Management of Acute Proximal Humeral Fractures

Abstract

Proximal humeral fractures, which typically occur in elderly persons, are among the most common fractures. A myriad of nonsurgical and surgical treatment options exist for these injuries, including short-term immobilization and early physical therapy, percutaneous fixation, plate osteosynthesis, intramedullary nailing, hemiarthroplasty, and reverse shoulder arthroplasty. The choice of treatment depends on the fracture type and severity, surgeon expertise, patient age, and patient health status.

Proximal humeral fractures are the third most common fractures, following hip and distal radius fractures. They account for approximately 5% of all fractures, and they are increasing in frequency. The elderly population has a higher incidence of proximal humeral fractures and typically sustains more complex fracture patterns than those sustained by a younger patient population. Given the likelihood of poor bone quality in this population, the surgeon should maintain a high level of suspicion for fragility fracture associated with relatively minimal trauma.

Anatomy

The proximal humerus is divided into four parts: the greater and lesser tuberosities, the head, and the diaphyseal region. Its articulation with the scapula produces a very mobile glenohumeral joint, which is supported by muscle groups about the shoulder girdle. Its articular with the scapula produces a very mobile glenohumeral joint, which is supported by muscle groups about the shoulder girdle. The rotator cuff muscle complex is made of four muscles that attach to the tuberosities. The supraspinatus, infraspinatus, and teres minor tendons insert onto the greater tuberosity, and the large subscapularis tendon attaches to the lesser tuberosity. Innervation to the supraspinatus and infraspinatus muscles occurs through the suprascapular nerve, whereas innervation to the subscapularis and teres minor muscles occurs through the subscapular and axillary nerves, respectively. These muscles are not only responsible for coronal and axial motion but also serve as dynamic stabilizers of the glenohumeral joint. The deltoid muscle is a large muscle innervated by the axillary nerve that originates from the lateral clavicle, acromion, and scapular spine and inserts on the deltoid tuberosity of the humerus. It is composed of three heads separated by intramuscular raphae: the anterior deltoid (responsible for forward flexion and internal rotation), the middle deltoid (responsible for abduction), and the posterior deltoid (responsible for extension and external rotation). On average, the humeral head-neck angle is 135°, and the humeral head angle is 19° to 22° and is retroverted in relation to the humeral shaft, although some evidence would suggest a variability ranging from −6°...
The bicipital groove is between the greater and lesser tuberosities. Immediately lateral to this groove is the insertion of the pectoralis major, which is innervated by the lateral and medial pectoral nerves and provides an internal rotation and adduction force to the proximal humerus. When these muscles work together, they provide wide degrees of motion in multiple planes simultaneously. However, in the setting of a proximal humeral fracture, the muscles become deforming forces, translating the bony attachments in the direction of the respective muscle force vectors.

Historically, the ascending branch of the anterior humeral circumflex artery has been described as the primary source of the vascular supply to the humeral head. The high rate of injury to this vessel and lower rates of osteonecrosis associated with proximal humeral fractures emphasize the importance of the vascular anastomoses about the humeral head. A cadaver study found that the posterior humeral circumflex artery supplied blood to 64% of the humeral head, which may explain the low rate of osteonecrosis after proximal humeral fractures.

Fracture Classification

The Neer classification is the most widely used system for classification of proximal humeral fractures. Building on the 1934 Codman classification, which divided the proximal humerus into the lesser tuberosity, the greater tuberosity, the head, and the shaft, Neer expanded the classification to include the concept of fracture displacement and angulation. A fracture was considered displaced in the setting of “an angulation of $>45^\circ$ or a separation of $>1$ cm” (Figure 1). Despite poor interobserver reliability (a mean kappa coefficient of 0.52), this system commonly is used to classify proximal humeral fractures. The addition of advanced imaging, such as CT, helps to improve intraobserver and interobserver reliability, although not substantially. These fractures also may be classified according to the AO/Orthopaedic Trauma Association classification system (Figure 2). In this classification, type A fractures are unifocal and extra-articular, involving one of the tuberosities without metaphyseal comminution. Type B fractures are bifocal and extra-articular, with metaphyseal and tuberosity involvement. Type C fractures are intra-articular and include fracture-dislocations or head-split fractures. As in the Neer classification, proximal...
humeral fractures carry the risk of osteonecrosis; type C fractures, in particular, present a substantial risk of osteonecrosis. Hertel et al noted the importance of the metaphyseal head extension—a radiographic measurement of the articular fragment from the head-neck junction to the inferior extent of the medial cortex—as a predictor of ischemia after proximal humeral fracture. The study found that metaphyseal head extension of <8 mm and medial hinge disruption >2 mm correlated strongly with humeral head ischemia. Despite these findings, Bastian and Hertel later found that initial postfracture humeral head ischemia does not predict the development of necrosis, suggesting that osteosynthesis with preservation of the humeral head is worth considering in the setting of adequate reduction and stable conditions for revascularization.

Nonsurgical Management

Most proximal humeral fractures are amenable to nonsurgical management; however, patients must understand the expectations and comply with the treatment program. In general, excellent results have been achieved with short-term immobilization (<2 weeks) in a sling and early physical therapy. Most of the literature supports early mobilization, but it is important to ensure that further fracture displacement does not occur.

Nonsurgical treatment of two-part fractures with early rehabilitation has been found to be at least as efficacious as surgical treatment in injuries with minimal displacement. In the setting of considerable displacement, a block to range of motion, and involvement of the anatomic neck, better outcomes may be achieved with surgical fixation, although well-designed comparative studies of surgical versus nonsurgical management of two-part fractures are lacking (Figure 3). Some authors have found that greater tuberosity fractures with >5 mm of displacement may benefit from surgical fixation to reduce the risk of subacromial impingement. Lesser tuberosity fracture with internal rotation impingement may benefit from surgery if nonsurgical management fails. In contrast to other parts of the proximal humerus, the anatomic neck is devoid of soft-tissue attachments and has a tenuous blood supply, which may result in an increased risk of osteonecrosis.

Although three-part and four-part fractures often require surgical fixation, nonsurgical management can be

considered for patients with poor baseline function and/or an inability to tolerate a surgical intervention. In select three-part and four-part fractures, particularly valgus-impacted fractures with <1 cm of displacement of the tuberosities in relation to the head fragment, nonsurgical treatment may yield good to excellent results.\(^{20}\) Although surgical management of complex fracture patterns generally is advocated, the efficacy of surgical versus nonsurgical management remains to be elucidated fully. In a study of 60 elderly patients with a displaced three-part fracture of the proximal humerus, Olerud et al\(^{21}\) found that surgical management with a locking plate resulted in better functional outcomes and health-related quality of life than did nonsurgical treatment, but at a cost of additional surgery in 30% of patients. In contrast, a meta-analysis of randomized controlled trials did not find improved functional outcomes with open reduction and internal fixation (ORIF) compared with nonsurgical treatment in elderly patients with displaced three- or four-part proximal humeral fractures.\(^{22}\) The study concluded that these results must be considered in the context of variable patient demographics. A systematic review supported the use of nonsurgical treatment of proximal humeral fractures and noted a 2% rate of osteonecrosis mainly associated with three-part or four-part proximal humeral fractures.\(^{23}\) Ultimately, the patient’s baseline physiology and function may help to quantify the potential advantages of nonsurgical management, even in the setting of complex fracture patterns.

### Surgical Management

Complex proximal humeral fractures are challenging to manage and frequently need to be addressed surgically. Internal fixation and arthroplasty are the most commonly employed strategies to manage complex fractures of the proximal humerus. In select patients, percutaneous fixation remains a feasible option in the surgeon’s armamentarium.

#### Percutaneous Fixation

Closed reduction and percutaneous pinning (CRPP) of proximal humeral fractures was initially described by Bohler in 1962 and, in some reports, has been purported to be superior to open techniques, with higher union rates, lower rates of osteonecrosis, decreased scar formation, and improved cosmesis.\(^{24}\) Classic surgical indications have included two-part fractures of the surgical neck, greater tuberosity, and lesser tuberosity; three-part surgical neck fractures with involvement of the greater or lesser tuberosity; and valgus-impacted four-part fractures (Figure 4). For CRPP to be successful, stable and satisfactory closed reduction must be achieved, adequate bone stock with minimal comminution and an intact medial calcar should be present, and the patient must comply with postoperative immobilization and management.\(^{24}\)

Biomechanical studies have found CRPP to be inferior to ORIF, although stability can be enhanced with the use of larger diameter pins, multiple pins, and cortically engaging pins placed in a multiplanar configuration.\(^{24}\) Historically, clinical studies have found the outcomes of CRPP to be satisfactory;\(^{24,25}\) however, in a comparative study of the outcomes of CRPP, ORIF, hemiarthroplasty (HA), and reverse shoulder arthroplasty (RSA) for management of three- and four-part proximal humeral fractures, Gupta et al\(^{1}\) found that the complication rate associated with CRPP was considerably higher than those associated with ORIF, hemiarthroplasty (HA), and reverse shoulder arthroplasty.
The overall complication rate was highest for CRPP (28.4%), followed by RSA (18.9%), ORIF (15%), and HA (11.3%). The revision rate for CRPP, excluding necessary surgery performed for implant removal, was 1% and involved revision to RSA. Revision rates for ORIF, RSA, and HA were 12.7%, 5%, and 4.9%, respectively.

CRPP techniques vary but have some similar principles. Typically, the humeral head and shaft are fixed first using terminally threaded 2.5-mm Schanz pins placed in a retrograde, lateral-to-medial direction, accounting for humeral head retroversion in a safe zone proximal to the deltoid insertion to avoid the radial nerve and distal to the course of the axillary nerve, approximately 5 cm distal to the acromion (Figure 5). The ideal starting point is typically twice the distance from the top of the humeral head to the most inferior margin of the articular cartilage. Tuberosity fixation can be achieved with pins or with 3.5-mm, 4.0-mm, or 4.5-mm cannulated screws inserted anterograde from the tuberosity bicortically into the calcar for the greater tuberosity or unicortically into the head for the lesser tuberosity. Medial calcar fixation should be performed at least 2 cm distal to the articular surface to minimize injury to the neurovascular bundle, including the axillary nerve and the posterior humeral circumflex artery. Pins and screws are buried underneath the skin, the arm is immobilized for 3 to 4 weeks, and the pins are removed in 4 to 6 weeks.24,25

Complications associated with CRPP include malunion (28%), pin migration or loosening in up to one third of patients, pin-track infection, neurologic injury affecting the axillary and radial nerves laterally and the musculocutaneous nerve anteriorly, soft-tissue injury to the cephalic vein and biceps tendon anteriorly, and osteonecrosis (28%), although the risk of osteonecrosis can depend largely on the initial fracture pattern.1,24,25

Plate Osteosynthesis

The advent of fixed-angle locking plates has revolutionized the management of proximal humeral fractures because the locking screw technology allows more secure fixation in comminuted and/or osteoporotic bone. Plate fixation is an excellent choice for management of substantially displaced two-part fractures that require surgery and for three-part fractures without considerable comminution (Figure 6). Four-part fracture fixation may be attempted with a locking plate construct but may be more challenging, with less predictable results. We believe that, in active patients aged <65 years with acceptable bone stock and minimal comminution, internal fixation should be attempted or should be considered strongly. Although low bone mineral density may not be predictive of mechanical failure, fracture collapse into varus is a risk after plate fixation; this can be minimized in the setting of a noncomminuted medial calcar and good calcar screw fixation. Care should be taken when plate osteosynthesis is performed; proud plate fixation may lead to impingement against the acromion with abduction, and a plate that is placed too low risks poor humeral head fixation.

Compared with HA, locked plate fixation has been shown to provide better functional outcomes and a higher rate of patient satisfaction. Solberg et al27 compared the results of HA and locked plate fixation for...
management of three-part and four-part fractures in a consecutive group of 48 patients treated with HA and 38 patients treated with locked plate fixation. At a mean follow-up of 36 months, the authors noted higher Constant scores in the patients who underwent ORIF. Poorer results were noted in patients with four-part fractures than in those with three-part fractures. A loss of fixation was more common in fractures with initial varus and extension deformities; patients with these fractures had worse outcomes than did those with valgus impaction fractures. Despite better outcomes, the complication rate can be higher with fixation than with HA, and the most common complications are osteonecrosis and screw cutout. Solberg et al\textsuperscript{27} also found that initial varus fracture displacement in a group of patients treated with plate fixation was associated with lower Constant scores, loss of fixation, head perforation, varus malreduction, and tuberosity displacement $>5$ mm. Osteonecrosis of the humeral head associated with a head metaphyseal segment of $<2$ mm was noted, as well.\textsuperscript{27} In a systematic review of locking plate fixation, Thanasas et al\textsuperscript{28} reported a 7.9\% rate of osteonecrosis overall; however, in patients with four-part fractures, the rate was 14.5\%. The revision rate was 13.7\%. Therefore, the surgeon must be aware of the potential complications associated with management of these unstable fracture patterns; the use of longer screws as well as strut grafting should be considered in patients with osteoporotic bone who lack a sufficient medial calcar.\textsuperscript{29} Hinds et al\textsuperscript{30} found that the clinical outcomes of locked plating with endosteal fibular strut allograft augmentation in patients aged $>65$ years were comparable to those in younger patients (mean age, 53 years). The authors noted that the enhanced stability provided by this fixation construct allowed early

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**Figure 5**

A, AP fluoroscopic image of the shoulder demonstrating intraoperative closed reduction and percutaneous pin fixation for a proximal humeral fracture. B, AP fluoroscopic image of the shoulder showing the three-part proximal humeral fracture post-reduction. C, Intraoperative AP fluoroscopic image of the shoulder. D, Postoperative AP radiograph demonstrating the shoulder at 11.5 weeks postoperatively.
intensive postoperative therapy and resulted in excellent outcomes regardless of patient age. In this series of 71 adults, osteonecrosis occurred >3 years postoperatively in one elderly patient (1%).

**Intramedullary Nail Fixation**

Although challenging and controversial because of historical reports of complications, intramedullary (IM) nail fixation for proximal humeral fractures has become more popular in recent years, with some reports of success. Postoperative problems, such as nonunion, malunion, rod migration in older patients, shoulder pain caused by rotator cuff violation, and nerve injury caused by interlocking screw insertion, must be balanced against a small incision, closed reduction, and excellent nail-bone purchase in osteoporotic bone. More research is needed, but some recent clinical studies have found locked rigid IM nail fixation to be equivalent to locked plate fixation for two-part, three-part, and even four-part proximal humeral fractures.

The indications for IM nailing of proximal humeral fractures include two-part surgical neck fractures, young age, concomitant humeral shaft fracture, and impending pathologic fractures (Figure 7). Improvements in nail design and surgical technique have led to a resurgence in the use of anterograde rigid IM nail fixation for select three-part and four-part fractures.

Modern humeral nails are straight instead of curvilinear, allow the use of multiplanar locking screws, and can be inserted from a more medial starting point near the articular margin such that injury to the rotator cuff tendon attachment site is minimized. Most nail insertion is performed anterograde with a rigid locked construct; however, some reports support the use of retrograde flexible unlocked implants despite their reduced axial and rotational stability.

A biomechanical study of two-part fractures treated with IM nailing versus locking plates demonstrated higher failure rates in torsion with IM nailing than with locking plates, which suggests that early motion and osteoporotic bone could predispose to poor results. Yoon et al examined stiffness and load to failure in a study of various fixation options for two-part proximal humeral fractures and found that IM nailing with a fixed angle blade was superior to IM nailing with locking screws, a 3.5-mm fixed angle plate, and a 4.5-mm fixed angle plate.

Modern IM nail fixation of proximal humeral fractures has yielded favorable results, including high union rates, low complication rates, and favorable subjective outcomes. In a retrospective review of 48 patients with two-part surgical neck fractures treated with an angular, stable, locked IM nail, Hatzidakis et al reported reliable fracture healing, a mean Constant score of 71, mean forward flexion of 132°, and little residual shoulder pain after 12-month follow-up. In studies of two-part, three-part, and four-part fractures, other authors found no marked objective or subjective differences between locking plate and IM nail fixation. However, Zhu et al studied two-part fractures with a 3-year minimum follow-up period and reported an overall complication rate of 4% and 31% for IM nailing and locking plate fixation, respectively. The IM nailing group had a significantly lower complication rate than did the locking plate group (P = 0.024).

Despite these findings, we do not use IM nail fixation for acute non-pathologic proximal humeral fractures at this time.

**Hemiarthroplasty**

Historically, HA was the treatment of choice for complex proximal humeral fractures and has been studied extensively. It is a technically challenging procedure with mixed results. The presence of a functioning rotator cuff and healed, anatomically reduced tuberosities are essential for satisfactory outcomes. A thorough preoperative history and intraoperative assessment can alert the surgeon to
rotator cuff pathology. Tuberosity malalignment has been noted to be a major source of failure following humeral replacement for proximal humeral fractures. Other important parameters include humeral head height and version. The humeral head level should re-create that of the anatomic head. In a cadaver study, the authors estimated an average distance of 5.6 cm between the top of the humeral head and the upper border of the pectoralis major muscle insertion. This distance also may be assessed by visually ensuring that the head sits on the well-reduced tuberosities. Humeral lengthening >10 mm causes excessive tension of the supraspinatus muscle and places the tuberosities at risk of detachment. The natural humeral head retroversion ranges from 19° to 22°, with some variability. The surgeon should be cognizant of this range and should aim to reproduce similar version when performing HA. Failure to do so may put the tuberosity repair under undue tension and may put the prosthesis at risk for instability. Adequate fixation of the tuberosities requires secure fixation of the tuberosities to each other, to the prosthesis, and to the humeral shaft through drill tunnels. Bone graft may be added to enhance healing and fill in any defects (Figure 8).

HA for fracture management may have a high complication rate, with functional gains that can be less than satisfactory. In a retrospective review of 66 patients who underwent shoulder HA for fracture, Boileau et al noted that 42% of the patients were unsatisfied with their final outcome. At final follow-up, the incidence of tuberosity malposition was 50%. The average forward flexion and external rotation was 101° and 18°, respectively. In a systematic review of 810 HAs performed for treatment of acute fractures, Kontakis et al noted similarly poor forward flexion (105.7°). The average postoperative Constant score in 560 patients was 56.6. A recent randomized study comparing HA with nonsurgical treatment of four-part fractures found no substantial difference in outcomes. Such results underscore the importance of performing HA after careful preoperative planning and with meticulous surgical technique.

**Reverse Shoulder Arthroplasty**

The initial indications for RSA (as a salvage option) were rotator cuff arthropathy and pseudoparalysis. The function of the reverse shoulder prosthesis is based on traditional Grammont principles of medializing the glenohumeral center of rotation and lowering the humerus. This gives the deltoid muscle a mechanical advantage by increasing its lever arm, obviating the need for the rotator cuff, and providing low shear forces about the glenoid. The increased use and popularity of RSA brought a corresponding rise in the number of complications, including scapular notching (44% to 96%), glenoid loosening (5% to 38%), instability (2% to 31%), and infection (1% to 15%). The longevity of RSA implants in patients with arthropathy or fracture has not yet been elucidated fully. A recent study noted that 91% of the implants were viable 10 years after implantation, but a decline in function was noted at the 6-year mark.

The indications for RSA have been expanded to include acute fractures, the sequelae of fractures (eg, malunion, nonunion), and revision of failed fixation or humeral replacement. RSA is an attractive option for patients older than 65 years with three-part or four-part fractures and comminuted tuberosities, and the procedure may...
provide more predictable results than those provided by standard anatomic HA in select patients.

The effectiveness of HA versus RSA has yet to be determined fully. Young et al\textsuperscript{46} retrospectively compared the outcomes of 10 patients who underwent RSA with those of 10 patients who underwent HA for similar proximal humeral fracture patterns (two three-part fractures and eight four-part fractures in each group). The greater tuberosity was fixed to the implant in 9 of 10 RSAs. At an average follow-up of 22 to 44 months, the authors noted similar forward flexion, external rotation, American Shoulder and Elbow Surgeons Shoulder scores, and Oxford scores in both groups. Despite similar results, the authors noted at the last follow-up visit that, on radiography, the humeral heads were not centered in five patients treated with HA. Gallinet et al\textsuperscript{47} retrospectively compared the results of 17 patients who underwent HA with those of 16 patients who underwent RSA for three- or four-part proximal humeral fracture. At a mean short-term follow-up (16.5 months and 12.4 months in the HA and RSA groups, respectively), the outcomes were substantially better in the RSA group than in the HA group. These patients had better abduction, forward flexion, and Constant scores. However, the patients who underwent HA had better external rotation than did those who underwent RSA (13.5° versus 9°).\textsuperscript{47} The authors claim that RSA provides more predictable function; however, the Constant scores of the RSA group were comparable to those of the HA group.\textsuperscript{48} A blinded, randomized prospective study substantiated some of these findings, reporting better pain and function and a lower revision rate for RSA than for HA.\textsuperscript{49} Multiple recent systematic reviews have reported equivalent clinical scores and a lower revision rate associated with RSA, as well as improved external rotation with tuberosity repair.\textsuperscript{50,51} In a systematic review of 92 studies with a total of 4,500 patients, Gupta et al\textsuperscript{1} observed that ORIF led to better clinical outcomes than those of RSA but was associated with considerably higher revision rates. HA and RSA were equivalent with regard to clinical scores, although tuberosity healing after HA was noted to be 15.4%. Uzer et al\textsuperscript{52} found that tuberosity union rates following RSA with autologous grafting improved from 40% (not grafted) to 77.8% (grafted), with associated improvements in functional outcomes.

Several patient factors and technical factors are necessary for successful management of complex proximal humeral fractures with RSA. Proper function of the deltoid muscle is required for RSA. Guidelines for surgical management of these fractures in the setting of axillary nerve palsy are lacking, but RSA can be performed in the setting of neurapraxia provided that some deltoid tone is noted on examination. A complete palsy may allow the use of only ORIF, HA, and/or arthrodesis, however. We recommend the use of CT imaging in addition to radiography when assessing these fractures. Adequate glenoid bone stock is required to allow implantation of the base plate. Bone loss about the humerus should be noted, and plans should be made to restore humeral length with an implant or graft material to ensure that the deltoid muscle is tensioned properly. If proximal bone loss is severe, imaging of the contralateral humerus may be performed to replicate the length of the humerus on the surgical shoulder. As with HA, tuberosity repair is recommended to improve rotation, tension, and stability (Figure 9). Substantial bone loss and detachment of the tuberosity and soft-tissue attachments may predispose the implant to dislocation.\textsuperscript{44,46,50}

Figure 9

A, AP radiograph of the shoulder demonstrating a four-part complex fracture in a 68-year-old man with poor bone quality. B, Axial CT showing a fracture line through the lesser tuberosity. Postoperative AP (C) and external rotation (D) radiographs of the shoulder after reverse shoulder arthroplasty.
We typically perform HA in active patients aged 40 to 65 years with complex four-part fractures or head split patterns that are likely to have complications with plate osteosynthesis. A stem that is convertible to an RSA without extraction can be advantageous and should be considered if the surgeon is familiar and comfortable with the design.

Summary

Management of proximal humeral fractures can be challenging, and the treatment choice is not always obvious. Most of these fractures can be treated nonsurgically with short-term immobilization and early physical therapy. Most complex fractures or fractures that fail nonsurgical treatment can be managed with a variety of surgical options. Surgical experience and evidence-based literature can help to guide the surgeon in the selection of a surgical option. Complex three-part and four-part fractures may be managed best by surgeons who have training in shoulder arthroplasty to allow intraoperative flexibility as needed. RSA is a relatively new addition to the treatment algorithm and may provide more predictable results than those derived from HA and osteosynthesis in elderly patients with complex fracture patterns. However, all patients must be counseled preoperatively about permanent functional limitations, even in the absence of pain.

References

References printed in bold type are those published within the past 5 years.


