



Management of Complex Proximal Humerus Fractures: What Is the Role of Open Reduction and Internal Fixation?

Rafael Kakazu¹ · John D. Wyrick¹

Published online: 2 October 2018
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Abstract

Purpose of Review Proximal humerus fractures are challenging injuries to treat and will become more common with an aging population. The purpose of this paper is to review the recent literature regarding the role of open reduction and internal fixation for this injury.

Recent Findings Complex proximal humerus fractures present a significant challenge in the elderly. The introduction of locked plating has improved surgical management of these injuries; however, complications including avascular necrosis, primary screw cutout, and secondary screw cutout remain obstacles. Newer technologies aim to combat these issues, with promising early results.

Summary Complex proximal humerus fractures call for experienced surgeons and remain challenging with high complication rates with open reduction and internal fixation. Newer fixation methods aim to reduce these complications.

Keywords Proximal humerus fracture · Geriatric fracture · Osteoporosis

Introduction

Proximal humerus fractures represent the seventh most common fracture overall and, among patients older than 65, the third most common [1, 2]. As the population ages, this fracture will be encountered more often. In fact, a 2006 study from Finland noted the incidence of these fractures has tripled since 1970 [3]. Efforts to determine optimal treatment of this injury are ongoing since Dr. Charles Neer's classification and treatment recommendations nearly 50 years ago [4, 5]. Advances in technology such as locked plating and computed tomography have allowed for solutions for poor bone quality as well as improved preoperative evaluation. The purpose of this paper is review the recent literature of geriatric proximal humerus fractures and the role of open reduction internal fixation.

Fracture Evaluation and Classification

Evaluation of proximal humerus fractures begins with a physical exam. Patients will often present with pain, limited range of motion, and ecchymosis about the shoulder. It is important to perform a thorough neurovascular exam since up to one in three can present with nerve injury by physical exam [6, 7]. An EMG study reported the most commonly affected are the axillary, suprascapular, and radial nerves—53, 37, and 24%, respectively. These are felt to be traction injuries with approximately 95% recovering at 3–4 months. It should be noted that sensation about the deltoid does not indicate that the axillary nerve is intact [8]. One suggestion is to place the hands over the deltoid and elbow to feel for deltoid contraction and abduction [9]. About 10% of these patients have an additional fracture, highlighting the importance of a secondary exam [10].

Radiographs including true AP, scapular Y, and axillary views are critical for evaluation. Attention should be paid to the tuberosities and alignment of the glenohumeral joint. Computed tomography (CT) may be helpful in evaluation of the medial calcar or any displacement. In our experience, CT is recommended with three- and four-part fractures and fracture-dislocations to assist in preoperative planning. MRI can be used to evaluate for rotator cuff tear, which can be seen in about 40% of proximal humerus fractures [7].

This article is part of the Topical Collection on *Geriatric Orthopedics*

✉ Rafael Kakazu
Kakazurl@uc.edu

¹ Department of Orthopaedic Surgery, University of Cincinnati, 231 Albert Sabin Way ML 212, Cincinnati, OH 45229, USA

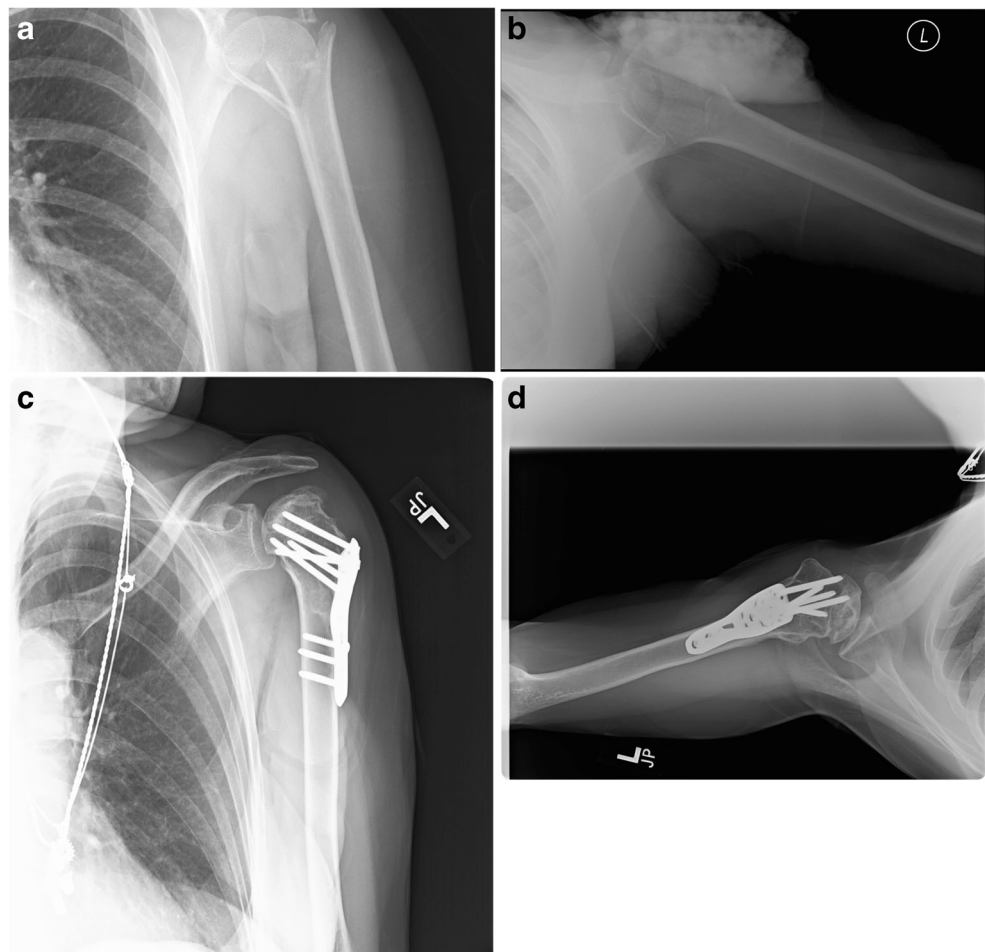
Dr. Charles Neer described four landmarks as the basis for his classification: anatomic neck, surgical neck, greater tuberosity, and lesser tuberosity [4, 5]. A displaced part was represented by minimum 1 cm displacement or angulation of 45° or more. However, these parameters were initially arbitrarily defined with variable interobserver reliability [11]. Additionally, Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) modified the Neer classification and focused on impaction and displacement. The AO/OTA classification was updated in 2018 to better integrate the original Neer classification [12]. These fractures can occur in multiple permutations and include the possibility of anterior or posterior dislocation. From the radiographs, head impaction angle can be measured as described by Hertel [13]. A head inclination angle less than 130° can be considered varus impacted and greater than 140° can be considered valgus impacted (Fig. 1).

Additionally, bone quality can be evaluated on the AP radiographs. There are two widely used techniques: the deltoid tuberosity index (DTI) and the Tingart measurement [14, 15]. Briefly, DTI can be measured at an area just proximal to the deltoid tuberosity where the outer cortical borders are parallel; the ratio between the outer cortical and inner endosteal

diameter is referred to as the DTI. A DTI < 1.4 is used to indicate poor bone stock [14]. Separately, the Tingart measurement can be obtained by the ratio of the outer cortical and inner endosteal diameter compared with the same measurement obtained 20 mm distal.

Bone density overall is a predictor of screw cut out as well as reduction quality [16–18]. However, bone quality is not associated with Neer fracture patterns; a study by Spross found no correlation between more complex fracture patterns and bone quality [19]. With regard to outcome, multiple studies have demonstrated no significant difference in functional outcome, motion, and complication rates between older and younger geriatric patients with proximal humerus fractures [20–22]. In other words, age alone should not be a contraindication for surgical fixation since those who are older can achieve the same outcomes as the younger geriatric population. Another study evaluating outcomes of proximal humerus fractures in the elderly has identified social independence as an important factor in their outcome [10]. This would indicate that physiologic age is a more important factor compared to chronologic age in considering treatment options [23]. Thus, bone quality and social independence can serve as surrogates for physiologic age and hence guide treatment decisions.

Fig. 1 AP and axillary radiographs from a 66-year-old female who sustained a left valgus impacted proximal humerus fracture during a motor vehicle collision. She underwent open reduction internal fixation with locked plating. At 3 months follow-up, her four-part fracture had healed and clinically, she was pain free with satisfactory range of motion



Anatomical Considerations

The anatomical deforming forces generally predict fracture displacement, and the humerus is no different. The greater tuberosity is subject to the pull of the supraspinatus, infraspinatus, and teres minor, producing posterosuperior displacement. The subscapularis inserts on the lesser tuberosity and produces medial displacement. Additionally, the humeral shaft is pulled medially due to the pectoralis major. Finally, the deltoid inserts laterally on the humerus, which leads to a lateral deforming force.

The vascular supply to the proximal humerus is provided by the anterior and posterior humeral circumflex arteries, which arise from the axillary artery. The anterior humeral circumflex artery branches superiorly into the arcuate artery, which enters near the anatomic neck [24]. The location of the main vascular supply explains why anatomic neck fractures have a high rate of avascular necrosis whereas valgus-impacted four-part fractures are less at risk compared to other four-part fractures. Hertel determined factors that contribute to avascular necrosis, including a calcar fragment less than 8 mm, disrupted medial hinge, or anatomic neck involvement [25]. The same study found that head-splitting fractures in isolation do not necessarily lead to avascular necrosis. A subsequent study has revealed that head-splitting fractures with associated tuberosity fractures are at risk for avascular necrosis [26]. Notably, avascular necrosis does not necessarily portend a poor outcome; Gerber reported a series of 13 patients with AVN with the majority reporting minimal pain and excellent or good outcome [27]. Injury to the axillary artery has been reported; however, this is very uncommon [28].

The axillary nerve is not often encountered during surgical exposure; however, care should be taken during the approach given its proximity and variability. The axillary nerve is also vulnerable during screw placement near the surgical neck when utilizing anterolateral plates [29]. The radial nerve courses posteriorly down the humeral shaft before turning laterally through the intermuscular septum. Consequently, the radial nerve is at risk when directing screws in a posterior direction when placing shaft screws when using long plates.

Treatment Options

Multiple factors must be considered in determining optimal treatment for geriatric proximal humerus fractures, such as fracture pattern, patient functional status, patient health, and surgeon preference. Additionally, more recent studies emphasized the distinction between physiologic age and chronologic age [10, 22]. Guy et al. surveyed surgeon preference for displaced three- and four-part proximal humerus fractures and found a trend towards surgery for younger patients but no consensus for older patients—45 years old versus 68 [30].

These subjective factors complicate the decision to operate as well as in interpreting studies. In fact, a recent Cochrane review which evaluated over 20 randomized controlled trials concluded that there is insufficient evidence to support treatment recommendations at this time [31]. However, there was significant heterogeneity between the studies, including type of surgical treatment, fracture pattern, and age. Open reduction internal fixation with locked plating was often categorized with arthroplasty in the surgical treatment group, which may confound outcomes. These reports underscore the complexity of geriatric proximal humerus fractures and the multiple factors that contribute towards the decision for surgical intervention.

Generally, the authors recommend a treatment ladder based on the complexity of the fracture pattern. Nondisplaced or minimally displaced fractures of the proximal humerus can be treated successfully without surgery. These types of fractures comprise about 50% of all proximal humerus fractures [32]. Arthroplasty has become a viable treatment option for proximal humerus fractures. A comparison to open reduction internal fixation is beyond the scope of this review, though there are many reports comparing the two with their respective benefits and faults [2, 33–35]. When surgery is indicated, our preference is for open reduction internal fixation since it preserves bone stock, maintains the option for arthroplasty, and restores native anatomy. From our experience, indications for arthroplasty include unreconstructable fracture patterns, head-splitting fracture, extruded head with no tuberosity attachment or with significant soft tissue stripping, and presence of chronic massive rotator cuff tear.

Two-Part Fractures

Two-part fractures of the proximal humerus can involve either the surgical neck or the tuberosities and account for 33% of all proximal humerus fractures [32]. Two-part fractures involving the surgical neck that are minimally displaced respond well to nonoperative management with acceptable outcomes [10]. Additionally, fractures involving the greater tuberosity also respond well to nonoperative management if less than 5 mm displacement; however, full recovery may take up to 12 months [36]. Generally, patients with advanced physiologic age and minimal displacement are recommended for nonoperative treatment.

Open reduction internal fixation for two-part proximal humerus fractures involving the surgical neck is most beneficial with significant displacement and, critically, acceptable bone quality. Reoperation rates for locking plate fixation can be up to 30%, with the most common cause being screw cutout [37]. Varus angulation and medial comminution have been shown to be risk factors for complication. Strategies to minimize

complications include use of bone graft, divergent screws, and ensuring fixation within the medial calcar [17, 38].

Three- and Four-Part Fractures

Proximal humerus fractures with three or four parts make up about 20% of all proximal humerus fractures [32]. Studies evaluating outcome following nonoperative management reveal low functional scores [10, 39]. However, patients are pain free and report satisfaction with their function. These studies emphasize the need to evaluate functional demand and social independence when managing these fractures. The Proximal Fracture of the Humerus: Evaluation by Randomisation (PROFHER) trial is one of the largest studies available on the topic. The authors found no difference in outcomes between operative and nonoperative management of proximal humerus fractures [40].

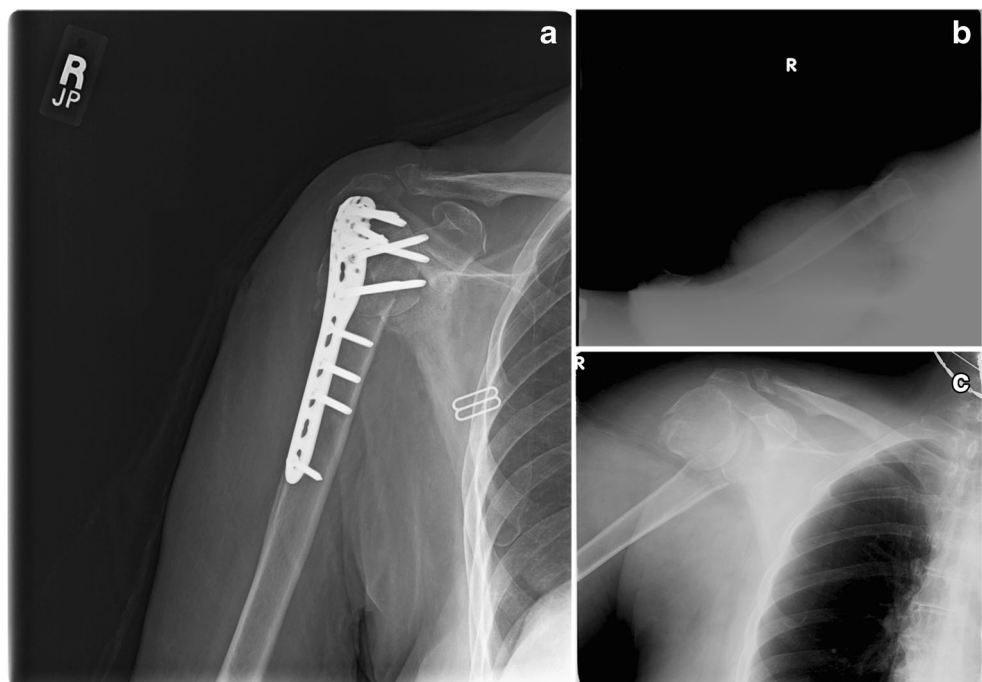
Locking plates—also known as angular stable plates—were developed as a solution for reliable fixation in osteoporotic bone. Modern designs include anatomic contouring, multiple options for screw placement into the humeral head, and screw pegs to combat cutout. A cadaveric study has shown the biomechanical superiority of locking plates compared to conventional plates [41]. As a result, there has been an increase in the use of locking plates for proximal humerus fractures and, consequently, more reports in the literature [9].

Treatment of three- and four-part fractures with locked plating can be challenging. Multiple studies have shown complication rates up to 49% [42–44, 45]. The most common reported complications are avascular necrosis, malreduction,

primary screw cutout, and infection. Due to the divergent screw trajectory and spherical humeral head, it can be difficult to fully evaluate for primary screw cutout intraoperatively. Spross et al. performed a cadaveric study evaluating primary cutout and determined that standard AP and outlet views may miss nearly half of screw cut outs [46]. A unique complication with locked plating involves screw penetration through subchondral bone with subsequent articular involvement due to the fixed angle construct [43]. Risk factors for failure include poor bone quality, age, poor reduction of medial calcar, nonanatomic reduction, and tobacco use [18, 47]. The authors noted that the number of risk factors correlated with the failure rate, up to 85.7% failure rate when four risk factors were present [18]. Further analysis reveals risk factors for complications include fracture-dislocation, head-splitting type fractures, and varus displacement [42]. Thus, even with the advantages of modern fixation technology, fixation of complex proximal humerus fractures remains a technically demanding procedure (Fig. 2).

Despite the high reported complication rate, functional outcomes following locked plating of proximal humerus fractures are acceptable. Brunner et al. reported a Constant score of 72 after 12 months among 157 patients with an average age of 55 [48]. Sproul et al. performed a systematic review that included over 500 patients with an average age of 62 [44]. At a mean follow-up of 29 months, they reported a Constant score of 74. Additional studies also report Constant scores in the same range [49–51]. Sudkamp et al. noted in their study that the majority of their complications were due to surgical technique; thus, they conclude that locked plating can provide good functional outcomes with a low complication rate. This

Fig. 2 AP and axillary views of a right proximal humerus fracture from a 60-year-old female sustained from a ground level fall. She underwent open reduction internal fixation with locked plating. Four weeks postoperatively, she developed persistent pain to her right shoulder. AP and axillary views demonstrate subchondral collapse of the humeral head with screw penetration. She subsequently underwent removal of hardware



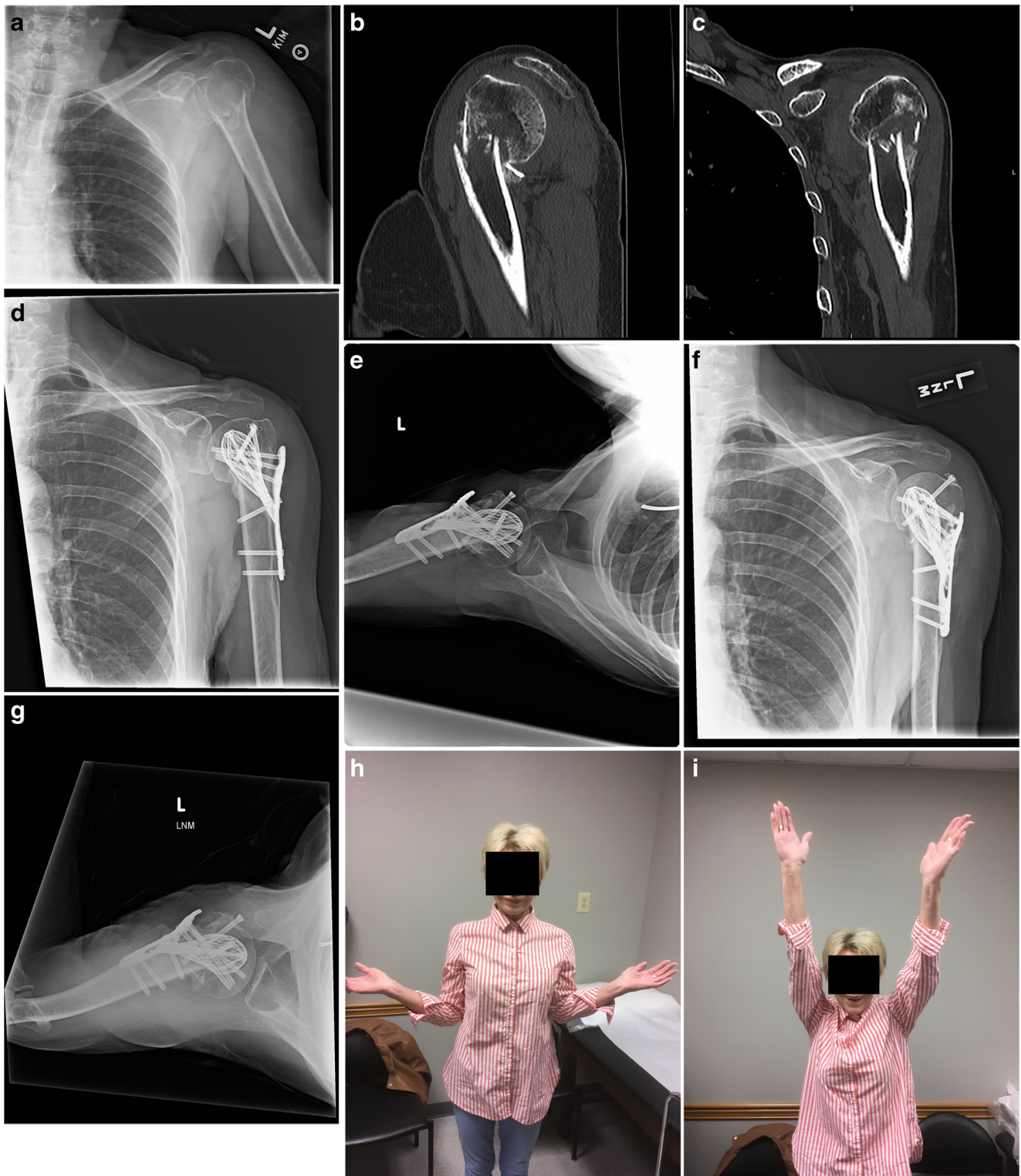


Fig. 3 Imaging from a 72-year-old female who sustained a left complex proximal humerus fracture from a ground level fall. CT reveals poor bone stock that would complicate reconstruction. She underwent open reduction

internal fixation with a proximal humerus cage. Radiographs at 3 months reveal healing fracture with no evidence of complication. Clinically, her range of motion was close to her uninjured side and she was pain free

has been consistent with the author's personal experience. Strategies to optimize outcome include anatomic reduction, hardware visualization, and periosteal preservation.

Managing three- or four-part proximal humerus fractures with poor bone quality is of particular interest in this patient population. The use of a fibular strut allograft to provide

additional structural support combined with locked plating has shown promising results. Hinds et al. reported a Constant score of 83 using this technique in geriatric patients [21]. Additionally, a systematic review of use of these grafts found a reoperation rate of 4.4%, significantly lower than that seen with locked plating alone [52]. While total patients are relatively low, these results are promising.

Future Directions

Technological advancements will continue to combat the problem of poor bone quality. Newer generation locking plates are available, and early results are encouraging. Rodia et al. reported 1 year follow-up of 54 patients with proximal humerus fractures treated with an updated locking plate and noted a Constant score of 75 with only five complications, none of which required revision surgery [53]. Schliemann et al. reported good functional scores at 2 years using a carbon fiber reinforced polyetheretherketone plate [54].

Problem areas remain which include potential screw penetration particularly with valgus impacted fractures which can settle and result in intra-articular screw penetration. Solutions include the use of pegs instead of screws as well as allograft cortical struts. A newer device which shows promise is an expandable nitinol mesh cage for the proximal humerus (Conventus, Minneapolis, MN). This cage provides a broad surface area to support a valgus impacted head as well as fills the void present in the intertubercular area in elderly osteoporotic patients. This lack of bone combined with poor medial support is likely the reason varus angulated fractures are still problematic. Fulkerson et al. reported a significantly decreased reoperation rate when using this device compared to historical controls (5.6 vs 19%) [55]. The cage can provide medial support as well as a surface for screws to gain purchase (Fig. 3).

Conclusions

Complex proximal humerus fractures remain a challenging problem for orthopedic surgeons. Technological advancements have improved fracture evaluation and surgical management, however, complications remain prevalent. The authors advocate for open reduction and internal fixation in order to restore native anatomy and preserve the option for arthroplasty. Future technologies designed to reduce complications are promising.

Compliance with Ethical Standards

Conflict of Interest John Wyrick reports personal fees from Stryker and Smith and Nephew, outside the submitted work. Rafael Kakazu declares no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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