Conversion From Temporary External Fixation to Definitive Fixation: Shaft Fractures

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Abstract

Temporary external fixation is the most common method of initial stabilization of diaphyseal fractures in forward surgical hospitals. Once the patient arrives at a stable environment, usually the United States, the fracture is managed with intramedullary nailing, small-pin external fixation, or a modified external fixator. Future research should be directed toward improving methods of care. It is not precisely known when is the best time to convert to definitive fixation without increasing the risk of infection. The risk factors leading to infection and nonunion are not well-established, making that determination even more difficult. Clinical studies of a suitable size should provide insight into these problems. Although temporary external fixation is commonly used, an optimal construct has not been determined. Data from studies of in vivo fracture-site motion after application of the temporary external fixator should be compared with biomechanical testing of similar constructs. These data could be used to recommend optimal temporary external fixation constructs of tibia, femur, and humerus fractures using currently available devices as well as to provide groundwork for the next generation of fixators.

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External fixation is the primary form of initial long-bone fracture stabilization for US and allied soldiers treated in battlefield hospitals.[1] Military use of external fixation is similar to current use in civilian trauma centers as a means of temporary limb stabilization.[1-4] The difference is that the wounded warrior is transported to a site of definitive care after initial stabilization at a battlefield hospital.[5] Once the patient is in a stable environment, the receiving surgeon can either continue with external fixation or select a different treatment method for definitive care.

External fixation is also used for civilian casualties. Although civilian casualties in a military area of conflict or a disaster-stricken region can sustain the same types of injuries as warriors in regions of conflict, their treatment is often more complicated because of limited resources and the uncertainty of follow-up care.[6-8]

Background

During the Yom Kippur War (1973) and the 1982 War, Israeli battle casualties were treated with external fixation for definitive care in certain in-

stances.[9,10] Reis et al[9] reported on 110 limbs in 99 patients from both conflicts who were treated with external fixation. The authors intended to use an external fixator for definitive care. Thirty-two of the patients were converted to another method of fixation before union, however.[9]

Conversion From Temporary to Definitive Fixation

Since the mid 1990s, external fixation has been used as a temporary solution for patients who either are severely injured and cannot tolerate more extensive surgery or have a severe limb injury, in which case a more extensive procedure would compromise the limb.[2-4]

Temporary external fixation is an option for service members who are wounded overseas and require evacuation to the United States. It enables standardized treatment with minimal physiologic insult, leaving the maximum options available for surgeons at the site of definitive care. There are no large published case series documenting the effectiveness of this treatment for warriors injured in the current conflict.

For patients with diaphyseal fractures, definitive treatment options include intramedullary (IM) nailing and external fixation (either small-pin or a "built up" external fixator). Conversion from external fixation to IM nailing has been reported in previous studies. Nowotarski et al[4] reported on 59 of 1,507 femoral shaft fractures managed with temporary external fixation and converted to IM nailing. Candidates for staged care were multiply injured patients who were too sick for immediate IM nailing or those with an ipsilateral vascular injury requiring expeditious stabilization. Forty of the shaft fractures were closed; 19 were open. Based on the Gustilo and Anderson classification, three of the open fractures were type II, eight were type IIIA, and eight were type IIIC.[4] Length of time for use of the fixators before conversion to IM nailing averaged 7 days (range, 1 to 49 days). One patient had a refractory infected nonunion, and four patients had pin site drainage at the time of conversion to IM nailing, which required a staged procedure. Based on these data, the authors recommend conversion to IM nailing within 2 weeks of external fixator application. They also recommend clinical evaluation of the patient to determine whether one-stage conversion is possible.[4]

Blachut et al[3] reported on 39 patients with tibia fractures that were initially managed with external fixation, then converted to IM nailing. External fixation was used for an average of 17 days and converted to IM nailing an average of 9 days after fixator removal. The authors reported two nonunions and one delayed union. Two patients had pin tract infection (one superficial, one deep).

Bhandari et al[11] studied published data in an attempt to better define the risk of infection and nonunion with temporary external fixation before IM nailing of shaft fractures of the femur and tibia. They also wanted to determine the relationship between the length of time a fixator is left in place and the infection rate. In nine studies, the authors found a 3.7% infection rate in 191 fractures with <28 days of external fixation; the rate increased to 22.1% with external fixation >28 days.[11] Patients with later conversion may have had more serious multiple trauma or other medical problems that did not allow earlier conversion, thus increasing the infection rate. To obtain more useful data, the authors recommend a future study incorporating 150 to 400 patients.

Care of Civilian Patients

In regions of conflict or natural disaster, military surgeons are often asked to provide humanitarian assistance to nonmilitary patients. Caring for civilians is often complicated by several factors: in war-torn or disaster-stricken areas, the patients are often homeless; the host country may lack a medical care system; and military missions often last for a limited period of time, making follow-up limited. Nongovernmental organizations also provide care to nonmilitary patients in regions of conflict or natural disaster.[6-8]

There are limited reports of external fixator use in refugee patients. Hammer et al[12] reported limited follow-up of 96 fractures managed with the Hammer external fixator system, a peel-pack single-use device with adjustable multipin clamps connected by a single bar. No short-term complications of deep infection or pin-site sepsis were reported. Follow-up was limited in both time and number of patients, however.[12]

Rowley[8] compared patients treated with either plaster casting or traction with patients treated with external fixation at International Committee of the Red Cross hospitals in Northern Kenya and Afghanistan. He reported on 64 tibia fractures, 24 of which were managed with casting and 40 with external fixation. Of the 86 open femur fractures, 51 were managed with skeletal traction and 36 with external fixation. There was no decreased hospital stay in patients with femur fracture managed with external fixation, and alignment was nearly the same in both groups. For patients with tibia fracture, however, hospitalization was 62 days for the external fixator group, compared with 32 for the casting group. There were also fewer complications in the casting group. The author concluded that use of external fixation was more likely to result in complications and require further, more extensive care beyond the capability of the hospital. These refugee patients stayed longer in the hospital than they would have in a country with a stable medical system.[8]

Has et al[7] reported on the use of external fixation for temporary and

definitive treatment of 192 patients with open fractures sustained during the war against Croatia in the early 1990s. Thirty-nine percent of the 1,658 patients admitted to the authors' institution were nonmilitary; the rest of the admissions were Croatian national guard and police.[7] Osteomyelitis occurred in 13 of 147 lower extremity fractures (8.8%) and in 7 of 68 upper extremity fractures (10.3%) treated with primary external fixation. Eight of the patients with lower limb injury and 13 of those with upper limb injury experienced delayed healing and were treated with internal fixation and bone grafting. Of those, 5 of 8 with upper limb injuries and 4 of 13 with lower limb injuries developed osteomyelitis.

Caution must be used in treating patients with external fixation when the treating surgeon may be unable to provide follow-up care. Device application should not be undertaken in a combat zone without reasonable assurance as to safe follow-up care and proper removal of the fixator.

Future Research

Open fractures caused by combat injuries are among the most serious in terms of both human and medical costs. Compared with other categories of injury, open long-bone fractures require the longest hospital bed days, third only to amputees and spinal cord–injured patients. Between 19% and 22% of battlefield casualties sustain open fracture, making this category one of the largest.[13-15] Rates of long-bone fracture infection (osteomyelitis) remain high (16% to 50%), even in more recent conflicts.[7,9,16]

Future research should be directed at developing the next generation of external fixation systems for both military and civilian use.[17-23] Pin-tract infection remains a concern for patients with temporary external fixation. Still to be determined is the precise length of time for which a fixator may be applied to a limb before being converted secondarily to another form of definitive fixation.[2-4,9] Clinical research with sufficient sample size should be a priority. Additionally, investigation should be done into manufacturing half pins out of bacteriostatic materials (ie, titanium, silver coating) or using an antibiotic-impregnated sleeve to potentially extend the time an external fixator may safely used before conversion to IM nailing.

It is unclear just what the minimum biomechanical requirements should be for an external fixator system.[17-23] Patients who sustain lower extremity fractures overseas are not required to bear weight on the limb and are transported via litter throughout the evacuation system. However, not bearing weight by use of crutches may be possible for the patient with a lower extremity fracture. Minimizing fracture-site motion during transport to a definitive care facility is important to prevent pain and sepsis at the fracture and pin sites, as well as to retain reduction. Because of limited radiographic capability, any fixation system should enable fracture reduction even after frame application.

A military fixator system also could be used for definitive care in civilian casualties and selected patients evacuated from overseas. Thus, such a fixation system should have the capability of being built up to support greater weight-bearing loads.

The use of external fixation in Iraq during the present conflict has some limitations. Clasper and Phillips[24] reported that 13 of 15 fixators (Centrafix [Forward Medical Technology, Oxford, UK] and Hoffmann II [Stryker Howmedica Osteonics, Rutherford, NJ]) applied to patients had to be revised because of complications of the injury or the fixator. Instability was a problem with 10 of the fixators, and the single-bar construct was insufficent for most long-bone fractures. This indicates that the system currently used by the US military is relatively unstable with one bar, even for temporary stabilization at a forward hospital. Additionally, the current system is not economically optimal; using two bars necessitates opening two peel packs.

Stability of the construct also can be improved. Bosse et al[17] noted marked deficiencies in the evaluation and approval of external fixation systems. Previous studies have been concerned with the biomechanical behavior of fixator constructs applied to simple experimental or computational models.[17,21,22,25-33]

In vivo levels of fracture-site motion in external fixators considered for military use, and the acceptable amount of motion, are not well established. Also, the adequacy of simplified experimental and computational models for the assessment of in vivo performance is not well understood.[14-20] With the advent of newer designs of external fixators that meet US Army requirements, now is a good time to address these issues and reevaluate the selection of fixators for military use.

Future investigations should include comparison of in vivo temporary external fixators with ex vivo biomechanical testing of fixators on a material testing machine. Correlation of the two would validate or disprove the use of simple biomechanical testing in the assessment of fixators. This would allow for better prediction of the behavior with different fixators and fixator configurations in vivo. Additionally, it would help determine both minimal acceptable biomechanical standards as well as the ideal standard constructs for use on diaphyseal fractures of the tibia, femur, and humerus.

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