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. 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. 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 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 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. However, these systems have been criticized for poor interobserver reliability and reproducibility.

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. 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. 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 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 reviewed both the importance of soft-tissue attachments in directing displacement and a possible relationship between the degree of displacement, physical 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°. 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. 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.8

Understanding the role of blood vessels and posterior 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 remainder provided by the anterior humeral circumflex artery.9 Hertel et al10 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 features were predictive of a posterior humeral circumflex artery. In addition, on an anatomical examination test by Lavy et al9 no restoration of the humeral calcar support. The failure rate of ORIF was 71% and 86% with the presence of three risk factors and six risk factors, respectively.

In a retrospective review by Hertel et al10 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 include a true anteroposterior view (tangential to the glenohumeral joint), an axillary lateral view, and a scapular Y view.11-13

Additionally, results of computed tomography scans, Gallo et al13 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).14,15 A prospective observational study16 of 67 patients with proximal humerus fractures found four significant risk factors related to unsuccessful treatment: age greater than 65 years, bone mineral density less than 95 mg/cm², no anatomical reduction, and no restoration of the humeral calcar support. The failure rate of ORIF was 71% and 86% with the presence of three and four risk factors, respectively. Sproul et al17 found surgical outcomes to depend on these risk factors, with a 26.6% 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, and osteoporosis. A retrospective review of 268 surgically treated proximal humerus fractures described reoperation rates as high as 38% in patients with type C fractures (AO classification) compared to 15% in those with initial varus displacement.18 Additionally, in a 2-year follow-up study19 of 74 patients treated with locking-plate fixation, significantly worse constant scores and more abnormal findings from EMG (43%-50% vs. 1%-10%) were found. The study did note trends in the deltoid-deltoid splitting with the deltopectoral group such as bone quality, number and location of screws, and quality of fracture reduction. The higher failure rate in deltopectoral group (30%) in those with varus angulation of 30° or greater, including those with varus angulation less than 30°.

In a follow-up study by Greenfeld et al20 of 18 patients treated with and 17 treated without a medial calcar support reported an average of 1.2 mm longer than measured length, which pushed the allograft gauge measured length. The use of blunt-tipped screws and live intraoperative fluoroscopy of images perpendicular to the screws may help prevent problems with surgical technique.21 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.22 In a cadaveric study,22 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 inferior medial calcar 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 al26 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 calcar, medialization of the shaft with stable impact, and use of an interfragmentary 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 al27 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 fibular 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 study29 of 38 patients treated with use of endosteal strut allografts had excellent results, with a mean constant score of 87.
Proximal humerus fractures are common with older patients and subsequently tend to necessitate minimally invasive treatment. 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


Surgical Experience and Possible Techniques

Because of the challenges associated with operative treatment, a learning curve for orthopaedic surgeons can be expected. Ruchholtz et al32 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 reinforce the importance of training and perhaps the need of assistance from experienced surgeons to help successfully treat proximal humeral fractures.

Several intraoperative techniques have been described to assist surgeons with reduction and stabilization of the proximal humeri. 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 detachment 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 varus 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.