Nonunion of Humeral Shaft Fractures Following Flexible Nailing Fixation

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Abstract: The treatment of humeral shaft fractures ranges from conservative modalities to operative fixation, including plate osteosynthesis and intramedullary fixation. Nonunion is a complication of conservative and operative interventions but is more often associated with elastic nailing. This article discusses elucidates the successful outcomes achieved with flexible nailing of humeral shaft fractures.

Fractures of the humeral diaphysis represent approximately 10% of all long bone fractures and occur >70,000 times per year in North America. Although >95% of patients can be managed conservatively, operative indications exist. Plate osteosynthesis and intramedullary nail fixation are the 2 most common forms of operative treatment.

Despite the success of nonoperative and operative management of these fractures, complications can occur in either treatment modality. Humeral nonunion is defined as a fracture with no evidence of healing 24 weeks after injury. It has been reported to occur in 8% to 12% of all humeral shaft fractures (Figure 1). Flexible nailing is frequently linked with operative nonunion.

This article provides an overview of humeral shaft fractures, with a focus on flexible nailing as a treatment modality and its association with nonunion.

Epidemiology

Fractures of the humeral diaphysis occur in a bimodal distribution, with the first peak comprising predominantly men in their third decade of life (25 per 100,000) and the second, larger peak comprising women in their seventh and eighth decades of life (100 per 100,000). Although high-energy trauma is associated with these injuries in young patients, low-energy mechanisms such as simple falls are mainly responsible for humeral shaft fractures in the elderly. An increasing number of osteoporosis-related fragility fractures of the humerus are occurring in the elderly.

Nonoperative Management

Humeral shaft fractures have tremendous healing potential due to the excellent blood supply of the bony fragments provided by the surrounding soft tissue and muscle envelopes; reported union rates with nonoperative management are >90%. Although anatomic reduction is rarely achieved via conservative treatment, it is not usually necessary; angulatory, rotational, and axial deformities are compensated for by the wide range of motion at the shoulder and elbow joints.

Acceptable alignment includes up to 20° of anterior angulation, 30° of varus angulation, and 3 cm of bayonet apposition. Reduction can be accomplished via various techniques, including hanging casts, coaptation splints, slings and swaths, shoulder spica casts, olecranon pin traction, and functional bracing.

Operative Management

Indications

Despite the anticipated success of nonoperative treatment...
in the majority of patients, indications for surgical intervention exist and can be stratified based on fracture characteristics, associated injuries, and patient-related indications. Fracture patterns requiring operative fixation are those in which adequate closed reduction cannot be maintained, those with segmented fractures, those with existing or impeding pathologic fractures, and those with intra-articular extension.

Associated injuries that are indications for operative stabilization include open wounds, vascular injuries, ipsilateral forearm fractures (ie, floating elbow), bilateral humerus fractures, and multiple injuries. Patient attributes that favor an operative approach include poor patient tolerance, a concern for noncompliance with conservative modalities, and an unfavorable body habitus, such as large breasts or morbid obesity.

Plate Osteosynthesis vs Intramedullary Fixation

Operative stabilization of humeral shaft fractures is most commonly performed with open reduction and plate fixation or with closed intramedullary nailing. Although plate osteosynthesis is considered the gold standard, both techniques have advantages and disadvantages. Plating creates a stable construct, enables direct visualization of the fracture and radial nerve, and is associated with minimal shoulder and elbow morbidity. It is also associated with high union rates, low complication rates, and a rapid return to function. Disadvantages of plating include large exposures, disruption of the periosteal blood supply, infection, nonunion, malunion, hardware failure, and radial nerve injury.

The advantages of intramedullary nailing include closed insertion techniques, preservation of the periosteal blood supply and surrounding soft tissue envelope, decreased operative time, decreased blood loss, and load-sharing mechanical properties that are closer to the normal mechanical axis of the humerus. The disadvantages of intramedullary fixation include shoulder pain and stiffness when inserted antegrade and the risk of iatrogenic fracture at the insertion site when placed in a retrograde fashion. Excessive reaming of the medullary canal, at times required when implants are placed in smaller canals, can cause heat necrosis and iatrogenic fractures. Other complications are similar to those seen with plate osteosynthesis, such as infection, radial nerve injury, and nonunion.

Nonunion, which is often caused by distraction or excessive motion at the fracture site, is thought to occur more commonly following nailing as opposed to plate osteosynthesis. Distraction occurs when cortical apposition of the bone ends is not achieved. Excessive motion due to poor rotational control at the fracture site occurs when the intramedullary implant is not locked or, in the case of flexible nails, when the canal is not filled. Other causes of nonunion following intramedullary fixation include disruption of the nutrient artery during nailing (because it is located in the middle third of the humerus), extreme fracture comminution, infection, open fractures, and inadequate or improperly placed fixation (Figure 2).

Figure 2: Anteroposterior radiograph of a 59-year-old woman with a humerus nonunion following locked intramedullary nail fixation. The patient was obese and a heavy smoker. The hypertrophic fracture pattern indicates motion at the fracture site, despite the fixation. The patient was relatively asymptomatic until a nail broke at the nonunited fracture site (A). Anteroposterior radiograph showing complete healing following compression plating and bone grafting of the nonunion (B).

Types of Humeral Nails

Many types of humeral nails are available. Elastic nails, such as Rush pins (Rush Pin, LLC, Meridian, Mississippi) and Ender nails (Smith & Nephew, Memphis, Tennessee) are some of the first nails that were used. Although they are effective in the setting of simple fracture patterns, they confer minimal axial and rotational stability, which can lead to nonunion. Newer nails attempt to minimize complications and include rigid and elastic types. Compression and locking mechanisms have been devised to minimize distraction and the subsequent development of a nonunion. In addition, smaller diameter nails have been created, reducing the need for excessive reaming and decreasing the risk of fracture distraction. Due to these advancements in humeral nail design, a recent meta-analysis by Heineman et al14 found nonunion rates to be similar between plates and rigid nails. This refutes the aforementioned belief that nailing is associated with higher nonunion rates. However, the study excluded flexible nailing from its analysis.

Elastic or Flexible Nailing

The current authors continue to use elastic nailing, in addition to plate osteosynthesis and locked rigid nail fixa-
patient. Most fractures heal and blood loss in the trauma tion, at their institution. Insertion of retrograde elastic nails to stabilize humerus fractures has many advantages, including decreased operative time and blood loss in the trauma patient. Most fractures heal without incident. However, the authors had several nonunions following this method that were all successfully treated with subsequent nail removal and rigid plate fixation (Figures 3, 4).

**DISCUSSION**

Many studies have assessed the effectiveness of flexible nailing as the treatment for humeral shaft fractures. In a prospective study by Hall and Pankovich, flexible nailing with Ender nails in 89 humeral shaft fractures was studied over a 6-year period. The study’s outcome measures included time to union and the frequency of complications. Average time to union was 7.2 weeks, a duration similar to that seen in conservatively treated fractures—the literature suggests a range of 6.2 to 9.4 weeks for those treated nonoperatively. Healing rates were high and nonunion was rare in the study population, occurring only once. Although distraction was cited as the cause, the authors theorized that flexible nails compensated for this via their ability to preserve the perios- teum and soft tissues during insertion.

Other studies have demonstrated different, but favorable, experiences with flexible nailing. Chen et al reported the average time to union of acute humeral shaft fractures treated with Ender nails to be 10.5 weeks, a duration greater than that observed with nonoperative treatments. Regardless, their >90% union rate is comparable with that seen in fractures treated conservatively. Nonunion fractures were thought to be caused by overdistraction. However, Chen et al reported higher nonunion rates (6.8%). Despite this, the authors felt their results satisfactory and comparable with other series investigating the surgical fixation of humerus fractures, in which nonunion rates ranged from 4% to 25%. Thus, the use of Ender nails for the treatment humeral shaft fractures was advocated. Zatti et al also endorsed their use because no difference was observed in the time to union between fractures treated via plate osteosynthesis and those with flexible nailing (11 weeks).

Distraction is a well-documented cause of nonunion. Flexible nails that do not adequately fill the canal may lead to hypertrophic nonunion because of excessive motion at the fracture site. Other factors have also been implicated. In a case report involving the use of a titanium elastic humeral nail, titanium-alloy wear particles were thought to have exerted an osteolytic effect at the fracture site, preventing healing.

**CONCLUSION**

A conservative approach to the treatment of humeral shaft fractures is typically all that is required. However, operative indications exist, and orthopedic surgeons treating these fractures must be familiar with the advantages and disadvantages of each fixation option. Although plate osteosynthesis is considered the gold standard, rigid and flexible intramedul- lary nailing are also feasible options. Elastic nails, which are more commonly linked to nonunion, have been shown to have many benefits, with good results attainable and even comparable with those seen with conservative modalities. These devices should remain in
orthopedic surgeons’ armamentarium because they can be effectively implemented in the treatment of diaphyseal fractures of the humerus. When a nonunion occurs following elastic nail fixation, the authors recommend plate fixation of the fracture with predictable subsequent healing of the nonunion.

REFERENCES