Outcomes of Proximal Humerus Fracture Open Reduction Internal Fixation with Concomitant Ipsilateral Shoulder Girdle Injuries: a Case Control Study

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Received: 7 November 2015/Accepted: 25 February 2016/Published online: 1 April 2016
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Abstract *Background:* Proximal humerus fractures treated in the face of ipsilateral injuries to the shoulder girdle may be predisposed to worse clinical outcomes. *Questions/Purposes:* The purpose of this investigation was to examine outcomes of proximal humerus fractures treated with open reduction internal fixation (ORIF) using an endosteal augment in the presence of a concomitant shoulder girdle injury in comparison to isolated proximal humerus fractures treated with ORIF and endosteal augment. *Methods:* A prospective database was used to identify proximal humerus fractures with ipsilateral shoulder girdle injuries (glenohumeral and acromioclavicular

dislocation, fractures of the acromion, clavicle, scapula, or humeral diaphysis). These were compared to isolated proximal humerus fractures treated in the same fashion (ORIF with endosteal augment). Minimum of 1 year follow-up was required for inclusion. Outcomes assessed included range of motion (ROM), development of avascular necrosis (AVN), hardware-related complications, reoperation, and subjective outcome assessments including the Disabilities of Arm Shoulder and Hand questionnaire (DASH), Constant score, UCLA rating scale, and the Short Form-36 (SF-36). *Results:* Fifteen ipsilateral injuries were seen in 14 patients. Seventy-seven isolated proximal humerus fractures were available for comparison. The ipsilateral injury group had significantly worse forward flexion (141 vs 156°, $p=0.02$), external rotation (56 vs 64°, $p=0.03$), higher rates of avascular necrosis (4 of 14, 28.6% vs 1 of 77, 1.3%, $p=0.002$), and inferior SF-36 physical health scores (48.5 vs 63.5; $p=.04$). Despite these differences, no significant differences were seen with hardware-related complications or DASH, Constant score, or UCLA rating scale results. No patients required secondary reconstructive procedures. *Conclusion:* Despite a statistically higher rate of AVN and decreased ROM, patient-based outcomes of proximal humerus fractures with ipsilateral shoulder injuries approached those seen in isolated proximal humerus fractures. This suggests that these injuries can achieve similarly good clinical results provided any associated shoulder pathology is identified and treated appropriately.

Work performed at New York Presbyterian Hospital and Hospital for Special Surgery, New York, NY.

Level of Evidence: Level 3: Therapeutic.

Electronic supplementary material The online version of this article (doi:10.1007/s11420-016-9498-4) contains supplementary material, which is available to authorized users.

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Keywords proximal humerus fracture · dislocation · avascular necrosis · clavicle fracture · acromion fracture · acromioclavicular separation

Introduction

Much has been written in the literature regarding the treatment of proximal humerus fractures by means of open

reduction internal fixation (ORIF). While the surgical techniques, biologics, implants, and postoperative protocols continue to improve, there is a mass of data on outcomes and complications of proximal humerus fractures treated by means of locking plate fixation, the current standard of care [4, 6, 8, 11, 13–15, 18, 19, 22]. What is not well described are the outcomes and complications among proximal humerus fractures treated in conjunction with an injury to the ipsilateral shoulder girdle. These injuries include dislocations of the glenohumeral joint and additional fractures of the shoulder girdle including the glenoid, acromion, clavicle, ipsilateral humeral shaft as well as acromioclavicular joint instability. Empirically, one would hypothesize that patients with a proximal humerus fracture treated in conjunction with an ipsilateral injury would experience a worse clinical outcome compared to their counterparts with an isolated fracture of the proximal humerus. However, scant data exists to describe these injuries and resulting outcomes when managed with surgical intervention.

It was our hypothesis that patients with an additional ipsilateral shoulder injury will experience worse outcomes compared to patients with an isolated fracture of the proximal humerus. The purpose of this investigation is to compare a series of proximal humerus fractures with an ipsilateral injury to the shoulder to patients with an isolated proximal humerus fracture when the proximal humerus fractures were all treated with locking plate fixation and endosteal augmentation. The outcomes specifically compared included range of the shoulder motion at 1 year as well as the Disabilities of Arm Shoulder and Hand questionnaire (DASH), Constant score, UCLA rating scale, and the Short Form-36 (SF-36). Radiographs were also compared assessing loss of fixation, development of avascular necrosis, and evidence for hardware penetration into the shoulder joint.

Patients and Methods

This study was performed at a level I trauma center utilizing patients treated by a single surgeon (DGL) after an institutional review board approval was obtained. Data collection occurred in a prospective manner. The surgical log was used to identify patients that had undergone open reduction internal fixation of their proximal humerus fracture from January 2008 to January 2012. All of these patients underwent a uniform treatment protocol including open reduction by means of the anterolateral approach with care to preserve the axillary nerve and blood supply to the proximal humerus and fixation using a lateral locking plate and endosteal augment to re-establish the medial calcar and enhance fixation [13]. More specifically, endosteal augmentation in these cases involved intramedullary allograft fibular placement beneath the subchondral bone of the humeral head into the metaphysis. This provides a medial strut to help support the humeral head fragment, re-establish the medial calcar and allow for screw purchase from the laterally based plate, and screw construct to enhance fixation (Fig. 1). Postoperatively, all patients were managed with an aggressive physical therapy regimen including active and passive range of motion as

tolerated and kept non-weight bearing until 6 weeks post-op. Follow-up occurred at regular intervals until at least 1 year from the surgical date.

All patients having undergone proximal humerus ORIF were eligible for inclusion, unless the following exclusion criteria applied: skeletal immaturity, follow-up less than 1 year, no endosteal augment utilized, or injuries to the ipsilateral upper extremity exclusive of the shoulder or humeral shaft. After selecting the cases that met these criteria, two groups were created for analysis. The first group consisted of those patients with an ipsilateral injury to the shoulder. This included ipsilateral fractures of the clavicle, acromion, glenoid, or humeral shaft, as well as any glenohumeral dislocations. These injuries were identified and confirmed by examining the inpatient and outpatient medical record, radiology reports, and injury films themselves. The other group consisted of those cases with isolated fractures of the proximal humerus treated with ORIF, without an ipsilateral injury. Data collection for both groups included basic demographic data, injury and operative details, and follow-up information which were collected from the inpatient and outpatient medical record, as well as a review of all pertinent radiographs.

A total of 91 proximal humerus fractures met inclusion and exclusion criteria for analysis. Seventy-seven fractures were considered isolated proximal humerus fractures, while the remaining 14 cases had 15 identifiable ipsilateral injuries to the shoulder girdle. This included three glenohumeral dislocations, one glenoid fracture, one acromion fracture, one clavicle fracture, and nine humeral diaphyseal fractures. All of these ipsilateral injuries were managed with fracture-specific fixation independent of the proximal humerus except for the three glenohumeral dislocations and glenoid fracture, which were treated with no further surgical intervention. No differences in demographics, comorbidities, or fracture pattern were seen between groups (Table 1).

Final range of motion was assessed and recorded by the treating physician at final follow-up. The need for revision operations was recorded. Outcome surveys and questionnaires were completed at a minimum of 1 year follow-up. This included the Disabilities of Arm Shoulder and Hand questionnaire (DASH), Constant score, UCLA rating scale, and the Short Form-36 (SF-36). The injury radiographs including computed tomography scans were reviewed to determine the fracture classification (Neer and AO/OTA), as well as identify the presence of any ipsilateral injury. The final follow-up radiograph was compared to the initial postoperative radiograph to quantify any loss of reduction that might have occurred. This was performed by correcting for magnification and comparing the change in humeral head height according to the method described by Gardner et al. [4]. Cases with more than 3 mm of loss of humeral height were considered to have a loss of reduction. All postoperative radiographs were scrutinized to identify cases of screw penetration, nonunion, or avascular necrosis (AVN).

The outcomes assessed in this investigation included the following: DASH, UCLA rating scale, Constant score, SF-36, loss of reduction, range of motion, secondary operations, screw penetration, nonunion, and avascular necrosis.

Fig. 1. This series of radiographs illustrates the technique of endosteal augmentation. Fibular cortical struts are inserted to support the humeral head fragment, re-establish the medial calcar, and allow for screw purchase from the laterally based plate and screw construct.

Statistical analysis was performed by comparing groups with the use of *t* test for continuous variables and Fisher's exact test for categorical variables. No sources of external funding were utilized for this investigation.

Results

The ipsilateral injury group had statistically significant decreased average shoulder range of motion compared to the isolated injury group. Specifically, differences were detected with regards to forward flexion (141 [SD 25.8] vs 156° [SD 20.3], $p=0.02$) and external rotation (56 [SD 13.2] vs 64° [12.9], $p=0.03$) at final follow-up.

The radiographic complication rate between groups was higher among the ipsilateral injury group. AVN was observed at a significantly higher rate in the ipsilateral injury group (4 of 14, 28.6% vs 1 of 77, 1.3%, $p=0.002$); none of these cases resulted in complete articular collapse at most recent follow-up. Of the four cases in the ipsilateral injury group that developed avascular necrosis, two were glenohumeral dislocations, one was an acromion fracture, and one was associated with an ipsilateral diaphyseal humerus fracture. Screw penetration was seen as a hardware-related complication more frequently in the ipsilateral injury group as well (3 of 14, 21.4% vs 6 of 77, 7.8%, $p=0.14$), although this did not reach statistical significance. Three of

the four cases that developed avascular necrosis in the ipsilateral injury group experienced screw penetration. There was no difference between groups with regard to loss of reduction (1 of 14 vs 12 of 77, $p=0.6829$), and there were no cases of nonunion observed in either group. No patients in either group required secondary arthroplasty procedures at final follow-up. However, 4 of 14 patients in the ipsilateral injury group underwent removal of hardware, 2 for screw penetration and 2 for hardware irritation. In the isolated injury group, one patient underwent revision ORIF for early postoperative displacement of the greater tuberosity. Twenty-eight of 77 patients had hardware removed; 6 for screw perforation, 3 for infection, and 19 due to hardware irritation.

Despite the fact that radiographic complications occurred at a higher rate in the ipsilateral injury group, there were no statistically significant differences observed between groups with regard to the majority of the patient and surgeon-based outcome scores. This was true of the DASH (18.7 [SD 21.8] ipsilateral injury group vs 17.6 [SD 18.0] isolated injury group, $p=0.87$), Constant (91 [SD 7.5] vs 87.1 [SD 10.1], $p=0.27$), UCLA (28.6 [SD 8.0] vs 29.5 [SD 6.1], $p=0.71$), and SF-36 mental health component (53.9 [SD 16.7] vs 66.7 [SD 20.2], $p=0.06$) scores. Only the SF-36 physical health components scores were significantly worse in the ipsilateral injury group (48.5 [SD 11.6] vs 63.5 [SD 22.5]; $p=.04$).

Discussion

In this review of patients with proximal humerus fractures treated by means of endosteal augmentation and locking plate fixation, 15% of cases were seen in conjunction with either a glenohumeral dislocation or fractures of the ipsilateral glenoid, clavicle, acromion, or humeral shaft. These patients with ipsilateral injuries were found to have statistically significant decreased range of motion, although not likely clinically significant, particularly with regard to range of motion. Additionally, a higher rate of complications including postoperative avascular necrosis and screw cutout was seen in the ipsilateral injury group. Despite these

Table 1 Comparison of demographic, comorbidity, and injury data between patients with isolated fractures of the proximal humerus and those with a concomitant ipsilateral shoulder girdle injury

Variable	Isolated fracture (<i>n</i> = 77)	Ipsilateral injury (<i>n</i> = 14)	<i>p</i> value
Age	62 (SD 14.3)	68 (SD 12.4)	0.1448
% Male	31% (24 of 77)	50% (7 of 14)	0.222
% Smokers	13% (10 of 77)	14% (2 of 14)	1
% Diabetes	12% (9 of 77)	7% (1 of 14)	1
% Low Energy	86% (66 of 77)	100% (14 of 14)	0.2034
% 4-part Fx	26% (20 of 77)	21% (3 of 14)	1
Avg follow-up (month)	18 (SD 11.5)	14 (SD 5.4)	0.2003

findings, no significant differences were found between these two groups with regard to validated outcome scores, including the DASH, Constant, and SF-36 mental health scores.

The main limitation to this study is the length of follow-up. A minimum follow-up of 1 year was required for inclusion in this study. While this allows for a higher number of patients to be enrolled and analyzed, the results should be interpreted with the understanding that outcome may change over time. Griener et al. followed 48 patients with treated proximal humerus fractures for an average of 45 months and reported interesting results [8]. While the average Constant score did not change between the 12-month and 45-month time point, the rate of AVN more than doubled, from 4 to 9 observed cases. Thus, while the present data may provide an accurate projection of outcome with regard to the Constant scores (and perhaps other functional outcome scores), it may in fact underestimate the true rate of AVN in this cohort. This can only be substantiated as these patients are followed over time. Secondly, 43 patients were excluded from analysis because of lack of adequate follow-up. The ultimate results of these patients are unknown and may have had some influence on the study findings. Lastly, this study provides no recommendations on how to best manage these concomitant shoulder injuries. All the humeral shaft, clavicle, and acromion fractures in this series were managed with ORIF, and the glenohumeral dislocations and glenoid fracture were managed with no further operative intervention. These decisions in management were at the discretion of the surgeon. No conclusions regarding how to treat these injuries should be made, as the focus of this paper was the treatment and outcome as it pertained to the proximal humerus fracture.

There are some reports in the literature regarding ipsilateral injuries to the upper extremity found in concert with operatively treated proximal humerus fractures. Robinson et al. provided a large case series of anterior glenohumeral dislocations seen in conjunction with a proximal humerus fracture [17]. Overall, 30 patients were treated with open reduction internal fixation, 23 with retained capsular and soft tissue attachments to the head (“type I”), and 7 which were completely devoid of any soft tissue attachments and presumably avascular (“type II”). The rate of AVN in type I injuries was low (2/23, 8.7%), while a dramatically higher rate was seen in the type II cohort (4/7, 57.1%). The same group also reported on their outcomes of proximal humerus ORIF in conjunction with a posterior glenohumeral dislocation [16]. Outcomes were generally good, with only one case of partial avascular necrosis and average 2-year DASH and Constant scores 17.5 and 84, respectively. A more recent report has identified glenohumeral dislocation as a strong predictor of complications in fractures treated with open reduction and fixation with the PHILOS plate. In this review of 294 cases, glenohumeral dislocation was found to correlate strongly with screw perforation as well as AVN [20]. Looking exclusively at the fracture dislocations in this series ($N=26$), there was an overall complication rate of 53% and a 30% rate of AVN. Case reports and case series documenting outcomes of proximal humerus fractures seen

in combination with fractures of the ipsilateral shaft have shown slightly lower rates of complications and AVN, compared to fracture dislocations. Zhang et al. described an open treatment of this injury pattern with a long lateral locking plate in 35 cases and found only 1 case of AVN and no screw perforations at 18 months [23]. Using the Neer shoulder scoring system, they reported outcomes as good/excellent in 25 cases. Garmavos et al. reported their technique of intramedullary nailing of combined head and shaft fractures and reported that 18 of 21 healed between 4 and 7 months with only 1 case of avascular necrosis and an average Constant score of 74.4 [5]. Other case reports describe satisfactory treatment of combined head and shaft fractures as well [3, 21]. No data describing outcomes of proximal humerus fractures seen in combination with the clavicle, glenoid, or acromion fractures is available for comparison.

Since the advent of locking plate technology, open reduction internal fixation of proximal humerus fractures has become an attractive treatment strategy. Despite this available technology, outcomes have not consistently been superior with frequently reported Constant scores ranging between 58 and 71 and DASH scores between 15 and 29 [6, 18, 19, 22]. Additionally, locking plate fixation alone has not sufficiently decreased observed rates of AVN after operative treatment, with rates reported up to 30% [6, 15, 18, 19, 22]. However, endosteal augmentation in conjunction with locking plate fixation has shown promising results with regard to clinical outcomes and minimizing AVN. Nevaizer et al. reported no cases of complete AVN and mean DASH and Constant scores of 15 and 87, respectively, when using this technique in isolated proximal humerus fractures [13, 14]. Promising results have also been shown when using autogenous iliac crest in a similar fashion [11].

In this report, all fractures were managed with locking plate fixation and endosteal augmentation. Very good results were again seen in the isolated injury group, with a low rate of AVN, screw perforation, and above average outcome scores, lending further credence to this surgical technique. It is notable that the single case in which AVN developed in the isolated injury group occurred in a patient with a massive, chronic rotator cuff tear. This chronic, retracted rotator cuff tear was repaired with suture at the time of ORIF. While it is impossible to draw any conclusions from this single case, it is interesting that AVN developed in this scenario. Whether or not excessive cuff tension can play some role in humeral head ischemia is unknown, but may serve as an area of future research.

The patients with ipsilateral injuries were managed in the same fashion with regard to their proximal humerus fracture, but a higher rate of AVN and screw perforation was seen compared to the group with isolated fractures. However, in comparison to outcomes reported among these combined proximal humerus and shoulder injuries in the literature, this cohort experienced favorable outcomes and complication rates. This is not entirely surprising. While the blood supply to the proximal humerus is largely understood [7, 10], predicting which injury patterns will result in osteonecrosis is murky. While some variables have been identified that may be predictive of AVN, including the length of the

metaphyseal spike, disruption of the medial hinge, and increasingly complex fracture patterns, [2, 9] these are not absolute [14]. In fact, Bastian et al. have documented that 80% of fractures without evidence of vascularity at the time of ORIF went on to heal in the absence of AVN [1]. Additionally, cases where absolutely no soft tissue attachments remain to the humeral head following fracture dislocation have been reported to heal and avoid AVN [12, 17]. Thus, there appears to be some potential for revascularization of the humeral head. This may be optimized in the setting of an anatomic reduction and stable fixation. The locking plate and endosteal augment construct may provide for this necessarily sufficient reduction and fixation, and thus allows for some of these proximal humerus fractures to heal without frank avascular necrosis and collapse.

In this clinical investigation of proximal humerus fractures managed with locking plate fixation with endosteal augmentation, good results were obtained overall. When analyzing fractures that presented with ipsilateral injuries to the shoulder girdle, a higher rate of complications including screw perforation and avascular necrosis was observed compared to isolated proximal humerus fractures. Despite this, good clinical results were observed and no revision operations or arthroplasties were necessary at final follow-up. While proximal humerus fractures seen in concert with ipsilateral injuries to the humeral shaft, the clavicle, acromion, or glenohumeral joint may be at a higher risk of complications, appropriate recognition and treatment of associated injuries, as well as ORIF with endosteal augmentation of the proximal humerus with attention towards adequate fracture reduction may provide sufficient fixation to allow osseous union and good clinical outcomes. Thusly, this treatment strategy is a viable option for these injuries.

Compliance with Ethical Standards

Conflict of Interest: Marschall B. Berkes, MD, Milton T.M. Little, MD, Nadine C. Pardee, BS, Patrick C. Schottel, MD, Lionel E. Lazaro, MD, and Dean G. Lorch, MD have declared that they have no conflict of interest.

Human/Animal Rights: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5).

Informed Consent: Informed consent was waived from all patients for being included in the study.

Required Author Forms Disclosure forms provided by the authors are available with the online version of this article.

References

- Bastian JD, Hertel R. Initial post-fracture humeral head ischemia does not predict development of necrosis. *J Shoulder Elb Surg.* 2008; 17(1): 2-8.
- Brooks CH, Revell WJ, Heatley FW. Vascularity of the humeral head after proximal humeral fractures. An anatomical cadaver study. *J Bone Joint Surg (Br).* 1993; 75(1): 132-136.
- Flint JH, Carlyle LM, Christiansen CC, Nepola JV. Case report and literature review anterior shoulder dislocation with three-part proximal humerus fracture and humeral shaft fracture. *Iowa Orthop J.* 2009; 29: 105-113.
- Gardner MJ, Weil Y, Barker JU, Kelly BT, Helfet DL, Lorch DG. The importance of medial support in locked plating of proximal humerus fractures. *J Orthop Trauma.* 2007; 21(3): 185-191.
- Garnavos C, Lasanianos N. Intramedullary nailing of combined/extended fractures of the humeral head and shaft. *J Orthop Trauma.* 2010; 24(4): 199-206.
- Geiger EV, Maier M, Kelm A, Wutzler S, Seebach C, Marzi I. Functional outcome and complications following PHILOS plate fixation in proximal humeral fractures. *Acta Orthop Traumatol Turc.* 2010; 44(1): 1-6.
- Gerber C, Schneeberger AG, Vinh TS. The arterial vascularization of the humeral head. An anatomical study. *J Bone Joint Surg Am.* 1990; 72(10): 1486-1494.
- Greiner S, Kaab MJ, Haas NP, Bail HJ. Humeral head necrosis rate at mid-term follow-up after open reduction and angular stable plate fixation for proximal humeral fractures. *Injury.* 2009; 40(2): 186-191.
- Hertel R, Hempfing A, Stiehler M, Leunig M. Predictors of humeral head ischemia after intracapsular fracture of the proximal humerus. *J Shoulder Elb Surg.* 2004; 13(4): 427-433.
- Hettrich CM, Boraiah S, Dyke JP, Neviaser A, Helfet DL, Lorch DG. Quantitative assessment of the vascularity of the proximal part of the humerus. *J Bone Joint Surg Am.* 2010; 92(4): 943-948.
- Kim SH, Lee YH, Chung SW, et al. Outcomes for four-part proximal humerus fractures treated with a locking compression plate and an autologous iliac bone impaction graft. *Injury.* 2012; 43(10): 1724-1731.
- Kofoed H. Revascularization of the humeral head. A report of two cases of fracture-dislocation of the shoulder. *Clin Orthop Relat Res.* 1983; 179: 175-178.
- Neviaser AS, Hettrich CM, Beamer BS, Dines JS, Lorch DG. Endosteal strut augment reduces complications associated with proximal humeral locking plates. *Clin Orthop Relat Res.* 2011; 469(12): 3300-3306.
- Neviaser AS, Hettrich CM, Dines JS, Lorch DG. Rate of avascular necrosis following proximal humerus fractures treated with a lateral locking plate and endosteal implant. *Arch Orthop Trauma Surg.* 2011; 131(12): 1617-1622.
- Owsley KC, Gorczyca JT. Fracture displacement and screw cutout after open reduction and locked plate fixation of proximal humeral fractures [corrected]. *J Bone Joint Surg Am.* 2008; 90(2): 233-240.
- Robinson CM, Akhtar A, Mitchell M, Beavis C. Complex posterior fracture-dislocation of the shoulder. Epidemiology, injury patterns, and results of operative treatment. *J Bone Joint Surg Am.* 2007; 89(7): 1454-1466.
- Robinson CM, Khan LA, Akhtar MA. Treatment of anterior fracture-dislocations of the proximal humerus by open reduction and internal fixation. *J Bone Joint Surg (Br).* 2006; 88(4): 502-508.
- Schliemann B, Siemoneit J, Theisen C, Kisters C, Weimann A, Raschke MJ. Complex fractures of the proximal humerus in the elderly—outcome and complications after locking plate fixation. *Musculoskelet Surg.* 2012; 96(Suppl 1): S3-S11.
- Solberg BD, Moon CN, Franco DP, Paiement GD. Locked plating of 3- and 4-part proximal humerus fractures in older patients: the effect of initial fracture pattern on outcome. *J Orthop Trauma.* 2009; 23(2): 113-119.
- Spross C, Platz A, Rufibach K, Lattmann T, Forberger J, Dietrich M. The PHILOS plate for proximal humeral fractures—risk factors for complications at one year. *J Trauma Acute Care Surg.* 2012; 72(3): 783-792.
- Srinivas S, Kasis A. Co-existing fractures of the proximal humerus and humeral shaft without shoulder dislocation—a rare injury. *Ann R Coll Surg Engl.* 2010; 92(2): W25-W28.

22. Sudkamp N, Bayer J, Hepp P, et al. Open reduction and internal fixation of proximal humeral fractures with use of the locking proximal humerus plate. Results of a prospective, multicenter, observational study. *J Bone Joint Surg Am*. 2009; 91(6): 1320-1328.
23. Zhang H, Ni W, Gao S, Liang X, Zhou A. Long PHILOS locking compression plate for treatment of proximal humerus and humeral shaft fractures. *Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi*. 2009; 23(4): 419-422.