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# Humeral shaft fractures

**Andre R. Spiguel · Robert J. Steffner**

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**Abstract** Management of humeral shaft fractures has historically been largely conservative. A significant body of literature, dating back to the 1970s, has shown that functional bracing may achieve greater than 90 % union rates and acceptable functional outcomes. More recently, however, with the advent of new surgical techniques and implant options, less tolerance for acceptable deformity and functional deficits, and less patience with conservative management, many treating orthopaedic surgeons are increasingly likely to consider surgical intervention. This article reviews the current recommendations for treatment of humeral shaft fractures, including both nonoperative and operative intervention. It also discusses the current thinking and operative trends in humeral shaft fracture fixation.

**Keywords** Humeral shaft · Fracture · Anatomy · Functional bracing · Nonunion · Surgical approaches · Operative management · Plate fixation · Intramedullary nail · Trauma · Musculoskeletal

## Introduction

Humeral shaft fractures represent approximately 1-5 % of all fractures, occurring over 70,000 times a year in North America [1–3]. There is a bimodal distribution with peaks primarily in young male patients, 21–30 years of age, and a larger peak in older females from 60–80 years of age [4]. Management of these fractures has been discussed in surgical texts for more than three millennia and has challenged medical practitioners since the beginning of recorded medical history. In the earliest surgical texts dating back to 1600 BC, reduction maneuvers were discussed using traction, followed by bandaging with linen and other conservative measures [5].

Conservative management is not only important from a historical perspective, but also continues to be the mainstay of treatment for isolated humeral shaft fractures with overall good results. However, non-surgical management is associated with some morbidity and complications have included nonunion, as high as 20 % in some studies, malunion, and persistent radial nerve deficits [6–9, 10•]. Operative treatment is indicated in specific circumstances including open fractures, associated neurovascular injury, proximal and distal articular extension, patients with multiple injuries or polytrauma, floating elbow, progressive radial nerve deficits, significant soft tissue injury (unable to brace), pathologic fractures and failed non-operative management [2, 10•, 11]. More recently, the general patient as well as the treating orthopaedic surgeon is less tolerant of the more labor intensive methods of conservative management, and less tolerant of what was formerly thought to be acceptable deformity [1].

## Anatomical considerations

The humerus itself is a cylinder proximally, which provides strength and resistance to both torsional and bending forces, and distally it tapers to a triangular shape. It is enveloped in muscle and soft tissue, hence the favorable prognosis for healing in uncomplicated fractures. Muscles originating on

A. R. Spiguel (✉)
University of Chicago Medical Center,
5841 S. Maryland Ave, MC# 3079,
Chicago, IL 60637, USA
e-mail: aspiguel@uchicago.edu

R. J. Steffner
University of California – Davis Medical Center,
Ellison Ambulatory Care Center,
4860 Y Street, Suite 1700,
Sacramento, CA 95817, USA
e-mail: robert.steffner@ucdmc.ucdavis.edu

the humeral shaft include the brachialis, brachioradialis, and the medial and lateral heads of the triceps brachii. The deltoid, pectoralis major, teres major, latissimus dorsi, and coracobrachialis all insert on the humeral shaft and depending on the location of the fracture, all will have specific deforming forces acting on the fracture fragments. The blood supply to the humeral shaft is provided predominantly by the nutrient artery that should be protected during surgical dissection [12].

The arm can also be divided into anterior and posterior compartments by thick fibrous bands – the medial and lateral intermuscular septa. The brachial artery, median nerve and musculocutaneous nerve remain in the anterior compartment for their entire course and are rarely encountered in surgical exposures to the humerus. The median nerve receives contributions from the medial and lateral cords of the brachial plexus, and then travels just medial to the brachial artery, adjacent to the coracobrachialis muscle belly and along the anterior surface of the medial intermuscular septum. It provides no innervation to muscles proximal to the elbow.

The ulnar nerve arises from the medial cord of the brachial plexus and begins in the anterior compartment. It travels anterior to the medial intermuscular septum and posterior to the brachial artery. At the arcade of Struthers, approximately 8 cm from the medial epicondyle, it crosses to the posterior compartment to enter the cubital tunnel. It also provides no innervation to muscles proximal to the elbow.

The radial nerve is a terminal branch of the posterior cord of the brachial plexus. It begins in the posterior compartment and then passes through to the anterior compartment. It begins anteromedially and travels along the subscapularis proximally to join with the profunda brachii at the triangular interval. About 10–14 cm from the lateral acromion, the nerve and artery travel along the posterior humerus in the spiral groove, separating the medial and lateral heads of the triceps at about the level of the deltoid tuberosity. It enters the anterior compartment though the lateral intermuscular septum approximately 10 cm from the distal articular surface, here it is tightly bound by the septum and therefore susceptible to traction injuries and radial nerve palsies [12, 13].

## Current concepts in nonoperative versus operative intervention

Because the glenohumeral joint has an exceptional range of motion in many planes, deformity is well tolerated after union. Acceptable fracture alignment, which is the guide to continued conservative management, includes 20 degrees of anterior bowing, 30 degrees of varus angulation, 15 degrees of malrotation, and 3 cm of shortening or bayonet apposition [14]. Traditionally, nonoperative management of humeral shaft fractures is the mainstay of treatment although there can be some drawbacks. Treatment with functional bracing can lead to loss of some shoulder external rotation, flexion, and abduction in 10 % to 30 % of patients. Also, loss of elbow flexion and extension is impaired in less than 10 % of patients [6, 15, 16]. Sarmiento and colleagues have published a relatively large series of 620 patients with 97 % union rates and high satisfaction rates with functional bracing. They demonstrated the benefits of treatment with functional bracing as it leads to acceptable outcomes with little morbidity [7, 8]. These excellent results have not been universally reproduced in other studies, which is why there continues to be significant controversy regarding optimal management.

There is also significant controversy regarding what specific type of humeral shaft fractures are best treated with a fracture brace. Rutgers and Ring retrospectively reviewed treatment of diaphyseal humerus fractures that were treated with functional bracing and found proximal third long oblique fractures may be at greater risk of nonunion (39 % in their study), they attribute this to the pull of the deltoid on the distal aspect of the proximal fragment and muscle interposition [9]. Toivanen et al also noted that over half of the fractures of the proximal third of the humerus in their study treated with functional bracing also went on to nonunion [17].

Other authors have concluded that treatment of transverse, displaced fractures of the middle and distal thirds of the humeral shaft are also at increased risk of nonunion. Wallny et al retrospectively evaluated the indications and results of treating humeral shaft fractures with functional bracing. They concluded that the ideal indication for functional bracing of the humeral shaft is in spiral or oblique fractures of the middle or proximal third of the humerus, and they did not recommend bracing for distal humerus fractures [18].

With regard to extra-articular distal third humeral shaft fractures, Jawa et al retrospectively compared functional bracing and plate fixation. In the plate fixation cohort of 19 patients, they found that all patients regained shoulder motion within 10 degrees of normal, and the average loss of elbow motion was 3 degrees. There were no nonunions and complications included one infection, one distal fixation screw loosening due to osteopenia, and 3 patients with new onset radial nerve palsies post operatively. Of the 21 patients in the nonoperative cohort, two patients ended up with surgery and plate fixation, both for malalignment. The rest of the patients treated nonoperatively went on to heal, although six healed with 11–20 degrees of malalignment and three healed with greater that 20 degrees of malalignment. Their conclusion was that both treatment methods have advantages and disadvantages. Operative treatment, although associated with additional operative risks, is associated with more predictable alignment and immediate stability and therefore more rapid restoration of function [19].

Lastly, Denard et al directly compared outcomes of nonoperative versus operative management of humeral shaft fractures in a retrospective study of 213 patients. They found a statistically significant difference in the occurrence of nonunion (20.6 % versus 8.7 %) and malunion (12.7 % versus 1.3 %), more common in the nonoperative group. They demonstrated that operative intervention had no significant difference in time to union, infection, or iatrogenic radial nerve palsy. They concluded that with recent improvements in plating techniques and implants, acute surgical management of humeral shaft fractures should be considered; and that although functional bracing achieves acceptable results with few complications, the incidence of nonunion and malunion may result in further operations with added morbidity to correct the problem [10•].

## Operative management of humeral shaft fractures

Absolute indications for surgical intervention in humeral shaft fractures were discussed earlier in this review. Other relative indications include 1) obese patients, who do not tolerate bracing well and frequently end up with coronal plane deformities; 2) patients with associated brachial plexus injuries due to the loss of muscle co-contraction and its ability to maintain bony alignment; and 3) non-compliant patients, who do not adhere to upright posture, elbow motion, and brace tightening instructions [6, 7]

Approaches to the humeral shaft should be dictated by the location of the fracture. The anterolateral exposure utilizing the deltopectoral interval with extension down the arm through a brachialis split provides excellent exposure to the proximal diaphysis. Distal extension is limited by the radial nerve piercing the lateral intermuscular septum [13]. Posterior approaches facilitate exposure of distal third fractures and can be extended proximally with mobilization of the radial nerve from the spiral groove. Variations include the triceps split, paratricipital release, and triceps slide. The triceps split interval is between the lateral and long heads of the tricep and then splits the medial triceps. The paratricipital approach involves elevating the triceps off the lateral and medial intermuscular septae. The triceps slide utilizes the posterior antebrachial cutaneous nerve to identify the radial nerve and then elevates the tricep from lateral to medial. Described by Gerwin and Hotchkiss, this approach allows extensive exposure to the humeral shaft and is limited proximally by the axillary nerve [20]. Medial approaches are rare and often necessitated by accompanying vascular injuries requiring repair. A straight lateral approach utilizing the posterior compartment of the arm and lifting the lateral tricep off the intermuscular septum can also be used and has the advantages of being extensile in either direction and affording direct visualization of the radial nerve [21].

Minimally invasive approaches are now being used in conjunction with anterior humeral plating. This utilizes the proximal and distal limbs of the anterior approach. The proximal incision is made 5 cm distal to the anterior acromion along the medial border of the deltoid tuberosity and utilizes the interval between the bicep and deltoid. The distal incision is placed lateral to the biceps tendon and 5 cm proximal to the elbow flexion crease. Upon developing the interval between the bicep and brachioradialis, the brachialis is split at its medial two-third and lateral one-third junction facilitating protection of the musculocutaneous and radial nerves.

Once exposed, the humeral shaft can be stabilized with external fixation, plating, or intramedullary nailing. Most fractures are still fixed with plate osteosynthesis; however, intramedullary nailing is becoming more common. Use is often determined by the fracture personality and surgeon preference (Fig. 1) [22•].

External fixation is primarily used in damage-control situations where the patient is too unstable for more time consuming procedures. In such scenarios, the frame is constructed for temporary stabilization to facilitate wound care, patient transfers, line access, and pain control. These patients are frequently converted to internal fixation once hemodynamics and associated injuries have improved. Safe conversion to a plate can be done within two weeks; the same interval is assumed for intramedullary nails, although this has not been demonstrated in the literature [23•]. Additional indications for external fixation application include severe soft tissue injuries, vascular injuries requiring quick stabilization before repair, and an unstable elbow joint after bony fixation [24–26]. When placing the frame, it is important to appreciate the possibility of neurovascular injury with Schanz pin placement. Anterolateral pins both proximal and distal in the arm can threaten the axillary and radial nerves. Injury can be prevented by making larger incisions to allow improved visualization, palpation, and surgical dissection down to bone [27].

Humeral plating has been the predominant mode of fixation due to its reliable union rate, lower reoperation rate, and avoidance of adjacent joint discomfort [28]. There is substantial variability in plating that allows the surgeon to modify the construct to the personality of the patient and fracture. Simple fractures are best treated with compression plates, comminuted fractures are often bridge plated, and osteopenic or torsionally unstable fractures are candidates for locked or hybrid plate fixation [29]. Contemporary plates used in humeral shaft fractures are 4.5 mm limited-contact plates with combination holes to accommodate either cortical or locking screws. These plates come in

**Fig. 1** Three examples of different humeral shaft fracture stabilization options determined by the personality and location of the fracture. Posterolateral precontoured periarticular plate with lag screw fixation for a distal humeral shaft fracture through a posterior approach. Anterior humeral compression plating through an anterolateral approach for a simple, diaphyseal, short oblique fracture with minimal comminution. Intramedullary nailing for a comminuted proximal third humeral shaft fracture

narrow and broad varieties. Both have holes at the plate ends that allow use of an articulating tensioning device to provide fracture site compression. The broad plate has staggered holes to improve screw density and limit the development of stress risers. These robust plates allow early weight-bearing [12, 30•]. Fractures in the more proximal and distal humeral shaft benefit from use of precontoured periarticular plates that provide multiple points of fixation in small segments of bone. These holes utilize smaller screws with greater thread density and often permit use of compression or locking screws. In the distal-third of the humerus, "90–90" degree dual plating with a malleable lateral reduction plate and a more stout posterolateral extraarticular plate has been shown to lead to good alignment and union [31]. When plating fractures with far cortex bone loss or severe osteopenia, placement of a cortical strut allograft can be considered to augment the far cortex and provide purchase for the screws at that level [32].

Traditional plate fixation has the drawback of requiring larger incisions, violation of the fracture hematoma, and higher incidence of iatrogenic radial nerve palsy [1, 12]. In an effort to avoid these drawbacks, Minimally Invasive Plate Osteosynthesis (MIPO) has been developed for humeral shaft fractures. Indicated for fractures 6 cm below the surgical neck and 6 cm above the olecranon fossa and using the two-incision approach described earlier, a 10 to 12 hole narrow 4.5 mm plate is inserted submuscularly and provisionally stabilized through each incision [29]. Reduction is obtained through traction, arm manipulation, and sometimes temporary use of an external fixator frame. Three screws are then placed on each side of the fracture. This method protects the radial nerve and preserves fracture site biology [33]. Potential drawbacks include brachial scarring and subsequent loss of elbow motion, difficulty obtaining an adequate reduction and resultant increase in radiation exposure and operative time, and risk of nerve injury with percutaneous screw placement [34•]. Recent studies evaluating outcomes of MIPO plating have been favorable [33, 35]; however, more prospective studies will be necessary before wide-spread use is recommended.

Intramedullary nailing of humeral shaft fractures has the benefit of smaller incisions, preserved fracture site biology, and load sharing properties [36, 37]. Use of these implants, however, has been infrequent due to concerns of nonunion, reoperation, stiffness, start site fracture, and adjacent joint pain [1, 12]. Interest in this mode of treatment has been renewed due to shifts in humeral shaft fracture epidemiology, implant design, and surgical technique. Intramedullary nails are currently the preferred mode of treatment for fractures with associated soft tissue injury, pathologic fracture, diaphyseal segmental fractures, and osteopenic bone. Humeral shaft fractures in elderly patients with poor bone quality is on the rise, particularly in the United States [38, 39]. These patients are best treated with a load sharing device. The load sharing properties have been augmented by developments in nail design. Conventional nails are larger, more rigid, anatomically contoured in the proximal coronal plane, allow for dynamic fracture compression, and equipped with multiple points of fixation both proximal and distal to provide angular stability. Greater interlocking options have expanded nail indications for more proximal and distal shaft fractures. The improved proximal geometry of nails reduces the amount of fracture site displacement. Some nails designed for proximal shaft fractures have a straight proximal geometry that helps align the medial calcar and avoids insertion through the Sharpey fibers at the footprint of the insertion of the rotator cuff. Patients with larger canals are good candidates for an intramedullary nail as they can accommodate a 9 mm or greater nail diameter with minimal reaming. Reaming is kept to a minimum to avoid bone loss and iatrogenic fracture. From a technical standpoint, using the surgical interval between the anterior and middle deltoid raphe makes it easier to expose and work through the rotator interval. This, in addition to a more medial start site with the guide pin, makes it easier to mobilize and protect the subscapularis and supraspinatus tendons [40]. Joystick Kirschner wires can then be placed into the humeral head to gain better control of the proximal segment and facilitate reduction of the calcar. This can then be held in place by provisional Kirschner wires out of the anticipated path of the intramedullary nail [41]. If reaming is to be performed, the reamer head should be stopped and pushed across the fracture zone in order to prevent secondary mechanical injury to soft tissues and thermal effect on the radial nerve. Once the nail is placed, it should be countersunk below the humeral head articular surface to avoid subacromial impingement [1]. In fractures conducive to compression, the nail can be buried further and "backslapped" to achieve cortical contact and aid union [42]. An intramedullary nail performed with attention to technical detail has a high incidence of union and good functional outcomes [43, 44]. While antegrade nails are more common and easier to perform, retrograde humeral nails are a consideration in distal shaft fractures and have the same union rate as antegrade [45]. To avoid angular malalignment, iatrogenic supracondylar fracture, and olecranon impingement, an in-line start site in the superior olecranon fossa is advocated. This site should be reamed 2 mm larger than the nail diameter to allow unforced entry of the implant [46]. Reaming for retrograde nails should be done carefully to avoid an unfavorable situation of bone loss with an iatrogenic fracture at the start site.

Choosing to plate or nail a humeral shaft fracture is becoming more a matter of patient preference with potential complications and surgeon familiarity. A meta-analysis that previously favored plating over nailing was recently updated and noted equivalent outcomes in rates of nonunion, infection, nerve palsy, reoperation, and total complications between humeral plating and nailing [47]. With modern implants and surgeons adept to their use, humeral union and functional outcomes has been shown to be the same between plates and nails [48•]. Implant selection should ultimately be based on patient factors, fracture personality, associated injuries, and surgeon preference [8]. Patients should be counseled about iatrogenic radial nerve palsy with plates and rotational malalignment and adjacent joint pain with intramedullary nails [49•, 50].

## Conclusion

Surgeon experience and newer studies assessing functional outcomes in nonoperative patients have challenged the belief that humeral shaft fractures uniformly do well without surgery. Studies have noted permanent loss of motion and elevated rates of nonunion with non-surgical management. Further, specific patterns have been shown to demonstrate higher rates of nonunion including simple fractures patterns (little surface area for bone to bone apposition and higher fracture site strain) and proximal-third oblique patterns (soft tissue interposition and deforming muscle forces). This has led to broader operative indications. As a result, patient factors are receiving greater consideration and leading to doctor-patient discussions weighing the benefits of early full motion, rapid return to therapy and work, and pain control versus the risks of iatrogenic radial nerve palsy, infection, bleeding, nonunion, reoperation, and anesthetic risk.

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