CHAPTER **10**

# OPEN FRACTURES OF THE FOOT AND ANKLE: A Management Algorithm

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The objectives in the management of open fractures are to prevent infection, facilitate healing, and restore function. Established general principles and further advancements in the management of open fractures of the axial skeleton have dramatically improved the level of success in treating these injuries, and may reduce the incidence of unsatisfactory results. Open fractures of the foot and ankle often involve specific joint and soft tissue relationships that are necessary to appreciate and then restore for return of function. Open fractures of the foot and leg must be treated appropriately for successful return to pre-injury levels. General principles of open fracture management and anatomic and functional relationships contribute to a specific management algorithm for open fractures of the lower extremity.

Figure 1A. Gustilo Classification Type I. A fracture with a clean wound less than 1 cm long. There is minimal soft tissue involvement, and minimal contamination.

## CLASSIFICATION

The Gustilo classification of open fractures remains the most accepted means of classification, and is based on the nature of the injury, degree of soft tissue involvement, fracture characteristics, and level of contamination. This system of categorization has been well-studied and also serves as a prognostic indicator as to the statistical outcomes of these injuries based on type (Figs. 1A-1C).

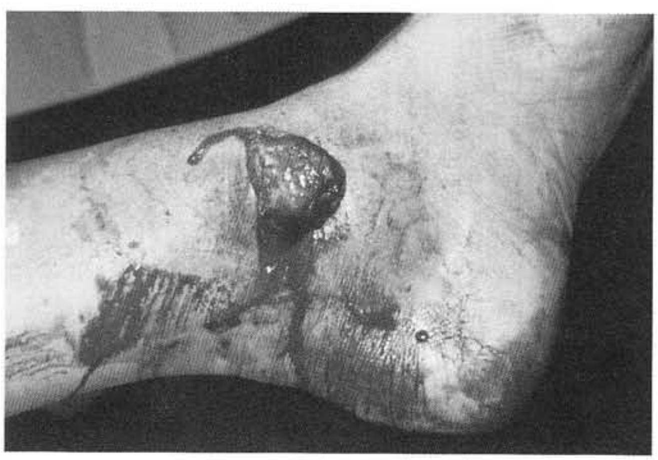

Figure 1B. Gustilo Classification Type II. A fracture with a wound greater than 1 cm long. There is moderate soft tissue involvement, and moderate contamination.

Figure 1C. Gustilo Classification Type III. A fracture with a wound greater than 5 cm long. There is extensive soft tissue involvement, and heavy contamination. There is some degree of periosteal stripping and potential neurovascular injury.

## MANAGEMENT ALGORITHM

A stepwise approach to the management of open fractures of the foot and leg has been developed by the author to provide a pragmatic and practical guide for the timely and appropriate treatment of these injuries (Table 1). The algorithm is based on accepted principles specific to the many components and considerations necessary for inclusion in the successful management of open fractures. This injury, when efficiently managed in a stepwise approach will optimize the likelihood of a successful outcome and reduce the risk of untoward complications and sequelae.

**Table 1**

### MANAGEMENT ALGORITHM FOR OPEN FRACTURES

A. Initial Considerations
   - Triage Patient
   - Wound Assessment
   - Initial Culture
   - Tetanus Prophylaxis
   - Antibiotic Selection
   - Radiographic Analysis
   - Operative Planning
   - Surgical Consent

B. Operative Considerations
   - Irrigation/Debridement
   - Operative Cultures
   - Fracture Stabilization
   - Antibiotic Considerations
   - Operative Follow-Up
   - Secondary Debridement/Closure
   - Grafting Considerations
   - Primary Amputation

C. Rehabilitation

### Initial Considerations

*Triage.* Triage is defined as the medical screening of a patient to determine the appropriate sequence of treatment. Open fractures can be associated with other traumatic injuries. Individuals presenting with this type of injury often have an established medical history. A thorough history and examination is a prerequisite to the initiation of the management algorithm. A detailed inventory, and primary and secondary survey are critical for appropriate treatment and avoidance of medical negligence. A comprehensive assessment is necessary, and is performed prior to the commencement of the open fracture management algorithm for specific open lower extremity injuries.

*Wound Assessment.* The initial wound assessment is vital prior to the initiation of treatment. A thorough wound inspection should include the neurovascular status of the involved limb/part, appropriate documentation of the injured component, presence of gross deformity, assessment of soft tissue injury or loss, degree of contamination, presence of foreign body, and general nature of the injury. The wound should be described in detail including the location, size, degree of soft tissue and/or bone loss, level of contamination, and relevant associated factors for the medical record.

The initial wound assessment should be performed prior to initial culture. Following inspection, the wound should be covered with an appropriate sterile dressing and remain stable until definitive treatment is undertaken. This protocol will reduce the risk of acquired nosocomial infection and further contamination or complication.

*Initial Cultures.* Numerous studies have documented the fact that 50% to 70% of open fracture injuries are contaminated at the time of initial presentation. All open fractures are considered contaminated wounds if evaluated and treated within 8 hours from time of injury. Open fractures presenting following this 8 hour "golden period" are considered infected wounds.

If an infection should develop following an open fracture injury, the initial wound cultures procured prior to the initiation of treatment and/or antibiotic therapy may be helpful in the identification of the infecting organism. The attainment of initial cultures has demonstrated a statistically significant correlation between the initial cultured organism and the organism later found to be a pathogen in the development of infection in some studies. Although recent controversy exists in the current literature with regard to the value of initial culture in the management of open fractures, it is generally recommended as a judicious and meaningful component in the management algorithm for open fracture injury.

Gram-positive rods and cocci remain the predominant pathogens associated with infection secondary to open fractures, however gram-negative rods are statistically becoming more prevalent. Initial cultures containing gram-negative organisms predispose an open fracture injury to a higher risk of subsequent and problematic infection.

*Tetanus Prophylaxis.* Due to the fact that the majority of open fractures are either contaminated or infected at the time of presentation, attention to tetanus history and current tetanus status is of paramount importance. It is important to implement appropriate tetanus prophylaxis prior to extension of the management algorithm for open fractures.

*Antibiotic Selection.* Numerous studies have directed attention to the prevalence of contamination in open fractures of the axial skeleton. Attending surgeons often underestimate or misinterpret the presence of contamination by clinical examination alone. It is well-known that the risk of infection following open fracture is a direct function of the type and number of bacteria present following definitive irrigation and debridement. The microbiology of open fractures is presently increasing, with the appearance of more cases involving gram-negative organisms. Specific antibiotic therapy and regimens used in the management of open fractures continues to be confusing, and the published data and current recommendations continue to be controversial.

The majority of the well-performed research data support the use of antibiotics, and their efficacy in the management of open fractures is well-established. The goal of antimicrobial therapy is directed toward initiation of rapid therapeutic concentrations of antibiotic to the tissues involved. This will reduce or eliminate the number of contaminating bacteria in a given wound. Antibiotic administration in open fracture management should be considered therapeutic and not prophylactic, and is appropriately initiated as soon as possible following patient triage.

*Radiographic Analysis.* Plain radiography is indicated in all suspected open fracture injuries involving the lower extremity. Multiple views are evaluated and comprise an important component of preoperative planning. Attention should focus on soft tissue coverage and the corresponding open fracture injuries and patterns. Comminution and isolated bone fragments should be identified and surgically approached accordingly. Many open fracture injuries of the foot and ankle involve joint surfaces, therefore preservation of joint structure and anatomic alignment are necessary for satisfactory functional outcome. The fractures are classified and an appropriate operative plan is devised based on the extent of soft tissue injury and the radiographic analysis.

*Operative Planning.* Attentive and pragmatic operative planning are essential in the management of open fracture injuries. Decisions regarding incision placement, debridement, method of fracture stabilization, intraoperative culture procurement and handling, soft tissue coverage, use of surgical drains and antibiotic considerations are itemized. The successful management of open fracture injuries may be complicated by lack of comprehensive and timely decision making or oversight. An algorithmic approach, as presented, serves as a practical template for treatment.

*Surgical Consent.* Open fractures comprise a potentially significant and complicated injury. Appropriate and timely management of these injuries enhances the potential for a successful outcome. Infection, poor healing, revisional debridement, additional surgery, utilization and removal of fixation devices, amputation, and a potential lengthy rehabilitation need to be discussed with the patient and documented. These injuries can often lead to a variable course of treatment which is dependent on multiple factors following the initial assessment and management. All potential sequelae should be discussed with the patient and family concerning the nature of the injury and potential complications.

**Operative Considerations**

*Irrigation and Debridement.* All open fractures are considered surgical emergencies. Operative treatment should ideally be initiated within 6 to 8 hours following injury. The singularly most important component in open fracture management is timely and copious irrigation, and adequate debridement of all devitalized tissue, including bone. The contribution of injured and devitalized tissue to resultant infection and complications in wound and fracture healing are well-documented. Many studies on this topic demonstrate a diminished cell mediated response to injury, as devitalized tissues remaining in the wound serve as a potential or actual nidus for poor healing and/or infection.

It is often difficult to differentiate non-viable tissue, particularly subcutaneous tissue and muscle, from healthy surrounding tissue. Tissues which are questionable should be removed, and further debridement may be necessary for definitive identification and debridement. Bone fragments which do not maintain a function in the overall stability of the fracture are also excised. Gentle pulsed irrigation in copious volume is recommended for mechanical lavage of foreign material and reduction of potential bacterial pathogens. Studies suggest that copious volume in a pulsed delivery method is of much greater importance, then usage of topical antibiotics for reduction of bacteria counts. Following repeated irrigation and debridement of all devitalized tissue and foreign material, the surgical wound is redraped, and sterile instrumentation is introduced for the remaining components of surgical intervention.

*Intra-operative Cultures*. The value of intra-operative cultures is of critical importance in the management of open fractures. Appropriately obtained deep tissue cultures at the onset of surgical intervention, and following satisfactory debridement have historically been established as a recommended protocol. Gram's stain and deep cultures procured appropriately in a controlled environment can be used to direct antibiotic therapy should infection develop. Positive cultures obtained following complete and aggressive debridement and irrigation provide the most reliable laboratory resource in determining the organism(s) responsible for subsequent infection.

Positive cultures taken prior to irrigation and debridement and negative cultures following irrigation and debridement generally indicate successful perioperative management, and reduction of contamination. Clinical wound follow-up and correlation is mandatory and gram stain and culture results should be utilized as an important, yet still adjunctive tool.

*Fracture Stabilization*. Fracture stabilization is of prime importance for satisfactory healing in open fracture management. Anatomic reduction and alignment of fracture fragments optimize the opportunity for primary bone healing and early rehabilitation. Additionally, fracture stabilization influences the healing response of soft tissues through the influx of revascularization and the promotion of host defense mechanisms involved in the healing processes. Immediate and precise anatomic reduction of fracture fragments is accomplished through internal fixation in the foot and ankle as indicated. Severe soft tissue loss and comminution of bone may require the placement of external fixators.

Open reduction and internal fixation provides an optimal environment for primary union of bone fragments, and allows early rehabilitative range of motion. Internal fixation has been documented in several studies to serve as an effective method of fracture stabilization, and is preferable to closed immobilization. The advantages of rigid bone stabilization and the resultant positive effects on soft tissue healing outweigh the possibility of complications secondary to infection. All internal fixation should remain in place until a point in time when the fixation is no longer necessary.

Most intra-articular fractures which commonly occur in the lower extremity, coupled with adequate soft tissue coverage, are well suited for internal fixation methods of fracture repair. External fixation is indicated in those fractures with gross contamination, proven infection and comminution of bone. External frames and fixators are useful in the acute management of certain open fractures and also provide for secondary and adjunctive procedures such as repeat wound debridement and soft tissue transfers. External fixators are also useful as temporary initial management prior to internal fixation placement in certain cases. Once the fracture is stabilized, treatment can be continued through internal fixation.

*Antibiotic Considerations*. The clinical use of antibiosis, specific antibiotic regimens and the duration of antibiotic therapy is a controversial and exhausting subject matter. Most well-structured prospective randomized studies on the use of antibiotics in the management of open fractures support their judicious use. Antibiotic use in the management of open fractures is considered therapeutic and not prophylactic. In this context, selection of antibiotic therapy is directed toward suspected pathogens. Clinical studies have demonstrated a historical predominance of gram-positive organisms, namely *Staphylococcus aureus* as the most common primary pathogen resulting in an infection following open fracture. Gram-negative organisms, including pseudomonas, enterobacter, and other resistant pathogens are becoming increasingly pathogenic in some patient populations and geographic centers in open fracture infection. Nosocomial multiresistant organisms and compromised hosts can account for increasing infection rates and added difficulty in the successful management of these injuries.

Antibiotic usage in the treatment of open fractures is directed towards gram-positive organisms. Gustilo recommends first and second generation cephalosporins in the management of Type I and II open fractures. An additional aminoglycoside is recommended for Type III open fractures and those injuries with significant contamination. Many appropriate alternatives exist depending on the clinical scenario and drug tolerances.

The duration of antibiotic therapy has been carefully examined, and a range of one dose to fourteen days of therapy has been recommended. Patzakis et al. have compared antibiotic regimens of 3, 5 and 10 days and recommend a 3-day course of appropriate antibiotic therapy following open fracture injury. Overall an infection rate of 3.3% compares favorably with the infection rate seen with longer therapy duration as suggested by other authors. Gustilo recommends a 3-day course as well, including as a rationale, sufficient time for final growth of wound cultures, comparison with longer courses proven to be statistically insignificant, and the fact that antibiotic toxicity is generally directly correlated with duration of therapy.

Infection rates following open fractures comprise varying statistical outcomes depending on injury type. Type I injuries are reported to have an infection rate of 0% to 9.0%. Type II injuries are reported to become infected in 1.8% to 16.0% of cases. Type III injuries and subsequent infections develop in 13.7% to 55.0% of cases. Type IIIB comprise the highest risk injuries, and Type IIIC injuries are often treated with primary amputation, thus reducing the incidence of subsequent infection in this category.

*Operative Follow-Up.* Careful follow-up and observation are indicated in these injury patterns. Attention to wound progression and tissue demarcation, as well as culture results will direct continued antibiotic therapy and further debridement.

*Secondary Debridement/Closure.* Following initial treatment and postoperative care, secondary debridement and/or primary closure are generally indicated. Care is taken to debride all non-viable tissue. Further debridement may be necessary depending on the nature of the original injury and soft tissue damage. Many crush injuries with associated open fractures lead to severe soft tissue damage, which can progress over time. Repeat surgical evaluation and debridement are often routine.

Primary closure is usually not indicated in the initial management of open fractures. Primary closure of uninjured soft tissue, opened for additional exposure to the fracture injury, can be performed, and is reserved in these scenarios. It can also be done in uncomplicated Type I injuries.

*Grafting Considerations.* Soft tissue augmentation and adequate wound coverage are contributory to successful outcomes when indicated, and should be instituted relatively early in the treatment plan. Early wound coverage consisting of rotational flaps, free tissue grafts and musculofascial transfer provide the necessary coverage for wound healing to continue.

Ideally, appropriate management and application of the algorithm will lead to an infection-free healing. As early as 3 to 10 days following open fracture, soft tissue coverage should be performed. Many authors recommend certain timing of coverage, however, general recommendations are clear that early coverage will optimize wound healing.

Bone grafting, if necessary, is delayed for two weeks or longer depending on wound characteristics and injury type. More severe injuries may require additional time prior to bone grafting. Soft tissue coverage needs to be adequate and viable, prior to osseous repair. Infection must be completely resolved, and delayed grafting can still be performed adequately at longer post-injury intervals.

*Primary Amputation.* In severe injury involving either soft tissues, neurovascular structures or bone, primary amputation of a given part or entire segment is sometimes indicated. The mangled extremity severity score (MESS) is an objective measure of severity of injury based on a point system (Table 2). A MESS score of 7 or greater generally has a 100% predictability value for amputation. This serves as a useful model for decision making relative to the indication for primary amputation.

**Table 2**

## MANGLED EXTREMITY SEVERITY SCORE (MESS)

| TYPE | CHARACTERISTICS | INJURIES | POINTS |
|---|---|---|---|
| **Skeletal/soft-tissue Group** | | | |
| 1 | Low energy | Stab wounds, simple closed fractures, small-caliber gunshot wounds | 1 |
| 2 | Medium energy | Open or multiple-level fractures, dislocations, moderate crush injuries | 2 |
| 3 | High energy | Shotgun blast (close range), high velocity gunshot wounds | 3 |
| 4 | Massive crush | Logging, railroad, oil rig accidents | 4 |
| **Shock Group** | | | |
| 1 | Normotensive hemodynamics | BP stable in field and OR | 0 |
| 2 | Transiently hypotensive | BP unstable in field but responsive to intravenous fluids | 1 |
| 3 | Prolonged hypotension | Systolic BP less than 90mmHg in field and responsive to intravenous fluid only in OR | 2 |
| **Ischemia Group** | | | |
| 1 | None | A pulsatile limb without signs of ischemia | 0* |
| 2 | Mild | Diminished pulses without signs of ischemia | 1* |
| 3 | Moderate | No pulse by Doppler, sluggish capillary refill, paresthesia, diminished motor activity | 2* |
| 4 | Advanced | Pulseless, cool, paralyzed and numb without capillary refill | 3* |
| **Age Group** | | | |
| 1 | <30 years | | 0 |
| 2 | >30 <50 years | | 1 |
| 3 | >50 years | | 2 |

* Points x 2 if ischemic time exceeds six hours. OR-operating room BP-blood pressure

### Rehabilitation

Open fracture injuries are potentially debilitating, and generally involve extensive rehabilitation. Timely and appropriate treatment protocols as discussed within the algorithm, which will increase the likelihood of successful outcomes and reduce protracted recovery time. Anatomic reduction of fractures and careful management of soft tissue injury are critical in enhancing the recovery from this type of injury.

## SUMMARY

A management algorithm based on current scientific data is presented as a primer and guide for the management of open fractures of the lower extremity. A step-wise approach serves to itemize the injury into its relative components. A comprehensive understanding of general principles of open fracture management is necessary for optimum treatment and successful outcomes in the management of lower extremity open fractures.

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