

Principles of Management of Open Fractures

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Background: Open fractures are known orthopedic emergencies associated with risk of infection and healing problems. They also present as part of the spectrum in multiply injured patients in a third of cases. The cases of open fractures are common in our environment because of motor vehicle and motorbike accidents, falls from height and sometimes gun-shot wounds. They do carry significant morbidity and subsequent disability, if not managed appropriately. The initial management of Open fractures usually affects the ultimate outcome. A closer look at principles of evaluation and management of open fractures is necessary if they are to be managed appropriately.

Methods: An English literature survey done using different search engines and databases like Google, Pubmed, Medline, EMBASE, and Cochrane library concentrating on major review articles, prospective randomized trials, selected instructional courses, current concept reviews on principles of evaluation and management of open fractures to optimize outcome.

Results: Open fractures occur isolated or as part of spectrum of injuries patients in multiply injured patients. Initial evaluation according to Advanced Trauma Life Support principles and exclusion of life threatening injuries take priority. The goals of management of open fractures are prevention of infection, appropriate management of bone and soft tissue with resultant bone healing, and restoration of function to the injured extremity. Adjuncts to management include antibiotic therapy and anti-tetanus prophylaxis and management. Classification of open fracture depends on the fracture type, the related soft tissue injury and level of contamination. In severe cases like mangled extremities clinical assessment and use Mangled Extremity Severity Score may aid in management. Definitive management includes early and through debridement, generous lavage and soft tissue closure or reconstruction, and bone stabilization. There is still controversy on timing of closure, type of fluid or method of irrigation. Extensive soft tissue injury requires the collaboration between the orthopedic and plastic surgeons and mode of fixation of the fracture will depend on fracture characteristics, anatomic location and other supplemental procedures like flaps and bone grafting.

Conclusion: Open fractures managed by following management principles heal well with decreased morbidity and extremity function is restored.

Introduction

Open fractures are complex injuries of bone and soft tissue. They refer to osseous disruption in which a break in the skin and underlying soft tissue communicates directly with the fracture and its hematoma. They are orthopedic emergencies due to risk of infection secondary to contamination and compromised soft tissues and sometimes vascular supply and associated healing problems. Any wound occurring on the same limb should be suspected as result of open fracture until proven otherwise. The principles of management of open fracture are initial evaluation and exclusion of life threatening injuries, prevention of infection, healing of fracture and restoration of function to injured extremity.

Initial Assessment

Open fractures usually result from high energy trauma and occur in 1/3 of cases of multiply injured trauma. Injury dissipated to the soft tissues and bone is equivalent to the kinetic energy ($K_E = \frac{1}{2}mv^2$), where m is mass and v is velocity of the body. It is imperative to initially manage the patient in accordance with Advanced Trauma Life Support (ATLS) principles, exclude life threatening injuries of the head, chest, abdomen and Pelvis. Resuscitation immediately instituted as may be necessary and management of associated injuries according to their priorities. Co-morbidity factors like Diabetes mellitus, malnutrition, liver disease, peripheral vascular disease, extremes of age, immune deficiency syndromes, smoking and use of steroids are associated with delayed healing and should be taken into consideration early in management.

The injured extremity is assessed for extent of wound, soft tissue injury and contamination. The neuro-vascular status of the limb is also assessed and noted and should exclude compartment syndrome¹. Soft tissues are assessed for contamination, stripping, devascularization and degree loss as they affect method of fracture immobilization and infection risk. Soft tissue injuries are vital in management of fractures and Tscherne classified them into groups according to severity and initially for closed fractures and later as understanding of pathophysiology of soft tissue improved more sophisticated and detailed grading system were developed by Hannover fracture scale and AO soft tissue grading system which can be of use in severe open fractures^{2,3}.

Exploration of the wound in emergency rooms is not indicated, if operative intervention is planned to decrease risk of further contamination. After removal of obvious foreign bodies and acquiring trauma radiographs, wounds are covered with saline soaked gauze. Appropriate antibiotic coverage and tetanus prophylaxis should be given. The current dosage of toxoid is 0.5ml regardless of age, and immune globulin is 75U for <5years, 125U for 5-10years, and 250U for >10years. They should be injected intramuscularly each from a different syringe and into different sites. Recommended Tetanus Prophylaxis is based on patient immunization history and type of wound whether tetanus prone or non tetanus prone. Non tetanus prone wound is a clean minor wound < 6hours after injury. Tetanus prone is one more than 6 hrs after injury, irregular configuration, > 1cm deep, from missile, crush, burn or frost bite. Below is a table for requirements of Tetanus Prophylaxis⁴.

Table1. Tetanus Prophylaxis Requirements for the Injured Patients⁴.

<i>Type of wound</i>	<i>Non-tetanus prone</i>		<i>Tetanus prone wound</i>	
	Td^a	TIG	Td^a	TIG
History of Adsorbed Tetanus Toxoid (Dose)				
Unknown: < 3	Yes	No	Yes	Yes
Three or more ^b	No ^c	No	No ^d	No

Td- Diphtheria and Tetanus toxoid, **TIG-** Tetanus immune globulin- human

- ^{a-} Children <7years old: (DT, if pertussis vaccine is contraindicated) is preferred to tetanus toxoid alone.
- ^{b-} If only 3 doses of fluid toxoid were received, a fourth dose of toxoid is given and preferably adsorbed vaccine.
- ^{c-} Yes, if > 10years since last dose.
- ^{d-} Yes, if > 5years since last dose.

Provisional reduction and splinting also accomplished in emergency department to decrease further injury to fracture site while moving patient or extremity.

Classification

Any system of fracture classification helps in communication between clinicians and may aid in decisions of management and prognosis. The system of classification of open fractures into three types of increasing severity was first introduced by Veliskakis⁵. This concept was fully developed by Gustilo and Anderson⁶. It was subsequently modified by Gustilo et al⁷ and is the most commonly used classification and is shown below in Table 2. The above classification had an interobserver agreement of about 60% as shown by Brombark and Jones in a study of classification of tibial fractures by 245 orthopedic surgeons⁸. Because of this disagreement, it is advisable to classify open fractures in operating theatre after extending the wound, assessing the contamination and state of the fractured bone and soft tissues. The risk of clinical infection as shown in a study by Patzakakis and Wilkins is shown in the table below and depends on fracture characteristic and location⁹. The infection of tibia fractures is twice that of other locations.

In cases involving severe crush injuries of limbs and Gustilo grade III, decision on further management is controversial. The key issue is to decide on limb salvage or amputation. The following should be considered; presence of nonviable limb, irreparable vascular injury, warm ischemic time > 8hours, severe crush with minimal remaining tissues, post salvage function less satisfactory than use of prosthesis, limb constituting threat to patient's life and injury necessitating multiple operations and reconstructions which are not compatible with the will of the patient personally, socially and economically. To help in decision

making whether limb salvage or amputation the mangled extremity severity score is used. A score of 7 or above had predictive of 100% for amputation^{10,11}. Subsequent studies by Bosse et al did not prove this predictive value for this score and other four scores for lower limbs, this multicenter lower extremity assessment project (LEAP) found that the most important factors were tibial fracture patterns, presence of open fractures, foot fractures, muscle injury, vein injury, arterial injury, and loss of planter sensation¹². More recent studies did not prove loss of planter sensation as an important factor in deciding amputation as some patient regained sensation after reconstruction¹³. Whether a salvaged limb can be better than prosthesis is still controversial¹⁴. The decision for amputation should be taken carefully taking in consideration the MESS Score, The results of LEAP Study, the psychosocial aspects of the patient and available expertise.

Antibiotic use

Open fractures are contaminated, so antibiotic cover is inevitable. Use of antibiotics in the management in open fractures significantly reduces rate of infection^{6,7,8,9,10,15}. Delay of greater than three hours increase rate of infection, and if given reduces infection by six-fold. It is advisable to give the initial dosage as soon as possible¹⁶. There is still controversy in the duration of antibiotics given in open fractures. Current literature support duration of three days^{15,16}, to be repeated at times of wound closure, bone stabilization, or bone grafting. The recommended antibiotics in open fractures are cephalosporin alone for Gustilo type I, Cephalosporin and aminoglycoside for type II, and cephalosporin, Penicillin, and Aminoglycoside for type III injuries.

The Antibiotics given should target the contaminating organisms. The most common organism infecting open fractures is *Staphylococcus aureus* and coagulase negative staphylococcus. Infections occurring in open fracture later in hospital are nosocomial and are mostly caused by gram negative. That commonly occurring in puncture wounds of the feet is *Pseudomonas aerogenosa*. Of concern are open fractures occurring on the farm or those with deep tissues without debridement as they are prone to Clostridial infections. Methicillin resistant staph.aureus (MRSA) has been isolated in patients as a community acquired and nosocomial and its appearance is associated with morbidity and mortality and increased treatment costs. It occurs commonly in institutionalized patients and intensive care units in outbreaks. Daptomycin has been approved for use against MRSA in Europe and America and its efficacy against MRSA osteomyelitis has been effectively been shown but they is scanty data on its treatment of orthopedic surgical infections in a randomized control study¹⁷. Linezolid and Vancomycin are effective against MRSA and some old antibiotics like tetracycline, Rifampicin, clindamycin and Trimethoprim-sulphamethoxazole but culture and sensitivity patten should be respected. Ciprofloxacin and other quinolones should be used with caution in MRSA due to rapid resistance except if used in combination with other antibiotics^{17,18}.

Table 2. Classification of open fractures according to Gustilo et al

Grade I	<ul style="list-style-type: none"> Wound less than 1cm, minimal contamination and muscle crushing
Grade II	<ul style="list-style-type: none"> Laceration > 1cm, moderate soft tissue damage and crushing, bone coverage adequate, contamination minimal
Grade IIIA	<ul style="list-style-type: none"> Extensive soft tissue damage, high energy with crushing component, massive contamination, severely comminuted or segmental fracture and adequate soft tissue coverage
Grade IIIB	<ul style="list-style-type: none"> Extensive soft tissue damage and crushing, massive contamination and comminution, with periosteal stripping and bone exposure, which require flap coverage. Gunshot wounds included here.
Grade IIIC	<ul style="list-style-type: none"> Fracture associated with arterial injury requiring vascular repair.

Table 3. Risk of Clinical Infection in Open Fractures by Patzakis and Wilkins

Fracture Type	Infection Risk (Percentage)
Type I	0-2%
Type II	2-10%
Type III	10-50%

Table 4. Mangled Extremity Score (Adopted from Johansen et.al. 1990)

MANGLED EXTREMITY SEVERITY	SCORE
Skeletal/ soft tissue injury:	
Low energy (stab; simple fracture; pistol gunshot wound)	1
Medium energy (open or multiple fractures, dislocation)	2
High energy (high speed MVA or rifle GSW)	3
Very high energy (high speed trauma + gross contamination)	4
Limb ischemia	
Pulse reduced or absent but perfusion normal	1*
Pulseless; paresthesias, diminished capillary refill	2
Cool, paralyzed, insensate, numb	3*
Shock	
Systolic BP always > 90 mm Hg	0
Hypotensive transiently	1
Persistent hypotension	2
Age (in years)	
<30	0
30-50	1
>50	2
*Score doubled for ischemia > 6hours	
MVA- Motor Vehicle Accident, GSW- Gun- shot Wounds	

Recent studies advise addition of gram negative cover for grade I fractures. Aminoglycoside should be used with caution in multiply injured patients whose renal function may be compromised. Ciprofloxacin replace aminoglycoside and has the advantage of oral use¹⁹. Use of local antibiotics bead construct utilizing antibiotic powder (amino glycoside) and polymethylmethacrylate (PMMA) cement reduce incidence of infection²⁰. Tobramycin or gentamycin is commonly used.

Debridement and Irrigation

Debridement of open fractures is one of the single most important principles in management of open fractures. It was first described by Desault, and now involves generous lavage. It should be done meticulously and dissection should be sharp. All debris, devitalized tissue, loose cortical bone fragments should be removed. Dissection is continued to viable tissues edges identified by colour, consistency and contractility. Grade I and II wounds need to be extended to be able adequately debride them. The recommended time for debridement within 6 hours has for long been considered critical in prevention of infection. This 6 hour rule has been questioned by literature²¹. Knowledge of perforators and angiosomes is useful for proper placement of incisions. Before we have conclusive evidence against 6 hour time before debridement, debridement should be done as soon as possible if all requirements and expertise are available. Where necessary, a repeat debridement should be done within 24 to 48 hours.

Irrigation is very important principle in open fracture management, but the method of delivery, optimal amount or irrigation solution still remain controversial. Some have proposed 3 litres for grade I wounds, 6 litres for grade II and 10 litres for Grade III injuries. Antibiotic solutions appear more effective than saline but literature support is lacking. Detergents (soap) help remove bacteria and in one study were similar in reducing risk of infection to antibiotics²². Antiseptics should be avoided as they are toxic to tissues. The pressure required remains controversial, high pressure improves removal of bacterial but damages soft tissues and bone. Low pressure like bulb syringe and suction is adequate²³. No difference was noted between use water and saline in wound cleaning²⁴. Most surgeons still use saline. Based on current evidence, normal saline should be used routinely, use of additives should be limited until we have enough supporting evidence, low pressure lavage is advocated, if high pressure is used it should be limited to 50psi²⁵.

Closure of wounds

Most wounds in open fractures are closed with delayed primary closure. Surgical incisions performed during initial debridement can be closed primarily and original open fracture wound left open. Assisted wound closure using antibiotic bead pouch or vacuum assisted dressings are useful methods. Management of wounds in open fractures may necessitate early primary closure, split skin graft (SSG),

fasciocutaneous flap, rotational muscle flap and free muscle flaps. Godina showed that wide early experienced debridement to clearly healthy tissues and early rotational or free muscle flap cover may be better in experienced hands than sequential debridement and delayed closure²⁶. Early closure has shown to prevent nosocomial infections common with multiple repeated debridements with delayed closure. The aim should be to achieve closure in 72hours.

Fracture stabilization

Fracture stabilization may be temporary or definitive. Temporary fixation includes skeletal traction and sometimes external fixation. Definitive fixation includes external fixation, plate fixation and intramedullary nailing. Each of these procedures has advantages and disadvantages. Skeletal traction may be useful in pelvic fractures and temporarily in femoral fractures for very short time. External fixation is the mainstay of treatment in severe open fracture like IIIA and IIIB, and has the advantage of allowing easy access to management of soft tissues injuries and bone transport, and can be exchanged for an intramedullary nail²⁷. For safe exchange there should be no pin tract infection and within fourteen days. The main problem of External fixator is pin tract infections, loosening and delayed or nonunion²⁸. Plate and screw fixation has higher infection rates open fractures²⁹. Plates reserved for selected periarticular fractures.

The intramedullary nails are mostly used in open fractures of the femur, radius and ulna gun-shot wounds, and grade I open tibia fractures³⁰. They are also exchanged for type II open tibial fractures. There has been controversy over using either reamed or unreamed nails. Reaming has the advantage of decreased time to healing, decreased rate of non union, and less screw breakage³¹. The superiority of unreamed nails in multiply injured patient have been shown as it decreases pulmonary complications and spares endosteal blood flow, well knowing that the soft tissue blood flow is already compromised³¹. At present in isolated fractures no consensus has been reached for or against reaming.

Adjuncts to management

Bone grafting of non union in open fractures do occur. There is the option of use of human recombinant Bone morphogenic protein (BMP) 2 in severe open fractures³², and prophylactic bone grafting.

Conclusion

The management of open fractures presents a challenge due to risk of infection, healing problems and subsequent morbidity. Antibiotics and Tetanus prophylaxis started as soon as possible. Adequate debridement and copious levage remains one of the cornerstones of management of open fractures. Early internal fixation and soft tissue closure is advocated and collaboration with plastic or micro-vascular surgeon early where necessary is advocated. Use of adjuncts to management like vacuum assisted closure, recombinant human bone morphogenic protein 2 may improve tissue and bone healing respectively. The treating surgeon has to adhere to the principles of open fracture management for optimal outcome, prevent complications and decrease hospital stay and costs.

References

1. Blick SS, Brumback RJ, Poka A, Burgess AR, Ebraheim NA. Compartment syndrome in open Tibial fractures. *J Bone Joint Surg Am.* 1986; 68:1348-53.
2. Tscherne H, Goetzen L, *Fractures with soft tissue injuries*, Berlin: Springer-Verlag, 1984.
3. Hannover Fracture Scale “98- re-evaluation and new prospects of established extremity salvage score injury, vol 32, issue 4, pages 317-328.
4. Tetanus prophylaxis. Adopted from Rockwood and Green’s fractures in adults, Fifth Edition, Vol.1, p 516.
5. Veliskakis KP: Primary internal fixation in open fractures of the tibial shaft: The problem of wound healing. *J Bone Joint Surg Br* 1959; 41:342-354.
6. Gustilo RB, Anderson JT. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. *J Bone Joint Surg Am.* 1976; 58(4): 453-8.

7. Gustilo RB, Mendoza RM, Williams DN: Problems in the management of type III (severe) open fractures: A new classification of type III open fractures. *J Trauma* 1984; 24:742-746.
8. Brumback RJ, Jones AL. Interobserver agreement in the classification of open fractures of the tibia. The results of a survey of two hundred and forty-five orthopaedic surgeons. *J Bone Joint Surg Am*. 1994; 76:1162-6.
9. Patzakis MJ, Wilkins J. Factors influencing infection rate in open fracture wounds. *Clin Orthop Relat Res*. 1989; 243:36-40.
10. Johansen K, Daines M, Howey T, Helfet D, Hansen ST Jr. Objective criteria accurately predict amputation following lower extremity trauma. *J Trauma* 1990; 30:568-72.
11. Slauterbeck JR, Britton C, Moneim MS, Clevenger FW. Mangled extremity severity score: An accurate guide to treatment of the severely injured upper extremity. *J Orthop Trauma* 1994; 8:282-5.
12. Hansen ST. Overview of the severely traumatized lower limb: reconstruction versus amputation. *Clin Orthop* 1989;143:17-19.
13. Lange RH, Bach AW, Hansen ST Jr, Johansen KH. Open tibial fractures with associated vascular injuries: prognosis for limb salvage. *J Trauma* 1985; 25:203-8.
14. Bosse MJ, McCarthy ML, Jones AL, Webb LX, Sims SH, Sanders RW, *et al* . The insensate foot following severe lower extremity trauma: An indication for amputation? *J Bone Joint Surg Am* 2005; 87:2601-8.
15. Gosselin RA, Roberts I, Gillespie WJ. Antibiotics for preventing infection in open limb fractures. *Cochrane Database of Systematic Reviews* 2004, Issue 1. Art. No.: CD003764. DOI: 10.1002/14651858.CD003764.pub2.
16. Patzakis MJ, Wilkins J, Moore TM. Considerations in reducing the infection rate in open tibial fractures. *Clin Orthop Relat Res* 1983; 178:36-41.
17. Lamp KC, Friedrich LV, Mendez-Vigo L, Russo R. Clinical experience with daptomycin for the treatment of patients with osteomyelitis. *Am J Med* 2007; 120:13-20.
18. Patel A, Calfee RP, Plante M, Fischer SA, Arcande N, Born C. Methicillin-resistant staphylococcus aureus in orthopedic surgery, *J Bone Joint Surg (Br)* 2008.90-B:1401-6
19. Patzakis MJ, Bains RS, Lee J, Shepherd L, Singer G, Ressler R, Harvey F, Holtom P. Prospective, randomized, double-blind study comparing single agent antibiotic therapy, ciprofloxacin, to combination antibiotic therapy in open fracture wounds. *J Orthop Trauma*. 2000; 14:529-33.
20. Zalavras CG, Patzakis MJ, Holtom P. Local antibiotic therapy in the treatment of open fractures and osteomyelitis. *Clin Orthop Relat Res* 2004; 427:86-93.
21. Clement ML, Pierpont Y, Pollak AN, Urgency of surgical debridement in management of open fractures. *J Am Acad Orthop Surg* 2008; 16:369-375.
22. Conroy BP, Anglen JO, Simpson WA, *et al*. Comparison of castile soap, benzalkonium chloride, and bacitracin as irrigation solutions for complex contaminated orthopaedic wounds. *J Orthop Trauma* 1999; 13:332-7.
23. Bhandari M, Schemitsch EH, Adili A, Lachowski RJ, Shaughnessy SG: High and low pressure pulsatile lavage of contaminated tibial fractures: An in vitro study of bacterial adherence and bone damage. *J Orthop Trauma* 1999; 13:526-533.
24. Burd T, Christensen GD, Anglen JO, Gainor BJ, Conroy BP, Simpson WA: Sequential irrigation with common detergents: A promising new method for decontaminating orthopedic wounds. *Am J Orthop* 1999; 28:156-160.
25. Fernandez R, Griffith R, Ussia C. Water for wound cleaning. *Cochrane Databases Syst Review*, 2002,(2)CD003861
26. Godina M. Early microsurgical reconstruction of complex trauma of the extremities. *Plast Reconstr Surg*, 1986; 76:719-728.
27. Roberts CS, Pape HC, Jones AL, Malkani AL, Rodriguez JL, Giannoudis PV. Damage control orthopaedics: Evolving concepts in the treatment of patients who have sustained orthopaedic trauma. *Instr Course Lect* 2005;54:447-62
28. Court-Brown CM, Wheelwright EF, Christie J, McQueen MM. External fixation for type III open tibial fractures. *J Bone Joint Surg [Br]* 1990;78-B:801-4
29. Clifford RP, Beauchamp CG, Kellam JF, Webb JK, Tile M. Plate fixation of open fractures of the tibia. *J Bone Joint Surg Br* 1988; 70:644-8.

30. O'Brien PJ, Meek RN, Powell JN, Blachut PA. Primary intramedullary nailing of open femoral shaft fractures. *J Trauma*. 1991;31:113-6
31. Schemitsch EH, Kowalski MJ, Swiontkowski MF, Senft D. Cortical bone bloodflow in reamed and unreamed locked intramedullary nailing: a fractured tibia model in sheep. *J Orthop Trauma* 1994; 8:373-82...
32. Govender S, Csimma C, Genant HK et al. BMP-2 Evaluation in Surgery for Tibial Trauma (BESST) Study Group. Recombinant human bone morphogenetic protein-2 for treatment of open tibial fractures: a prospective, controlled, randomized study of four hundred and fifty patients. *J Bone Joint Surg Am*. 2002; 84:2123-34.