Skeletal Stabilization in the Severely Injured Limb: Fixation Techniques Compatible with Soft Tissue Trauma.

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Abstract

Reduction and stabilization of fractures in the context of the severely injured limb is an important part of the initial management. Skeletal instability puts the surrounding soft-tissues at risk for further injury during transfers and nursing care (1). Skeletal instability even in the absence of bone loss may also compromise vascular flow by allowing limb shortening and the kinking of vessels (1) . When the skeleton is stabilized using external or internal fixation, circumferential access to the limb can be improved for monitoring of skin, swelling and vascular flow as well as for surgical intervention. This paper reviews the rationale and techniques available in the management in these patient situations with particular focus on external fixation.

Introduction

Skeletal stabilization can be extremely helpful in the patient with a severe or dysvascular extremity injury. Mangled or crush injuries disseminate high energy to the extremity causing some combination of injuries to the artery, nerve, tendon, bone, skin and muscle of the arm or leg. The mechanism can include high velocity gunshot wounds, multiple lacerations (Picture1), skin degloving from mechanical devices, and crushing impact from large objects such as machinery or motor vehicles. These all render varying degrees of damage to the affected tissues.

Skeletal fixation can improve the condition of the limb to sustain it from the acute phase to the reconstructive phase with few disadvantages. Given the setting this occurs in, these techniques should be applied rapidly, be modular in that it can be adapted to fit the uniqueness of the individual patient, and can minimally disturb the local soft tissues. Given these requirements the focus of this paper will be on external fixation although for completeness sake we will include the indications for plate fixation and intramedullary nailing.

Peri-operative communication

Communication with the general trauma surgeon as well as other services is paramount in the management of the multi -traumatized patient. One must be assured that the patient has been stabilized according to ATLS protocol (2,3,4) and can safely tolerate surgical intervention. Close communication with vascular and the plastic surgical colleagues is key in order to avoid obstruction of their surgical access by the orthopedic fixation. Having a plan endorsed by the involved services will minimize conflict and the loss of efficiency caused by need for revision of external fixation.

Initial Wound Care

Prior to application of any skeletal fixation, aggressive debridement of the skin and soft tissues is critical. Each surgeon should create a method to assure that the wound is completely and thoroughly debrided. This author superimposes a clockface on the wound and proceeds clockwise until the wound has only clean, beefy, healthy appearing tissue. If the wound is highly contaminated debridement should be repeated every 24-48 hours until the wound is sterile (See

photos 2 a, b). In those cases where repeat debridement is likely, external fixation is the optimal skeletal stabilization technique as it is easily disassembled to provide access to deep tissues including the intramedullary canal. Use of a Vacuum Assisted wound management system (Wound V.A.C.; KCI, San Antonio, TX) can decrease interstitial fluid collection in the wound , improve blood flow and decrease wound size (5). There may be difficulty sealing the wound in the setting of external fixation pins but with care this is easily overcome.

Indications:
Plate Internal Fixation
There are rare indications for plate fixation in the acute setting with a severely injured extremity. This requires a situation where the wound must be clean without any residual contamination; the plate will be covered completely by the soft tissues and lastly no further stripping or soft tissue destruction is performed during the plating. Stated otherwise, plate fixation is indicated in those patients with a fracture where the entire potential plate position is exposed but coverable by local soft tissues after fixation. These situations are rare indeed.
One potential use of locking plate fixation is application either subsutaneously outside the skin in special circumstances (6, 7, 8). These circumstances include where rigid maintenance of a reduction is preferred or that a low profile fixation is helpful. (photo 3 a-d)
Intramedullary Nailing is useful in the mangled extremity in those circumstances where the fracture is diaphyseal, soft tissue and bony injury is such that the nail will not be exposed after placement. The advantages of nail fixation are the absence of external hardware; definitive fixation and an acceptable infection rate.
External Fixation
There are two potential scenarios where acute stabilization with fixation may be advantageous in the severely injured patient. First is in damage control and the second in the isolated severe extremity injury. In both scenarios the principles remain the same although the urgency of application may differ.
In the multiply injured patient there are several scenarios where external fixation would be to the patients advantage (See table 1)
More often than these scenarios is the use of external fixation for temporary stabilization bone until soft tissue swelling resolves and definitive fixation can be performed. This is extremely useful and has significantly decreased the complication rates for severe fractures of the proximal and distal tibia. (9,10,11)

External Fixation for Skeletal stabilization techniques-
External fixation is a mainstay in the management of the severely injured extremity, especially in its early phases of treatment. External fixation is the technique of stabilizing a limb by inserting threaded pins into or wires across bone fragments and connecting these pins or wires to a frame outside the tissue. The external fixator can maintain alignment and length and the reduction if constructed to do so. The disadvantages of external fixation are listed in table 2

Prior to placing external fixation pins, a working knowledge of the neurovascular, tendinous and soft tissue anatomy (such as the extent of the joint capsule) is needed. While placement of the external fixator is often relegated to junior members of the service this knowledge is necessary to avoid injury and complications.

External fixator pins/wires in the traumatized patient are applied outside the zone of injury to minimize soft tissue insult. These "spanning fixators" span the zone of injury. Pins placed within the zone of injury are disadvantageous for several reasons. Pins inside the traumatized area provide access for bacteria to invade potential spaces created by soft tissue disruption and their

associated hematoma and cause deep infection. Pins placed within the zone of injury insult already damaged soft tissue. Lastly they penetrate bone and may provide access for bacteria so as to increase the risk of infection when hardware is placed in the area. These spanning external fixators can be converted to internal fixation or definitive external fixation when operative and surgical risk decreases (photo 4 a-c)

Lower extremity spanning external fixators are placed using Schantz pins outside the zone of injury. Because these frames are temporary and are not meant to be functional, two 5.0-mm in the femur and tibia are adequate. (Photo 5) If the extremity is intended to be mobilized in an aggressive fashion then 3 or more pins placed in more than one plane would be more appropriate. Control of the foot usually requires a centrally threaded 4.5 mm pin placed through the calcaneal body and a second smaller pin placed typically in the base of the first metatarsal. The rule of thumb is to maintain pin size less than one third of the diameter of the bone (Table 3). Most modern external fixation systems are modular so that the fracture may be reduced after pin placement and the frame secured to maintain the reduction.

Proper pin insertion technique will avoid soft tissue damage and bone thermal necrosis. Most systems have a series of drill sleeves including trocar, drill sleeve and pin sleeve to minimize risk of neurovascular injury. The pin placement technique involves a generous skin incision; spreading soft tissues to bone; use of cannulated drill sleeves; use of a sharp drill; irrigation while drilling to avoid thermal necrosis of the bone and lastly placement of the pin.

Summary

Skeletal reduction and stabilization can improve the blood flow of the limb, minimize additional injury and help control pain. It has the added benefit of improving access, both visual and tactile when compared to splinting. Practitioners managing patients with severe lower extremity injuries should be well versed in applying these techniques.

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Table 1- External Fixation indications in the Multi-traumatized Patient

Hypothermia
Coagulopathic
Closed Head Injury
Hypotensive
Polyextremity
Spinal injury
Intraabdominal or chest catastrophe
ISS >20
Base deficit

Table 2- Disadvantages of Extrenal Fixation

Mechanical
–difficulty reducing fracture anatomically
–Inadequate immobilization
–Pin-bone interface failure
–Cumbersome
Biologic
– Pin track Infections
–Neurovascular injury
–Tethering of soft tissues
–Soft tissue irritation

Table 3- Location and Pin Size

Femur – 5 or 6 mm
Tibia – 5 or 6 mm
Humerus – 5 mm
Forearm – 4 mm
Hand, Foot – 3 mm

Legend1- Propellar Injury
Legend 2- open Fractures of the patella and distal femur
a. before debridement
b. after serial debridements
Legend 3- Subcutaneous and External Fixation using Locked plates
a. soft tissue contusion preventing intervention
b. subcutaneous locking plate maintaining reduction
c. swelling and contusion resolves
d. distal subcutaneous fixation
e. final AP fixation
Legend 4- Humerus Gun Shot Wound
a. after external fixation
b. intraop during minimally invasive plating
c. union accomplished by bony bar without bone graft
Legend 5- Spanning tibial external fixator