PERSPECTIVE

Open Fractures – What Is the Evidence, and How Can We Improve?

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Abstract

Open fractures can have devastating consequences, including chronic infections and amputations, leaving patients with life-changing disabilities. Prompt and appropriate treatment can spare patients the sequelae of open fractures and the long-term economic burden these injuries often inflict. The British Orthopaedic Association Standards for Trauma and Orthopaedics (BOAST-4) guideline outlines the acute management of patients with open fractures and is often considered the gold standard for open fracture management in the UK. In an era of evidence-based medicine, clinicians are continually mindful of the science behind current guidelines and practices. This article aims to critique the evidence underpinning the BOAST-4 guidelines and suggest improvements based on contemporary literature. Antibiotic delivery in the prehospital setting, the type and duration of antimicrobial therapy, timing for the conversion from external to internal fixation, and the differentiation between adult and paediatric open fractures were among the many pertinent topics critiqued, and evidence-based improvements suggested.

Level of evidence: V

Keywords: BOAST guidelines,Compound fractures, Evidence, Open fractures

Introduction

Open Fractures have an annual incidence of 30.7 per 10,000 in the UK (1). Tibial open fractures have the highest incidence of 3.4 per 100,000 (1-5). High energy trauma is the leading mechanism of injury for open fractures, with over 50% resulting from road traffic accidents or falls from significant height (1, 2, 6). The majority of patients with high-energy open fractures are young males and often have concomitant injuries with significant soft tissue trauma adding to the injury's complexity (1). Open fractures can be associated with significant morbidity if not managed correctly from the outset. Historically, these injuries would leave patients battling chronic infections, pain, and disability, with many patients eventually requiring an amputation; unfortunately, this continues to be the case in some developing countries (7-11). Care of patients with open fractures has improved considerably over the years; this is mostly the result of better recognition that early treatment must address contamination and achieve early definitive closure and fixation.

Numerous approaches exist to manage the traumatic limb successfully; thus, a universal protocol does not exist. In the UK, the British Orthopaedic Association (BOA) and the British Association of Plastic, Reconstructive and Aesthetic Surgeons (BAPRAS) have developed the BOA Standards for Trauma and Orthopaedics on open fractures (BOAST-4) [Figure 1] (12). These guidelines aim to standardise care and provide surgeons with a stepwise guide to caring for patients with open fractures and are being widely adopted in U.K. practice. But what is the evidence supporting these standards, and how can they be improved? This review aims to critique the evidence underpinning the BOAST-4 guidelines on open fractures and suggest evidence-based improvements.

Body text

BOAST-4: Critique and Improvements

The BOAST-4 guidelines include all patients with open fractures of long bones, hindfoot, or midfoot (excluding

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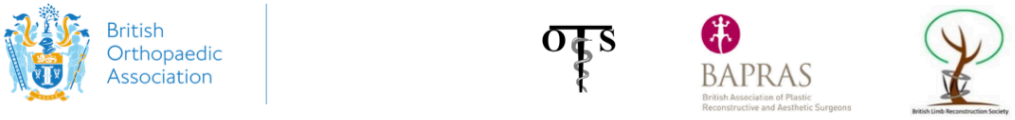

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Open Fractures

Background and justification
Open fractures may require timely multidisciplinary management. The consequences of infection, can be great both for the individual patient and the community. Trauma networks and hospitals require the appropriate pathways and infrastructure, to manage these patients, to enable optimum recovery and to minimise the risk of infection.

Inclusions:
All patients with open fractures of long bones, hind foot or midfoot (excluding hand, wrist, forefoot or digit).

Standards for Practice

1. Patients with open fractures of long bones, hind foot or midfoot should be taken directly or transferred to a specialist centre that canprovide Orthoplastic* care. Patients with hand, wrist, forefoot or digit injuries may be managed locally following similar principles.
2. Intravenous prophylactic antibiotics should be administered as soon as possible, ideally within 1 hour of injury.
3. There should be a readily accessible published network guideline for the use of antibiotics in open fractures.
4. The examination of the injured limb should include assessment and documentation of the vascular and neurological status. This shouldbe repeated systematically, particularly after reduction manoeuvres or the application of splints. Management of suspectedcompartment syndrome should follow BOAST guidelines.
5. The limb should be re-aligned and splinted.
6. Patients presenting with arterial injuries in association with their fracture should be treated in accordance with the BOAST for arterial injuries.
7. In patients where an initial "Trauma CT" is indicated there should be protocols to maximise the useful information and minimise delay:
   - The initial sequence should include a head to toes scanogram. This should be used with clinical correlationto direct further specific limb sequences during that initial CT examination.
   - There should be a local policy on the inclusion of angiography in any extremity CT related to open fractures.
8. Prior to formal debridement the wound should be handled only to remove gross contamination and to allow photography, thendressed with a saline-soaked gauze and covered with an occlusive film. 'Mini-washouts' outside the operating theatre environmentare not indicated.
9. All trauma networks must have information governance policies in place that enable staff to take, use and store photographs of openfracture wounds for clinical decision-making 24 hours a day.
10. Photographs of open fracture wounds should be taken when they are first exposed for clinical care, before debridement and at otherkey stages of management. These should be kept in the patient's records.
11. The formation of the management plan for fixation and coverage of open fractures and surgery for initial debridement should be undertaken concurrently by consultants in orthopaedic and plastic surgery (a combined orthoplastic approach).
12. Debridement should be performed using fasciotomy lines for wound extension where possible (see overleaf for recommendedincisions for fasciotomies of the leg)
    - Immediately for highly contaminated wounds (agricultural, aquatic, sewage) or when there is an associatedvascular compromise (compartment syndrome or arterial disruption producing ischaemia).
    - within 12 hours of injury for other solitary high energy open fractures
    - within 24 hours of injury for all other low energy open fractures.
13. Once debridement is complete any further procedures carried out at that same sitting should be regarded as clean surgery; i.e. thereshould be fresh instruments and a re-prep and drape of the limb before proceeding.
14. Definitive soft tissue closure or coverage should be achieved within 72 hours of injury if it cannot be performed at the time ofdebridement
15. Definitive internal stabilisation should only be carried out when it can be immediately followed with definitive soft tissue cover.
16. When a decision whether to perform limb salvage or delayed primary amputation is indicated, this should be based on amultidisciplinary assessment involving an orthopaedic surgeon, a plastic surgeon, a rehabilitation specialist, the patient and theirfamily or carers.
17. When indicated, a delayed primary amputation should be performed within 72 hours of injury.
18. Each trauma network should submit appropriate data to the TARN, monitor its performance against national standards and audit its outcomes.
19. All patients should receive information regarding expected functional recovery and rehabilitation, including advice about return to normal activities such as work and driving.

*The BAPRAS/BOA group recommend that for clarity the narrative description of an Orthoplastic Service by NICE is broken into its component parts as follows: a combined service of Orthopaedic and Plastic Surgery Consultants; sufficient combined operating lists with consultants from both specialties to meet the standards for timely management of open fractures; scheduled, combined review clinics for severe open fractures; specialist nursing teams able to care for both fractures and flaps. In addition, an effective orthoplastic service will also: submit data on each patient to the national trauma database (TARN) and hold regular clinical audit meetings with both orthopaedic and plastic surgeons present. Please note: the definition of an Orthoplastic Centre was updated in November 2019.

Evidence base:
NICE Complex fracture guideline https://www.nice.org.uk/guidance/NG37/chapter/recommendations

Figure 1. British Orthopaedic Standards for Trauma (BOAST-4) guideline.

hand, wrist, forefoot, or digit) and are distilled from the National Institute of Care Excellence (NICE) comprehensive guidelines for complex fractures (12, 13). The guideline aims to prevent infection and restore function by providing recommendations to clinicians on antibiotics, debridement, fixation and definitive cover, the right team to manage the injury, and decisions to amputate.

Antibiotics

Critique

Infection is a dreaded sequela of open fractures and is associated with devastating consequences, including multiple surgeries, prolonged antibiotic treatment, amputation, and even death (14-16). Preventing infection from developing is the cornerstone of acute care for patients with open fractures. The BOAST-4 guideline states that antibiotics should be administered as soon as possible, ideally within 1 hour from injury (12). The statement is based on evidence from 4 studies involving adult populations (17-20).

The first study was by Enninghorst et al; they studied 89 adult patients with high-energy tibial open fractures of varying Gustilo-Anderson grades (17). 15 of the 89 patients (17%) developed deep infection, including 4 requiring amputations. Regarding antibiotics' timing, the authors reported that all patients received antibiotics in a timely fashion (1.2±0.3 hours), and there was no statistical difference between the two groups for timing. Weber et al and Hull et al reported similar findings of no correlation; both of these studies were also based on adult-only populations and involved varying Gustilo-Anderson grades (18, 20). Interestingly, the last study by Lack et al showed an essential and significant independent effect of timing to antibiotics on deep infection (19). The effect was within 90 days and the analysis adjusted for age, Gustilo-Anderson grade, diabetes, and time to debridement and cover. Lack et al. showed that patients receiving antibiotics within 66 minutes were significantly less likely to develop deep infections when other abovementioned variables were considered (19). Of note, although this study involved fewer patients [137], the proportion of patients with higher Gustilo-Anderson grade and contamination were higher. According to the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) toolbox, the quality of these studies was very low. This was primarily because they were observational studies. Overall, although three studies showed no correlation with timing to antibiotic and deep infections, their conclusions were not reliable owing to the limitations of their methodology and analysis (18-20). From a pragmatic approach, the earlier antibiotics are delivered, the slower bacterial growth occurs, thus reducing the risks of developing infections (21).

Improvement

The BOAST-4 guidelines are limited to the timing of antibiotic administration. There is no mention of antibiotic type or duration; there is also little differentiation between low and high energy grossly contaminated fractures. Clinicians, therefore, follow local protocols, which may not always be available. Appropriate prophylactic antibiotic therapy should target the wound's contaminants to reduce the risks of developing surgical site infections and chronic osteomyelitis; incorrect antibiotic therapy can lead to infection and the associated complications. Metsemakers et al reviewed the literature for the choice of antimicrobial therapy in open fractures (22). Although the evidence was limited, they found that most open fractures were contaminated with gram-positive bacteria (78%), and gram-negative bacteria accounted for a minority (26%). There is a broad consensus amongst orthopaedic surgeons for covering against gram-positive bacteria, but the coverage for gram-negative organisms or even anaerobes remains divisive. The orthopaedic community would warmly welcome future guidelines shedding some light on this. In the same review, Metsemakers et al also explored the evidence for the antibiotic duration in open fractures (22). They found that for GA types I and II, antibiotic treatment should continue for at least 24 hours after wound closure but no longer than 72 hours, and for type III fractures, they recommended a total duration of 72 hours or 24 hours after wound closure or definitive soft tissue cover. These suggestions were similar to other guidelines and would be useful in future BOAST guidelines (23-25).

Surprisingly, local antibiotics do not feature in the BOAST guidelines, nor were they considered in the NICE guidelines on complex fractures. Local antibiotics would undoubtedly be an area of interest given that reduced infections could avoid amputations, return to theatre, and flap failures. Morgenstern et al performed a meta-analysis of 8 studies involving 2738 patients to investigate the potential of local antibiotics in open fractures to reduce infection rates and found a considerable risk reduction (11.9%) if used (26). The methods of delivering local antibiotics included PMMA (Polymethyl methacrylate) beads, calcium-sulphate beads, and antibiotic-coated intramedullary nails.

Another systematic review by Metsemakers et al found that existing literature exploring the merits of local antibiotics in preventing infection following open fractures was low quality and biased; however, this limitation does not mean local antibiotics do not have a role preventing infections (27). Many studies have shown that local antibiotics are a formidable tool in an orthopaedic surgeon's arsenal in fighting chronic osteomyelitis. Even if those studies investigating their role in open fractures were low quality and biased, they did show promising results. Clearly, this is an area worthy of further research and consideration in future guidelines.

Debridement

Critique

There is considerable variation in practice across the U.K. for timing and staging of each procedure with regards to debridement, closure, and fixation of open fractures. BOAST-4 advises initial debridement should be performed immediately for heavily contaminated

wounds, i.e., agricultural, aquatic, and sewage injuries, or when there is a concurrent vascular compromise; 12 hours is recommended for other solitary high energy open fractures and 24 hours for all others (12). For debridement, all of the studies used to develop the guidelines were cohort studies and had very low GRADE ratings (17-19, 28-32). One study by Hull et al investigated the relationship between time to initial debridement and deep infection in 364 patients with 459 open fractures (20). 46 patients developed deep infection; all infections occurred in Gustilo-Anderson grade II or III only. The authors reported a significantly increased rate of deep infection for each hour of delay to debridement (3% per hour of delay), tibial fractures, higher G.A. grade, and contamination level. Malhotra et al also reported similar findings when patients were grouped into early (<8 hours) and late (>8 hours); they did not describe any age restriction in their study of 415 open fractures with varying G.A. grades (31). A further study by Sears et al. suggested that early debridement on day 0 significantly reduced amputation rates (29). By contrast, Noumi et al and Harley et al found no difference in deep surgical site infection rates when initial debridement was delayed by 6 and 8 hours, respectively (30, 32). Overall, the current literature does support early debridement as soon as possible. Still, bearing in mind pressures on theatre spaces, the guidelines do allow up to 24 hours for the less contaminated fractures as these are less likely to develop deep infection (20).

The NICE guidelines used to develop BOAST-4, highlighted the very low quality and serious imprecision of evidence used to determine the optimal timings for debridement. The lack of high-quality evidence meant the recommendations were formulated through a pragmatic approach while considering the level of contamination and theatre pressure in the real world. In fact, delaying the initial debridement up to 24 hours has not been shown to cause significant harm in less contaminated open fractures, whereas having a quality initial debridement has shown to be beneficial (20, 33, 34).

Improvement

Other reviews have struggled to find convincing evidence to support very urgent debridement, and the onus seems to be shifting to prompt antibiotics and quality debridement with the correct expertise. The BOAST guidelines discourage any washouts in the emergency department (12). This has been the subject of debate in the consultation on the NICE draft guidelines (35). One argument is that if open fractures are heavily contaminated with grass and dirt, reduction will inevitably drag the debris into the wound. In fact, at the recent International consensus meeting (ICM) on Musculoskeletal Infection delegates voted overwhelmingly in favour of open fractures being adequately washed out in ED until all visible contaminants are removed before applying dressings (36). Washouts in ED by an appropriate clinician would reduce the contamination and essentially buy more time until an orthoplastic team can perform a quality debridement. The type and amount of irrigating fluid to be used is often debated. Low-pressure washout using normal saline would be the most feasible and safest option in the ED setting as it is readily available and least likely to cause tissue trauma whilst readily removing gross contaminants. It would be difficult to accurately recommend the volume of irrigation fluid as this would depend on the level of contamination. As a rough guide, enough fluid should be used until the wound is grossly clean. Basat et al showed that >1000mls was required to achieve this in 70.5% of the 68 hand open fractures they investigated (37). The definition of 'grossly clean', however, can be highly subjective.

Fixation and coverage
Critique

The guidelines advise that if internal fixation is performed, this should be done with definitive cover. Definitive fixation and cover can be done as immediate fixation with immediate cover, immediate fixation with staged cover, or staged fixation with staged cover. An RCT by Benson et al. studied 82 open fractures by dividing them into two groups: immediate cover after debridement performed (mean time to debridement 5.4hours) and another group with delayed cover at a mean of 5.9 days after injury (38). They reported that internal fixation with immediate closure had a significantly lower infection rate than internal fixation and staged closure. However, they did not use Gustilo-Anderson grading for fracture classification, and there were no aquatic, agricultural, sewage, or gunshot wounds. The randomisation process was unclear, as were the reasons for loss of follow-up, which were more than the deep infection rates, thereby representing a high risk of attrition bias. Three other cohort studies found similar findings; one cohort study by Schemitsh et al. also found that patients who had definitive fixation and immediate cover compared to definitive fixation and staged cover were less likely to require amputation or further unplanned surgery (39-41, 42). Several studies have investigated the optimum timing of cover, and there are various combinations of comparative timelines exploring outcomes at 1, 3, 5, 7, and beyond 7 days (19, 38-40, 43-50). The majority of these studies' recurring findings are that earlier cover achieves better results in terms of deep infection, return to weight-bearing, further unplanned surgery, time to discharge, and flap failure. A small minority found no correlation (44, 48).

Improvements

External fixators as temporising measures are often used in open fractures involving polytrauma and extensive soft tissue loss; they are invaluable in damage control orthopaedics or when resources do not allow for immediate internal fixation. After the acute management, clinicians are then faced with deciding when to convert to internal fixation. Conversion can be done as a single-stage procedure whereby the ex-fix is removed and immediately replaced with internal fixation or a two-stage procedure involving a period in a cast after the ex-fix is removed and the soft tissue allowed to heal before internal fixation is attempted. The BOAST or NICE

guidelines do not shed any light on this. A review by Fram et al aimed to answer this question at the second ICM on musculoskeletal infection (51). The authors also assessed the implications of pin site infection, which is not an infrequent complication of external fixators. The evidence was limited; however, they showed that one-stage conversion appeared to have similar or even lower infection compared to two-stage conversion. They also found no evidence suggesting higher deep infection rates in the presence of superficial or pin site infection when intramedullary nailing was performed in a single-stage procedure.

The Surgical Team
Critique

Traditionally, orthopaedic surgeons would debride the wound and stabilise the fracture, and then if required, a plastic surgeon would address the wound at a later date, which meant the wound and metalwork would essential be exposed until this happened. BOAST-4 recommends that both orthopaedic and plastic surgeons be involved in the management planning and present at the initial surgical excision and stabilisation of an open fracture. One cohort study by Naique reported on 72 adults with open fractures (52). 25 patients had a combined orthoplastic management and surgery while the remaining 47 were treated with a solely orthopaedic approach. They found that the initial orthoplastic approach resulted in fewer deep infections and lower flap failure rates; they also found no significant difference in terms of amputation rates and Enneking limb scores. In terms of economic benefit, a cost analysis found that a plastic surgeon's presence could potentially achieve significant cost savings as the cost of increased staffing was outweighed by less adverse events and fewer long-term complications, such as needing to return to theatre for further procedures (13). This analysis does have some limitations; it did not consider full lifetimes cost and assumed no mortality after injury; moreover, there was no health benefit measurement such as the Quality-Adjusted Life Year (QALYS) used in the analysis, which would have made a more robust study.

Amputation
Critique

BOAST-4 recommends that decisions on amputation should be based on MDT assessment (12). Although not explicitly stated, this may infer that decisions on whether to amputate or perform limb salvage should not be based on any scoring tool following the findings from NICE GDG on complex fractures, which states that scoring tools such as MESS, MESI, PSA, LSI, NISSSA, and HS'97 had severe inaccuracies and did not have the sensitivity and specificity to predict amputations (13).

Improvement

The evaluation, assessment, and decision-making of the mangled limb are incredibly complex. The factors involved in decision-making include local resources and expertise, patient factors and wishes, and the extent of the injury. Although BOAST touches on decision-making for amputation, this subject is beyond the guideline's scope and this review.

Waiting times
Critique

Increasing ambulance and emergency department wait times in the UK means initial doctor assessment could be delayed if patients do not have a life or limb-threatening injury, resulting in significantly later antibiotic delivery than within the stipulated 1 hour from injury time (53). The earlier antibiotics are delivered, the lower the bacterial load and, therefore, less chance of developing deep infection as shown by Vallejo et al on animal models (21, 54).

Improvement

Lack et al. showed that prehospital antibiotic delivery could be performed safely by emergency medical technicians (EMTs) for a substantial number of patients with open fractures (55). This would be vital in trauma patients from remote locations and countries with long scene-to-hospital times. EMTs would need further training, and more research would need to be performed to see if this translates into better antibiotic times and reduced deep infection rates. However, future revisions to the guidelines should be cognizant of the merits of prehospital antibiotic delivery and should tap into the rapidly progressing prehospital care. This could translate into better antibiotic times and reduced infections.

Adult and paediatric populations
Critique

The current BOAST-4 guidelines include adult and paediatric population; however, almost all the studies used in the development of the NICE guidelines, and therefore BOAST recommendations, are based on adult populations (12).

Improvements

Paediatric open fractures are known to fare better than adult counterparts, and this has been borne out in numerous studies (56-58). Iobst et al. treated 40 paediatric open fractures with saline irrigation in the emergency department, IV antibiotics, and cast immobilisation after reduction (57). They reported only 1 infection which resolved with further antibiotics; all fractures went on to unite. Doak et al. similarly investigated 25 paediatric open fractures but discharged them immediately with oral antibiotics; they achieved 100% union and only one infection which resolved with further antibiotics (56). This raises the question: are we over-treating paediatric open fractures? Future guidelines may need to re-consider the need for surgery in paediatric type 1 open fractures, and there may be a case for managing these non-operatively in subsequent recommendations.

In conclusion, the development of the BOAST recommendations on open fractures is based on the NICE complex fracture guidelines. The latter is mostly evidence-based and makes use of available literature to

answer review questions relevant to clinicians treating these injuries in an acute setting. Evidence is assessed for bias and quality, then employed in the development of recommendations by a panel of experts. Overall, the BOAST guidelines are useful at providing clear, concise, and feasible advice for managing these difficult injuries. There is, however, the scope for improvement, particularly in recognising the potential value of prehospital antibiotics, local antibiotics delivery, and the difference between adult and paediatric open fractures.

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