Open Reduction and Internal Fixation for Treatment of Proximal Humerus Fractures: A Review

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Abstract

Fractures of the proximal humerus are common in older patients, and the incidence of these fractures in the United States is expected to notably increase with the aging population. Nonoperative procedures have been preferred in elderly patients with stable fracture patterns to avoid complications associated with osteoporotic bone. However, more complex and unstable fracture patterns often necessitate operative techniques to allow for more anatomical healing. Although proximal humerus fractures have been thoroughly examined, systemized, and studied, no clear method to choosing an appropriate surgical treatment or candidate has been accepted. I reviewed the role of the following factors on successful treatment with ORIF: anatomical structures; blood vessels and morphological features of the humeral head; clinical evaluation, assessment, and outcomes; and surgical variables such as approach to the shoulder, plating techniques, position and placement of screws, medial calcar supports, augmentation of implants, and level of experience and familiarity of surgeons with the operation. Based on the complex nature of proximal humerus fractures, effective surgical treatment may be determined by the circumstances unique to each case.

Introduction

Fractures of the proximal humerus are common, composing about 6% of all fractures.[1] These typically result from low-energy trauma and thus rarely happen in younger individuals; occur more often in women than men; and rank as the third most common fracture reported with older patients.[1] Because of both the aging population of the United States and continued development of locking-plate techniques with open reduction and internal fixation (ORIF), the incidence of proximal humerus fractures treated surgically is expected to markedly increase.

Classification systems for proximal humerus fractures have identified typical injury patterns, predicted outcomes, and guided treatment. Neer[2] developed the most well-known system, which categorized fracture patterns by number of anatomical parts displaced greater than 1 cm or 45°. The AO system (renamed to AO/OTA in 2007 by Marsh et al[3] with some revised alphanumeric codes) divided fracture patterns into 27 subgroups based on location, type, and severity of the fracture. The Codman-Hertel binary fracture classification used 12 basic fracture patterns and included predictors of ischemia.[4] However, these systems have been criticized for poor interobserver reliability and reproducibility.[5]

Although an accepted algorithm to delineate treatment for proximal humerus fractures does not yet exist, options for treatment include ORIF, nonoperative management, closed reduction, minimally invasive techniques (reduction and pinning), intramedullary nail fixation, hemiarthroplasty, and reverse total shoulder arthroplasty. The goals of these procedures are to reduce the fracture, maintain reduction until healing is achieved, and restore shoulder function.

Relative indicators for ORIF have included head-shaft displacement greater than 50%, varus or valgus malalignment greater than 30°, and Neer three- or four-part fractures with more than 1 cm of greater tuberosity displacement.[6] Contraindications for ORIF have been described as nondisplaced and minimally displaced fractures, head-splitting fractures in which fragments of the humeral head are unreconstructable, and anatomical neck fractures in older patients.[6] In an attempt to correctly describe a method that could help lead to successful surgical treatment of proximal humerus fractures, I reviewed studies on the anatomical structures of the proximal humerus that serve as important reference points; role of blood vessels to the humeral head; factors affecting clinical evaluation, assessment, and outcomes; and variables affecting surgical outcomes and procedures.

Anatomy and Vascularity

The anatomy of the proximal humerus has been examined in great detail. In 1970, Neer[2] described a classification system based on the displacement of major segments such as the articular surface of the humeral head, greater tuberosity, lesser tuberosity, surgical neck of the humerus, and humeral shaft. This study revealed both the importance of soft-tissue attachments in directing displacement and a possible relationship between segments, physeal scars, and developmental centers of ossification.

Establishing reliable landmarks with anatomical structures can be helpful in preoperative planning. The humerus neck-shaft angle has been measured at about 130°, with about 20° of retroversion.[7] Although a reference point for humeral length has been better established with the upper border of the pectoralis major tendon (averaging about 5.6 cm distal to the top of the humeral head), retroversion may also be determined by prosthetic placement relative to the bicipital groove.[8] The axillary nerve, which wraps posteriorly around the surgical neck of the humerus, has been generally found between 4.3 cm and 7.4 cm from the lateral tip of the acromion.[9]

Understanding the role of blood vessels and morphological features in the humeral head may be critical in determining a treatment algorithm for proximal humerus fractures. The posterior humeral circumflex artery supplies most of the blood (64%) to the humeral head, with the rest provided by the anterior humeral circumflex artery.[10] Hertel et al[4] identified morphological features predictive of intraoperative ischemia of the humeral head, including an anatomical neck fracture, less than 8 mm of extension of the medial metaphyseal calcar, and greater than 2 mm of displacement in the medial hinge. Combined, these three risk factors had a positive predictive value of 97% for humeral head ischemia. However, a follow-up study by Bastian and Hertel[11] noted that fractures suggestive of intraoperative ischemia did not predictably develop avascular necrosis. The effect of additional factors on both head perfusion and development of ischemia has yet to be fully understood.

Clinical Evaluation and Assessment

Appropriate imaging has been important in evaluating fracture patterns of the proximal humerus. Radiographs of a standard trauma shoulder series typically have included a true anteroposterior view (tangential to the glenohumeral joint), an axillary lateral view, and a scapular Y view.[4,7,11-16] Additionally, results of computed tomography have helped classify complicated fracture patterns and decide preoperative planning.[4-7,14,15] Although not routinely performed, magnetic resonance imaging (MRI) has been useful in identifying torn rotator cuffs in patients with proximal humerus fractures.[4,10,12,13]

Clinical assessment of injuries associated with proximal humerus fractures has also been important. Injury to the axillary artery is a rare complication, mostly described in case reports. Severe displacement, dislocation, and high-energy trauma have increased the risk of vascular compromise.[12] Hettrich et al[10] noted that the anterior and posterior humeral circumflex arteries were injured in 80% and 15% of fractures, respectively. Stableforth[17] reported brachial plexus injuries in about 6% of four-part fractures of the upper end of the humerus, with a full recovery noted in a third of the patients. A study by Visser et al[12] described higher subclinical rates of neurological injury: electromyography (EMG) findings were positive for nerve injury in 82% and 59% of displaced and nondisplaced fractures, respectively. Additionally, based on results of MRI scans, Gallo et al[13] found a 40% incidence of rotator cuff tears in 30 patients with proximal humerus fractures.

Clinical and Surgical Outcomes

Factors affecting clinical outcome have been related to fracture pattern (displacement, comminution, varus angulation, lack of support from the medial calcar, and vascularity of the humeral head) and patient status (age, bone quality, medical comorbidities, smoking, and baseline physical-activity level).[1,6,10,18] A prospective observational study[19] of 67 patients with proximal humerus fractures found four significant risk factors related to unsuccessful treatment: age greater than 63 years, bone mineral density less than 95 mg/cm^3, no anatomical reduction, and no restoration of the medial calcar support. The failure rate of ORIF was 71% and 86% with the presence of three and four risk factors, respectively. Sproul et al[18] found surgical outcomes to depend on these risk factors, with a 96.6% healing rate in 514 patients treated with locking-plate fixation but a high complications rate of 48.8% and a reoperation rate of 13.8%.

Poor outcomes after surgery have been associated with severity of fracture pattern, initial varus alignment, medial comminution, and osteoporosis. A retrospective review of 368 surgically treated proximal humerus fractures described reoperation rates as high as 38% in patients with type C fractures (AO classification) and 30% in those with initial varus displacement.[14] Additionally, in a 2-year follow-up study[15] of 74 patients treated with locking-plate fixation, significantly worse constant scores and frequent varus collapse were reported with initial medial calcar comminution. Medial comminution has been shown to decrease the mean load to failure of a locking-plate construct by 48%, yet use of a medial calcar screw can help increase the load to failure by 31%.[20] Fixation stability and failure rates have also been affected by the presence of osteoporosis. Tingart et al[16] found that a mean cortical thickness of less than 4 mm is highly indicative of a low bone mineral density and may be a relative contraindication for operative fixation.

Success and Challenges of Operative Treatment

Deltopectoral and Deltoid-Splitting Techniques

The deltopectoral technique, traditionally used to approach the shoulder, is the more familiar method, allowing for better visualization and reduction of the medial calcar and a more extensile exposure along the humerus shaft if necessary. Although less familiar to most orthopaedic surgeons, the anterolateral or deltoid-splitting approach can allow for easier application of hardware laterally along the humerus.

Wu et al[21] examined these two approaches and described difficulties of the deltopectoral technique with extensive soft-tissue dissection, lateral placement of hardware, protecting the anterior humeral circumflex artery, and reducing the superiorly or posteriorly displaced fragment of the greater tuberosity. Disadvantages of the deltoid-splitting method included risk of injury to the axillary nerve, posterior humeral circumflex artery, and anterior deltoid; difficulty in visualizing the medial calcar; challenge with extensile exposure if required; and longer operating time owing to unfamiliarity of most surgeons with the technique.

However, no statistically significant differences in clinical, radiographic, and electrophysiological outcomes were found. The study did note trends in the deltoid-splitting compared with the deltopectoral group such as longer operating times (123 minutes and 114 minutes, respectively) and more abnormal findings from EMG (43% and 28%, respectively). Because of the lack of significant differences between the two approaches, the preference and comfort level of individual surgeons can be used for guiding treatment.

Plating Technique and Screw-Related Complications

Locking-plate techniques have a clear biomechanical advantage. The use of conventional nonlocking implants has often failed to control varus collapse and can lead to loosening of the screws and hardware failure.[22,23] A cadaveric study[22] reported that the use of locked plates, compared to nonlocked plates, offered 74% more elastic stiffness and increased the ultimate failure strength by 65%. However, primary and secondary screw perforations have been a frequent postoperative complication with use of locking plates.[21-25]

Most primary screw perforations through the articular surface have resulted from problems with surgical technique, including placing screws too near the articular surface, penetrating the articular surface during drilling, and inserting screws into the anterosuperior quadrant of the humeral head.[23] To avoid these complications, Brunner et al[23] recommended drilling the lateral half of the total distance to the bone, using a blunt K-wire as a depth gauge to detect resistance of the subchondral bone and choosing a final screw length at 2 mm to 3 mm shorter than the depth-gauge measured length. The use of blunt-tipped screws and live intraoperative fluoroscopy of images perpendicular to the screws may also help prevent problems with surgical technique.[23]

Secondary screw perforation, also known as cutout, is related to bone quality, number and location of screws, presence of a kickstand screw or medial calcar reduction, and quality of fracture reduction. Minimal pullout strength of screws has been noted in the superior-anterior region of the humeral head, an area which also had the lowest bone mineral density.[24] In a cadaveric study,[25] pullout strength was maximized when screw length reached the subchondral location, and increasing the number of screws reinforced overall strength of the construct. The cadaver group with use of 4 screws and an inferomedial support screw had the most stable construct that showed the greatest resistance to secondary screw perforation.

Medial Calcar Support

The use of a medial mechanical support has been important for achieving and maintaining reduction. A follow-up study by Gardner et al[26] of 18 patients treated with and 17 treated without a medial support reported an average of 1.2 mm and 5.8 mm of humeral head height loss, screw penetration in 1 patient and 5 patients, and subsequent revision surgery needed for 1 patient and 2 patients, respectively. Anatomical reduction of the medial cortex, medialization of the shaft with stable impact, and use of an inferiormedial locking screw within 5 mm of the subchondral bone were vital for maintaining reduction.

Bony Augmentation

Use of allografts may be helpful in treating osteoporotic bone with a deficient medial calcar. In a biomechanical cadaveric study, Chow et al[27] found that a fibular strut model allowed for increased cyclic loading before collapse and less construct deformation between cycles. A surgical technique for allograft augmentation has been described, which required a 6-cm to 8-cm segment of fibula allograft.[28] The steps involved seating the graft so that 2 cm to 3 cm was positioned proximal to the level of comminution; drilling the lateral cortex in the plate; and inserting a screw of 5 mm longer than measured length, which pushed the allograft to hinge against the surgical neck. A follow-up study[29] of 38 patients treated with use of endosteal strut allografts had excellent results, with a mean constant score of 87, forward flexion of 148°, incidence of varus collapse of 2.6%, incidence of superficial wound infection of 2.6%, and no cases of screw cutout.

Because of promising results in treating tibial plateau fractures, cement augmentation has become an increasingly popular option.[30] Calcium phosphate cement has been an effective construct because of its osteoconductivity, high compressive strength (greater by 4-10 times that of cancellous bone), and slow rate (30%-60% by 1 year) of reabsorption.[30] Disadvantages, however, have included extravasation and difficulty in altering fixation once the cement solidifies. A retrospective study by Egol et al[31] of 92 patients treated with calcium phosphate augmentation, cancellous chips, and no augmentation showed reduced settling of fragments, fewer screw penetrations, and lower complication rates with use of the cement. The authors recommended cement augmentation only when both the medial cortex was intact and evidence of osteoporosis existed, but emphasized the use of a fibular allograft if the medial cortex disrupted.

Surgeon Experience and Possible Techniques

Because of the challenges associated with operative treatment, a learning curve for orthopaedic surgeons can be expected. Ruchholtz et al[32] examined minimally invasive techniques for proximal humerus fractures and evaluated each case based on the relationship of surgeon work experience with both postoperative complications and operating time. The results showed that operations performed by experienced and untrained surgeons had complication rates of 8.9% and 45% and operating times of 57 minutes and 89 minutes, respectively. These findings reinforced the importance of adequate training and perhaps the need of assistance from experienced surgeons to help successfully treat proximal humerus fractures.

Several intraoperative techniques have been described to assist surgeons with reduction and stabilization of the proximal humerus.[33] For two-part varus fractures, the plate was secured to the humeral head and used as a "joystick" to reduce the head to the shaft. For three-part fractures, the most important step involved derotation of the greater tuberosity and lesser tuberosity, which involved the use of sutures within the rotator cuff to manipulate and reduce the fracture fragments. Additionally, fixing these sutures to the plate supplemented overall stability of the construct. For four-part valgus impacted fractures, sutures were recommended in the rotator cuff to allow for control of the greater and lesser tuberosity pieces, and the humeral head was elevated into appropriate position. Augmentation was considered with four-part fractures to fill the void and prevent fracture subsidence.

Conclusion

Proximal humerus fractures are common with older patients and subsequently tend to necessitate minimally invasive treatment.[1] Most of these injuries involve stable fracture patterns and can be treated without surgical intervention. However, in extremely displaced or unstable patterns of fractures, operative treatment should be considered. Because of the high rate of surgical complications, successful treatment can be individually based on each case, including factors such as fracture pattern, bone quality, patient characteristics, and level of experience or familiarity of surgeons with operative technique.

References

1. Court-Brown CM, Caesar B. Epidemiology of adult fractures: a review. Injury 2006;37(8):691-7.
2. Neer CS 2nd. Displaced proximal humeral fractures I: classification and evaluation. J Bone Joint Surg Am 1970;52(6):1077-89.
3. Marsh JL, Slongo TF, Agel J, et al. Fracture and dislocation classification Compendium—2007: Orthopaedic Trauma Association classification, database and outcomes committee. J Orthop Trauma 2007;21(10 suppl):S1-S133.
4. Hertel R, Hempfing A, Stiehler M, Leunig M. Predictors of humeral head ischemia after intracapsular fracture of the proximal humerus. J Shoulder Elbow Surg 2004;13(4):427-33.
5. Majed A, Macleod I, Bull AM, et al. Proximal humeral fracture classification systems revisited. J Shoulder Elbow Surg 2011;20(7):1125-32.
6. Murray IR, Amin AK, White TO, Robinson CM. Proximal humeral fractures: current concepts in classification, treatment and outcomes. J Bone Joint Surg Br 2011;93(1):1-11.
7. Robertson DD, Yuan J, Bigliani LU, Flatow EL, Yamaguchi K. Three-dimensional analysis of the proximal part of the humerus: relevance to arthroplasty. J Bone Joint Surg Am 2000;82-A(11):1594-602.
8. Murachovsky J, Ikemoto RY, Nascimento LG, Fujiki EN, Milani C, Warner JJ. Pectoralis major tendon reference (PMT): a new method for accurate restoration of humeral length with hemiarthroplasty for fracture. J Shoulder Elbow Surg 2006;15(6):675-8.
9. Burkhead WZ Jr, Scheinberg RR, Box G. Surgical anatomy of the axillary nerve. J Shoulder Elbow Surg 1992;1(1):31-6.
10. Hettrich CM, Boraiah S, Dyke JP, Neviaser A, Helfet DL, Lorich DG. Quantitative assessment of the vascularity of the proximal part of the humerus. J Bone Joint Surg Am 2010;92(4):943-8.
11. Bastian JD, Hertel R. Initial post-fracture humeral head ischemia does not predict development of necrosis. J Shoulder Elbow Surg 2008;17(1):2-8.
12. Visser CP, Coene LN, Brand R, Tavy DL. Nerve lesions in proximal humeral fractures. J Shoulder Elbow Surg 2001;10(5):421-7.
13. Gallo RA, Sciulli R, Daffner RH, Altman DT, Altman GT. Defining the relationship between rotator cuff injury and proximal humerus fractures. Clin Orthop Relat Res 2007;458:70-7.
14. Hardeman F, Bollars P, Donnelly M, Bellemans J, Nijs S. Predictive factors for functional outcome and failure in angular stable osteosynthesis of the proximal humerus. Injury 2012;43(2):153-8.
15. Osterhoff G, Hoch A, Wanner GA, Simmen HP, Werner CM. Calcar comminution as prognostic factor of clinical outcome after locking plate fixation of proximal humeral fractures. Injury 2012;43(10):1651-6.
16. Tingart MJ, Apreleva M, von Stechow D, Zurakowski D, Warner JJ. The cortical thickness of the proximal humeral diaphysis predicts bone mineral density of the proximal humerus. J Bone Joint Surg Br 2003;85(4):611-7.
17. Stableforth PG. Four-part fractures of the neck of the humerus. J Bone Joint Surg Br 1984;66(1):104-8.
18. Sproul RC, Iyengar JJ, Devcic Z, Feeley BT. A systematic review of locking plate fixation of proximal humerus fractures. Injury 2011;42(4):408-13.
19. Krappinger D, Bizzotto N, Riedmann S, Kammerlander C, Hengg C, Kralinger FS. Predicting failure after surgical fixation of proximal humerus fractures. Injury 2011;42(11):1283-8.
20. Ponce BA, Thompson KJ, Raghava P, et al. The role of medial comminution and calcar restoration in varus collapse of proximal humeral fractures treated with locking plates. J Bone Joint Surg Am 2013;95(16):113. e1-e7.
21. Wu CH, Ma CH, Yeh JJ, Yen CY, Yu SW, Tu YK. Locked plating for proximal humeral fractures: differences between the deltopectoral and deltoid-splitting approaches. J Trauma 2011;71(5):1364-70.
22. Seide K, Triebe J, Faschingbauer M, et al. Locked vs. unlocked plate osteosynthesis of the proximal humerus—a biomechanical study. Clin Biomech (Bristol) 2007;22(2):176-82.
23. Brunner F, Sommer C, Bahrs C, et al. Open reduction and internal fixation of proximal humerus fractures using a proximal humeral locked plate: a prospective multicenter analysis. J Orthop Trauma 2009;23(3):163-72.
24. Tingart MJ, Lehtinen J, Zurakowski D, Warner JJ, Apreleva M. Proximal humeral fractures: regional differences in bone mineral density of the humeral head affect the fixation strength of cancellous screws. J Shoulder Elbow Surg 2006;15(5):620-4.
25. Erhardt JB, Stoffel K, Kampshoff J, Badur N, Yates P, Kuster MS. The position and number of screws influence screw perforation of the humeral head in modern locking plates: a cadaver study. J Orthop Trauma 2012;26(10):e188-92.
26. Gardner MJ, Weil Y, Barker JU, Kelly BT, Helfet DL, Lorich DG. The importance of medial support in locked plating of proximal humerus fractures. J Orthop Trauma 2007;21(3):185-91.
27. Chow RM, Begum F, Beaupre LA, Carey JP, Adeeb S, Bouliane MJ. Proximal humeral fracture fixation: locking plate construct ± intramedullary fibular allograft. J Shoulder Elbow Surg 2012;21(7):894-901.
28. Gardner MJ, Boraiah S, Helfet DL, Lorich DG. Indirect medial reduction and strut support of proximal humerus fractures using an endosteal implant. J Orthop Trauma 2008;22(3):195-200.
29. Neviaser AS, Hettrich CM, Beamer BS, Dines JS, Lorich DG. Endosteal strut augment reduces complications associated with proximal humeral locking plates. Clin Orthop Relat Res 2011;469(12):3300-6.
30. Frankenburg EP, Goldstein SA, Bauer TW, Harris SA, Poser RD. Biomechanical and histological evaluation of a calcium phosphate cement. J Bone Joint Surg Am 1998;80(8):1112-24.
31. Egol KA, Sugi MT, Ong CC, Montero N, Davidovitch R, Zuckerman JD. Fracture site augmentation with calcium phosphate cement reduces screw penetration after open reduction-internal fixation of proximal humeral fractures. J Shoulder Elbow Surg 2012;21(6):741-8.
32. Ruchholtz S, Hauk C, Lewan U, Franz D, Kühne C, Zettl R. Minimally invasive polyaxial locking plate fixation of proximal humeral fractures: a prospective study. J Trauma 2011;71(6):1737-44.
33. Badman BL, Mighell M. Fixed-angle locked plating of two-, three-, and four-part proximal humerus fractures. J Am Acad Orthop Surg 2008;16(5):294-302.