Acta Orthop. Belg., 2017, **83**, 1-7

ORIGINAL STUDY

Functional outcome after proximal humerus fracture fixation : understanding the risk factors

Anthony Christiano, Christian Pean, Sanjit Konda, Kenneth Egol

From the NYU Hospital for Joint Diseases, New York, NY and Jamaica Hospital Medical Center, Queens, NY

The purpose is to identify risk factors of functional outcome following proximal humerus open reduction and internal fixation.

Patients treated for proximal humerus fractures with open reduction and internal fixation were enrolled in a prospective data registry. Patients were evaluated for function using the Disability of the Arm, Shoulder and Hand score for 12 months and as available beyond 12 months. Univariate analyses were conducted to identify variables associated with functional outcome. Significant variables were included in a multivariate regression predicting functional outcome.

Demographics and minimum of 12 month follow-up were available for 129 patients (75%). Multiple regression demonstrated postoperative complication (B=8.515 p=0.045), education level (B=-6.269p<0.0005), age (B=0.241p=0.049) and Charlson Comorbidity Index (B=6.578, p=0.001) were all significant predictors of functional outcome.

Orthopaedic surgeons can use education level, comorbidities, age, and postoperative complication information to screen patients for worse outcomes, establish expectations, and guide care.

Keywords : proximal humerus fracture ; open reduction and internal fixation ; locked plate ; education level.

INTRODUCTION

Fractures of the proximal humerus account for 50% of all humerus fractures and lead to 184,300 emergency department visits per year in the United States. *(17)* Women *(4)* and the elderly *(28)* are more commonly affected, with 5% of women over the age of 65 projected to have a fracture of the proximal humerus in their lifetime. *(1)* The risk of a proximal humerus fracture increases with associated bone fragility or increased fall risk. *(20)* The majority of these fractures is minimally displaced *(6)* and can be treated nonoperatively *(14)* with good functional outcome. *(12)*

In most displaced or unstable proximal humerus fractures, operative treatment is indicated. *(22)* There are many operative methods available to today's orthopaedic surgeon including closed reduction with percutaneous pinning, *(7)* intramedullary nailing, *(30)* locking plate fixation, *(34)* hemiarthroplasty *(3)* or reverse total shoulder arthroplasty. *(16)* Handoll et al demonstrated in an update for the Cochrane review that there was inadequate evidence to support any one technique over the others. *(11)* Despite this disagreement in optimal treatment, locking plate

■ Anthony Christiano, B.A.
■ Christian Pean, M.S.
■ Kenneth Egol, M.D.
New York University, Hospital for Joint Diseases, Department of Orthopaedic Surgery, New York, New York.
■ Sanjit Konda, M.D.
Jamaica Hospital Medical Center, Department of Orthopaedic Surgery, Queens, New York.
Correspondence : Anthony Christiano, 301 East 17th Street, 14th Floor, New York, NY, 10003. Phone: +1-(212)-598-6460, fax: (212) 460-0162. E-mail : anthonychristiano@gmail.com.

No benefits or funds were received in support of this study. The authors report no conflict of interests.

fixation has become more popular *(32)* with high union rates and good functional recovery. *(25)*

Despite its popularity and success, high complication rates after open reduction and internal fixation (ORIF) have been reported in the orthopaedic literature with one systematic review by Sproul et al demonstrating an overall complication rate of 49% and a reoperation rate of 14%. *(33)* In addition to complications increasing patient morbidity in the short term, Ong et al previously demonstrated significantly worse functional outcomes in patients with complications after proximal humerus ORIF compared to patients without complications. *(26)* The purpose of this study was to elucidate other patient specific factors associated with poor functional outcomes after ORIF of a proximal humerus fracture with a locked plate.

MATERIALS AND METHODS

Under an institutional review board approved protocol, all patients treated with a locking plate for a proximal humerus fracture (Figure 1) by one of 3 fellowship trained orthopaedic traumatologist were approached for enrollment in a prospective data registry. All patients underwent repair with a similar protocol. Charlson comorbidity index (CCI) was calculated based on patient comorbidities at the time of injury. Neer classification *(24)* was determined by the treating physician based on a standard preoperative shoulder trauma series including, anteroposterior, axillary, and scapular-Y radiographs of the affected shoulder. Individual patient demographic information including a five-value categorical education variable (less than high school, high school, some college, college, and post-graduate education) was collected prior to treatment. Following surgery, patients were followed at regular intervals with a minimum of 12 months. Functional status was assessed using the Disabilities of the Arm, Shoulder, and Hand Outcome Measure (DASH), Clinical evaluation included shoulder range of motion (ROM), and radiographs were obtained to assess for healing and the development of osteonecrosis. All patients engaged in a similar postoperative protocol including initial placement in a sling, early passive range of shoulder motion, and muscular strengthening. Complications were recorded.

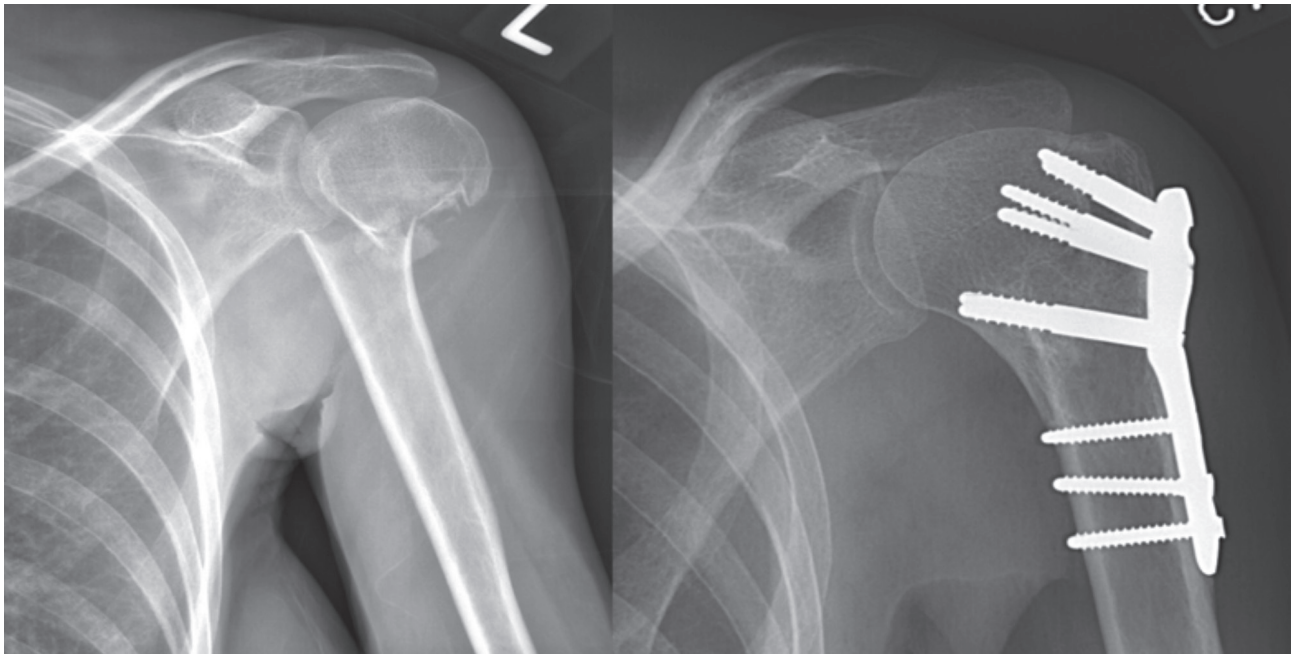

Fig. 1. — Anteroposterior radiographs demonstrating a proximal humerus fracture at time of injury (left) and 1 year after ORIF (right).

Statistical Analysis

Univariate analyses were conducted to determine significant differences in DASH scores based on patient independent variables. Separate Mann Whitney U tests were conducted to determine differences in median DASH score between smokers and non-smokers and patients with complications and patients without complications. Spearman's rank order correlations were conducted to determine association between DASH score and education level, body mass index (BMI), age, CCI, and Neer classification. A monotonic relationship between DASH and the test variable was verified for all Spearman's correlations. A significance cut off of $p < 0.05$ was used for all univariate analyses.

All variables found to have a statistically significant impact on DASH scores were included in a multivariate regression. A multivariate regression including presence of a postoperative complication, education level, age, and CCI was conducted to predict DASH score. The data were examined for the assumptions of linearity, independence of errors, homoscedasticity, and normality of residuals. A significance cut off of $p < 0.05$ was considered statistically significant in the multivariate regression. All statistical analyses were completed using SPSS 20.0 software (IBM, Armonk, NY).

RESULTS

Demographics and minimum of 12-month follow up were available for 129 patients (75%). Of the 129 eligible patients, 45 were male (35%) and 84 were female (65%). Mean age of the eligible patients was 61.5 years (SD 13.5). Mean DASH for all eligible patients was 22.6 (SD 22.2) at a mean follow up of 23.4 months (range 12 to 72 months). Mean DASH score by education level can be seen in figure 2. The overall complication rate in this cohort was 20.2%. A description of complications can be seen in Table I. Mean CCI was 0.5. The most common comorbidity was diabetes affecting 17.8% of the study population (Table II).

Results from the univariate analyses are shown in Table III. BMI and Neer classification

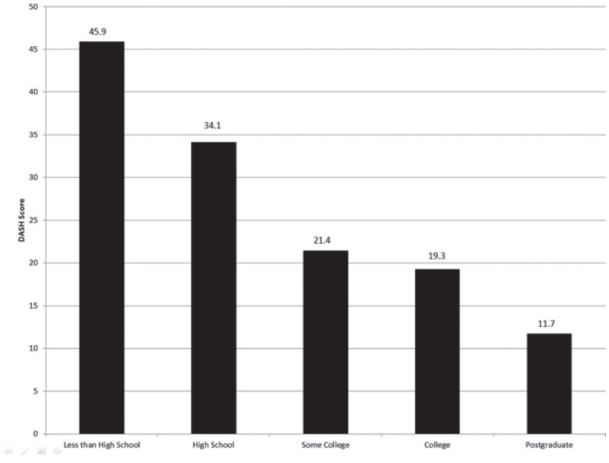

Fig. 2. — Mean DASH score by education level demonstrating lower mean DASH score with increased patient education level

(fracture pattern) were not significantly associated with DASH score. Presence of a complication, education level, age, and CCI were all significantly associated with DASH score and were included in a multivariate regression. The assumptions of linearity, independence of errors, homoscedasticity, and normality of residuals were met for all included variables. Multiple regression demonstrated presence of a postoperative complication ($B = 8.515$, 95% CI for B: 0.188 to 16.842, $p = 0.045$), lower education level ($B = -6.269$, 95% CI for B: -8.819 to -3.719, $p < 0.0005$), older age ($B = 0.241$, 95% CI for B: 0.001 to 0.482, $p = 0.049$) and higher CCI ($B = 6.578$, 95% CI for B: 2.905 to 10.250, $p = 0.001$) were all statistically significant predictors of worse DASH score.

DISCUSSION

The orthopaedic literature has demonstrated both a high complication and reoperation rate associated with locked plate fixation of proximal humerus fractures. There are several surgeon and patient specific risk factors influence functional outcome and complication rate. Egol et al previously showed augmenting the repair of proximal humerus fractures with calcium phosphate cement decreased fracture settling and rate of screw penetration into the glenohumeral joint. *(9)* Also, quality of the

Table I. — Description of complications after proximal humerus ORIF

Complication type	Total Number	Percentage of cohort
Screw penetration	8	6.2%
Avascular necrosis	7	5.4%
Infection	4	3.1%
Hardware failure	2	1.6%
Heterotopic ossification	2	1.6%
Malunion	1	0.8%
Nonunion	1	0.8%
Painful hardware	1	0.8%

Table II. — Description of comorbidities in the study cohort, with diabetes being the most common comorbidity

Comorbidity	Percent Affected
Diabetes	17.8%
Chronic Pulmonary Disease	7.0%
Connective Tissue Disorder	5.4%
Peptic Ulcer Disease	3.9%
Tumor without Metastasis	3.9%
Liver Disease	3.1%
Congestive Heart Failure	1.6%
Renal Disease	0.8%
Myocardial Infarction	0.8%

anatomic reduction and restoration of the medial cortical support are important factors in preventing fixation failure. *(18)* Patient specific factors influencing outcomes after ORIF of proximal humerus fracture include age, local bone mineral density, *(18)* increased fracture displacement, varus deformity, decreased humeral head vascularity, *(13)* and social independence. *(5)*

Our data demonstrate age and presence of a postoperative complication are negative predictors of functional outcome at final follow-up following ORIF of proximal humerus fractures using a locking plate. This is consistent with previous findings in which Ong et al demonstrated in a smaller cohort that patients with a complication after proximal humerus fracture ORIF had significantly worse functional outcome compared to patients that did not have a complication. *(26)* Age has also been previously established as a risk factor for worse functional outcome after proximal humerus fracture ORIF. Leonard et al demonstrated significantly worse functional outcome in patients greater than age 65 years old compared to patients younger than 65 years old. *(21)*

Education level and CCI were found to be independent predictors of functional outcome following proximal humerus fracture ORIF in this cohort. Petrigliano et al previously demonstrated that higher CCI is associated with increased mortality risk after non-arthroplasty fixation of proximal humerus fractures. *(29)* Orthopaedic surgeons can now be confident that, in addition to increased mortality risk, patients with more medical comorbidities and increased CCI are also at risk of worse functional outcome following proximal humerus ORIF. We postulate this is due to delayed postoperative recovery in the comorbid patient leading to deconditioning and an inability of patients with existing comorbidities to properly complete prescribed physical therapy.

Comorbidities have been associated with delayed fracture union. Specifically, diabetes mellitus, anemia, malnutrition, peripheral vascular disease, and hypothyroidism are all associated with delayed fracture healing. In addition, NSAID or corticosteroid use for the management of chronic conditions is linked to delay in fracture healing. *(10)* This delay in fracture healing of the comorbid patient becomes clinically important because successful fracture union is necessary for resolution of pain and restoration of functional capacity. *(8)* With decreased functional capacity, patients that are slow to heal are at greater risk of decreased mobility. Sedentary behavior predisposes patients with neuromuscular disabilities to deconditioning. *(31)* Therefore, we postulate that delayed recovery in the comorbid patient leads to deconditioning and loss of function that is never regained. This type of loss of functional status is similar to that described in patients after hip fracture, *(24)* and as with hip fractures these patients may benefit from home-based exercises programming focused on restoration of function. *(19)*

Patient education has previously been revealed as a predictor of functional outcome after operative

Table II. — Results of all univariate analyses demonstrating statistically significant relationships between DASH score and presence of a complication, level of education, age, and CCI

Variable	Test Completed	p-value
Smoking status	Mann Whitney U	0.902
Complication	Mann Whitney U	0.003*
Education Level	Spearman's Rank Order Correlation	< 0.0005*
BMI	Spearman's Rank Order Correlation	0.612
Age	Spearman's Rank Order Correlation	0.034*
Charlson Comorbidity	Spearman's Rank Order Correlation	< 0.0005*
Neer Classification	Spearman's Rank Order Correlation	0.487

* Denotes statistical significance at p<0.05

management of multiple fracture types. In a similar study, Paksima et al prospectively followed a group of 335 patients with distal radius fractures treated either operatively or nonoperatively. They demonstrated that each increase in level of patient education led to a doubling of improvement in pain, range of motion, grip strength, and DASH score at each observed time point. The authors noted that education level was easy to obtain and more indicative of socioeconomic status than yearly income. *(27)* Similar results were shown by Bhandari et al who followed 30 patients with operatively treated unstable ankle fractures over a two year period. They showed level of patient education was a significant predictor of physical function 3 months after surgery and accounted for a large percentage of the variance in postoperative physical function. They postulated that decreased physical function 3 months after surgery in patients with lower levels of education was possibly the result of underlying comorbidities that delayed healing or increased stress in the patient's lives. *(2)*

Our study results substantiate the continued applicability of patient education level as a predictor of functional outcome following proximal humerus fracture. Education level has been shown to be associated with decreased levels of stress after upper extremity trauma. Jaquet et al conducted a retrospective review of 107 patients diagnosed with traumatic nerve injury. They found that the vast majority of patients suffered some degree of psychological stress following their injury, which correlated with functional outcome. However, higher level of patient education was protective against psychological stress after trauma. *(15)* It is possible that it is this same protective mechanism at work in traumatic fractures including proximal humerus fractures.

Our study is limited by its generalizability. The patient cohort was disproportionately female and geriatric. Although this is consistent with the known epidemiology of proximal humerus fractures, *(4,28)* it weakens the applicability of these results to male and young patients. However, the findings are applicable to the typical patient presenting with a proximal humerus fracture.

Results from this study support the notion that comorbid patients and patients with lower education levels are at risk of poorer functional outcomes following proximal humerus fracture ORIF. To our knowledge, this is the first study establishing that a lower educational level correlates with poorer functional outcomes for patients undergoing locked plate fixation for proximal humerus fractures. We recommend that in addition to obtaining a patient's medical history, which may be limited by patient understanding of their comorbid conditions, patient care may benefit from ascertaining patient education level preoperatively. Patient education level has now been shown to be a significant predictor of functional outcome in multiple fracture types. Asking a patient their level of education may benefit patient care as a single question screen to identify patient at risk of poor functional outcome after fracture ORIF. Identified patients may benefit from increased disease specific counseling, social work consultation, and identification of patient barriers to physical therapy.

REFERENCES

1. **Barrett JA, Baron JA, Karagas MR, Beach ML.** Fracture risk in the U.S. Medicare population. *J Clin Epidemiol*. 1999;52:243-9.
2. **Bhandari M, Sprague S, Hanson B, et al.** Health-related quality of life following operative treatment of unstable ankle fractures: a prospective observational study. *J Orthop Trauma*. 2004;18:338-45.
3. **Cadet ER, Ahmad CS.** Hemiarthroplasty for three- and four-part proximal humerus fractures. *J Am Acad Orthop Surg*. 2012;20:17-27.
4. **Chu SP, Kelsey JL, Keegan TH, et al.** Risk factors for proximal humerus fracture. *Am J Epidemiol*. 2004;160:360-7.
5. **Clement ND, Duckworth AD, Mcqueen MM, Court-brown CM.** The outcome of proximal humeral fractures in the elderly: predictors of mortality and function. *Bone Joint J*. 2014;96-B:970-7.
6. **Court-brown CM, Garg A, Mcqueen MM.** The epidemiology of proximal humeral fractures. *Acta Orthop Scand*. 2001;72:365-71.
7. **Ebraheim N, Wong FY, Biyani A.** Percutaneous pinning of the proximal humerus. *Am J Orthop*. 1996;25:500, 501, 506.
8. **Egol KA, Gruson K, Spitzer AB, Walsh M, Tejwani NC.** Do successful surgical results after operative treatment of long-bone nonunions correlate with outcomes?. *Clin Orthop Relat Res*. 2009;467:2979-85.
9. **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;21:741-8.
10. **Gaston MS, Simpson AH.** Inhibition of fracture healing. *J Bone Joint Surg Br*. 2007;89:1553-60.
11. **Handoll HH, Ollivere BJ, Rollins KE.** Interventions for treating proximal humeral fractures in adults. *Cochrane Database Syst Rev*. 2012;12:CD000434.
12. **Hanson B, Neidenbach P, De boer P, Stengel D.** Functional outcomes after nonoperative management of fractures of the proximal humerus. *J Shoulder Elbow Surg*. 2009;18:612-21.
13. **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;43:153-8.
14. **Iyengar JJ, Devcic Z, Sproul RC, Feeley BT.** Nonoperative treatment of proximal humerus fractures: a systematic review. *J Orthop Trauma*. 2011;25:612-7.
15. **Jaquet JB, Kalmijn S, Kuypers PD, Hofman A, Passchier J, Hovius SE.** Early psychological stress after forearm nerve injuries: a predictor for long-term functional outcome and return to productivity. *Ann Plast Surg*. 2002;49:82-90.
16. **Jones KJ, Dines DM, Gulotta L, Dines JS.** Management of proximal humerus fractures utilizing reverse total shoulder arthroplasty. *Curr Rev Musculoskelet Med*. 2013;6:63-70.
17. **Kim SH, Szabo RM, Marder RA.** Epidemiology of humerus fractures in the United States: nationwide emergency department sample, 2008. *Arthritis Care Res* . 2012;64:407-14.
18. **Krappinger D, Bizzotto N, Riedmann S, Kammerlander C, Hengg C, Kralinger FS.** Predicting failure after surgical fixation of proximal humerus fractures. *Injury*. 2011;42:1283-8.
19. **Latham NK, Harris BA, Bean JF, et al.** Effect of a home-based exercise program on functional recovery following rehabilitation after hip fracture: a randomized clinical trial. *JAMA*. 2014;311:700-8.
20. **Lee SH, Dargent-molina P, Bréart G.** Risk factors for fractures of the proximal humerus: results from the EPIDOS prospective study. *J Bone Miner Res*. 2002;17:817-25.
21. **Leonard M, Mokotedi L, Alao U, Glynn A, Dolan M, Fleming P.** The use of locking plates in proximal humeral fractures: Comparison of outcome by patient age and fracture pattern. *Int J Shoulder Surg*. 2009;3:85-9.
22. **Maier D, Jaeger M, Izadpanah K, Strohm PC, Suedkamp NP.** Proximal humeral fracture treatment in adults. *J Bone Joint Surg Am*. 2014;96:251-61.
23. **Magaziner J, Hawkes W, Hebel JR, et al.** Recovery from hip fracture in eight areas of function. *J Gerontol A Biol Sci Med Sci*. 2000;55:M498-507.
24. **Neer CS.** Displaced proximal humeral fractures. I. Classification and evaluation. *J Bone Joint Surg Am*. 1970;52:1077-89.
25. **Norouzi M, Naderi MN, Komasi MH, Sharifzadeh SR, Shahrezaei M, Eajazi A.** Clinical results of using the proximal humeral internal locking system plate for internal fixation of displaced proximal humeral fractures. *Am J Orthop*. 2012;41:E64-8.
26. **Ong CC, Kwon YW, Walsh M, Davidovitch R, Zuckerman JD, Egol KA.** Outcomes of open reduction and internal fixation of proximal humerus fractures managed with locking plates. *Am J Orthop*. 2012;41:407-12.
27. **Paksima N, Pahk B, Romo S, Egol KA.** The association of education level on outcome after distal radius fracture. *Hand (N Y)*. 2014;9:75-9.
28. **Palvanen M, Kannus P, Niemi S, Parkkari J.** Update in the epidemiology of proximal humeral fractures. *Clin Orthop Relat Res*. 2006;442:87-92.
29. **Petrigliano FA, Bezrukov N, Gamradt SC, Soohoo NF.** Factors predicting complication and reoperation rates following surgical fixation of proximal humeral fractures. *J Bone Joint Surg Am*. 2014;96:1544-51.
30. **Riemer BL, D'ambrosia R, Kellam JF, Butterfield SL, Burke CJ.** The anterior acromial approach for antegrade intramedullary nailing of the humeral diaphysis. *Orthopedics*. 1993;16:1219-23.

31. Rimmer JH, Schiller W, Chen MD. Effects of disability-associated low energy expenditure deconditioning syndrome. *Exerc Sport Sci Rev*. 2012;40:22-9.

32. Ring D. Current concepts in plate and screw fixation of osteoporotic proximal humerus fractures. *Injury*. 2007;38 Suppl 3:S59-68.

33. Sproul RC, Iyengar JJ, Devcic Z, Feeley BT. A systematic review of locking plate fixation of proximal humerus fractures. *Injury*. 2011;42:408-13.

34. 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;71:1364-70.