics, tetanus prophylaxis, photographing the wound, re-alignment or reduction of the fracture, and covering the wound.
- Operative management should be a combined consultant orthopaedic and plastic surgery approach, ideally in a tertiary centre.
- The aim should be to definitively close all open fractures within 72 hours of injury to reduce the risk of infection.

Curriculum checklist

This article addresses the following requirements from the general internal medicine curriculum:

- Managing an acute specialty-related take
- Communicates effectively and is able to share decision making, while maintaining appropriate situational awareness, professional behaviour and professional judgement
- Is focused on patient safety and delivers effective quality improvement in patient care.

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