Fracture Severity Based on Classification Does Not Predict Outcome Following Proximal Humerus Fracture

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abstract

This study was conducted to determine whether proximal humerus fracture patterns as defined by the Orthopaedic Trauma Association (AO/OTA) classification and the Neer 4-part system predicted functional outcomes for patients treated with open reduction and internal fixation with locked plates and, if so, which system correlated better with outcomes. During a 12-year period, 213 patients with a displaced proximal humerus fracture who underwent surgical treatment with a locking plate at 1 academic institution were prospectively followed. All patients were treated in a similar way and were followed by the operating surgeon at routine intervals. Functional outcomes were measured with the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire. Of these patients, 164 were available for analysis. Functional outcomes based on DASH scores did not differ significantly by Neer system, AO/OTA classification, or varus/valgus humeral head alignment at more than 12 months postoperatively. However, patients with Neer 4-part fracture and AO/OTA type 11-C fracture had worse shoulder range of motion in terms of forward elevation and external rotation. Time to healing and complication rates also were not significantly different based on either classification system. Fracture classification can predict shoulder range of motion 12 months after surgical fixation, but its use is limited in predicting functional outcome scores, time to healing, and complication rates. Patients who undergo surgical repair of a proximal humerus fracture can expect good functional results independent of the initial injury pattern, but more severe fracture patterns may lead to decreased shoulder range of motion. [*Orthopedics*. 2017; 40(6):368-374.]

Fractures of the proximal humerus represent 4% to 5% of all fractures in the general population.[1] Although most are treated nonoperatively, many benefit from surgical fixation, and the decision to operate is based on functional status, medical comorbidities, and the severity of the fracture pattern.[2] There are a number of surgical options, but the optimal management is controversial and randomized trials have not established a clear treatment algorithm,[3-9] possibly because of a lack of consensus regarding the optimal system for classifying proximal humerus fractures and the poor reliability of the current classification systems.[10]

Fracture classification systems facilitate communication between orthopedic surgeons, assist in surgical planning, and help to predict patient outcomes. In 1934, Ernest Codman[11] conceptualized the proximal humerus as consisting of 4 segments that tend to be involved in frac-

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Ms Fisher, Dr Barger, Dr Driesman, Ms Belayneh, and Dr Konda have no relevant financial relationships to disclose. Dr Egol is a paid consultant for and receives royalties from Exactech and has received grants from the Orthopaedic Research and Education Foundation.

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Received: March 3, 2017; Accepted: August 9, 2017.

doi: 10.3928/01477447-20170925-04

tures: the articular surface (defined by the anatomic neck), the greater tuberosity, the lesser tuberosity, and the shaft (defined by the surgical neck). With this model as a basis, Neer[12] developed a classification system in 1970 that is based primarily on which and how many Codman "parts" are fractured and displaced. The Neer classification is the most commonly used system in practice today.[13] The internationally accepted system in common clinical use is the AO/Orthopaedic Trauma Association (AO/OTA) classification.[14] The AO/OTA classification uses a trichotomous branching schema to place fractures into 1 of 27 subgroups, with primary categories of unifocal extra-articular fractures (type A), bifocal extra-articular fractures (type B), and intra-articular fractures (type C).

The merit of a classification system is found in its ability to reliably communicate clinically relevant information that can guide management, provide prognostic value, and stratify the risk of complications.[14] To the authors' knowledge, no study has investigated whether the Neer system or the AO/OTA classification can reliably predict functional outcomes. Therefore, this study was conducted to determine whether the Neer 4-part system or the AO/OTA classification was more predictive of outcomes among patients undergoing surgical repair with a locking plate for proximal humerus fracture.

Materials and Methods

A total of 213 consecutive patients who had a proximal humerus fracture and were treated surgically with a locking plate at 1 academic institution between February 2003 and July 2015 were enrolled in a prospective database. Institutional review board approval was obtained. All patients were treated in a similar manner.[15,16] All patients had preoperative radiographs of the shoulder, including anteroposterior, scapular Y, and axillary views. Computed tomography scans were performed for a few select patients, but it was not the usual practice at this institution to obtain these scans preoperatively. Fractures were classified according to the simplified Neer 4-part system (2-, 3-, or 4-part fracture) as well as the AO/OTA classification by a trained orthopedic traumatologist (K.A.E.). Shoulder subspecialists and/or musculoskeletal radiologists were not consulted for classification. Humeral head angulation (varus, valgus, or neutral coronal angulation) was recorded as well.

All patients underwent open reduction and internal fixation with a locking plate and screws, performed under the supervision of a fellowship-trained shoulder or trauma surgeon. A total of 9 surgeons performed the operations, and most procedures (78%) were performed by the senior author (K.A.E.). Similar hardware (3- or 5-hole proximal humerus locking plate) was used for all procedures, and there was no change in technique by the senior surgeon that would cause a difference in results. Patients were placed in the beach chair position, and the proximal humerus was exposed with a deltopectoral approach. Tuberosity fragments, if present, were mobilized with nonabsorbable sutures placed through the associated rotator cuff tendons. The humeral head was elevated and reduced via a lateral cortical window. If a void was present, it was filled with either cancellous chips or calcium phosphate cement, based on surgeon preference. Once the humeral head and tuberosities were reduced, a precontoured locking plate was applied lateral to the bicipital groove. The distal portion of the plate was fixed to the humeral shaft with a combination of locking and nonlocking bicortical screws. Finally, rotator cuff tendon sutures were tied down to the plate. Screw placement was confirmed with intraoperative fluoroscopy throughout the procedure. To help mitigate intra-articular screw penetration, the C-arm was brought in from above the affected shoulder to allow a 90° axillary view. Postoperatively, patients were placed in a sling and encouraged to start early passive range of motion of the shoulder. Isometric deltoid, biceps, and triceps strengthening exercises were initiated on postoperative day 1. Passive range of motion exercises were continued for 4 to 6 weeks postoperatively until there was radiographic evidence of fracture healing, after which patients began active range of motion exercises as part of a formal physical therapy program.[15]

Functional outcomes were measured with the Disabilities of the Arm, Shoulder and Hand (DASH) validated functional outcome questionnaire preoperatively and at 3, 6, and 12 months postoperatively.[17] Initial demographic information, including age, sex, body mass index, additional comorbidities (reported as age-adjusted Charlson Comorbidity Index), race, marital status, education level, and employment status, also was collected at the time of enrollment.

Only patients with minimum follow-up of 12 months or more were included in this analysis. A previous study showed that functional outcomes do not significantly decay after the 12-month time point, so the authors considered it reasonable to use 12 months as the end time point.[18] Of the 213 patients who had reached the 12-month time point, 164 (77.0%) had a minimum of 12 months of follow-up available (mean, 19.2 months) and were included in this analysis. Patient were statistically compared in terms of demographics, DASH scores at 12 months or greater, time to healing, and range of motion assessed by goniometer at the final visit (active and passive forward elevation and external rotation) by the Neer system (2-, 3-, or 4-part fracture), AO/OTA classification (type 11-A, -B, or -C fracture), and humeral head angulation (varus, valgus, or neutral coronal angulation). Differences in continuous variables were assessed with 1-way analysis of variance, and Pearson's chi-square test was used for categorical variables. Significance was set at $P<.05$. Analysis was performed with SPSS version 20 software (SPSS, Inc, Chicago, Illinois).

Table 1

Patient Demographics According to the Neer Classification

Characteristic	Neer Classification 2-Part Fracture (n=40)	3-Part Fracture (n=92)	4-Part Fracture (n=32)	*P*
Age at injury, mean±SD, y	56.65±16.9	61.30±12.4	60.22±10.6	.188
Body mass index, mean±SD, kg/m^2	25.94±6.8	29.06±8.8	30.68±5.7	.043
Age-adjusted CCI, mean±SD	2.76±2.1	3.35±1.6	3.00±1.6	.230
White	77.5%	71.7%	78.1%	.678
Female	77.5%	70.7%	50.0%	.034
Married	53.1%	56.3%	46.7%	.672
College degree	54.5%	52.5%	57.7%	.896
Employed	45.5%	38.8%	51.9%	.464
DASH score at 12+ mo, mean±SD	18.58±20.9	22.29±21.8	25.00±22.1	.449
Complications	22.5%	20.7%	31.2%	.470
Time to healing, mean±SD, mo	4.28±2.6	4.27±3.4	4.35±1.7	.991
Final active forward elevation, mean±SD	143.91°±30.9°	139.25°±30.3°	122.92°±32.9°	.039
Final passive forward elevation, mean±SD	150.28°±27.3°	149.55°±24.2°	135.21°±35.4°	.092
Final external rotation, mean±SD	51.30°±13.8°	49.25°±15.5°	34.38°±16.8°	<.001

Abbreviations: CCI, Charlson Comorbidity Index; DASH, Disabilities of the Arm, Shoulder and Hand.

Results

The cohort included 112 (68.3%) women and 52 (31.7%) men; average age at the time of injury was 60 years. Average age-adjusted Charlson Comorbidity Index was 3.14±1.7. Patients were analyzed based on the Neer system (2-, 3-, or 4-part fracture), AO/OTA classification (type 11-A, -B, or -C fracture), and fracture angulation (varus, valgus, or neutral angulation). For all 164 patients, mean DASH score at latest follow-up (mean, 19 months) was 23.34±21.8.

Fractures were classified by the Neer system as 40 (24.4%) 2-part fractures, 92 (56.1%) 3-part fractures, and 32 (19.5%) 4-part fractures (**Table 1**). Patients with 3- and 4-part fractures were on average 5 years older than those with 2-part fractures, but the difference was not significant. Body mass index was significantly different between the groups (*P*=.043), with a higher body mass index among those with 3- and 4-part fractures, but pairwise comparisons did not indicate statistical significance. In addition, no significant difference for body mass index was found between patients with high- and low-energy injuries (*P*=.369). Additionally, patients with 2- and 3-part fractures had a greater percentage of women than the patients with 4-part fractures (*P*=.034). Patients with Neer 2-, 3-, and 4-part fractures also did not differ in terms of age-adjusted Charlson Comorbidity Index, race, sex, marital status, education level, employment status, or complication rate. Although patients with 4-part fractures had a higher average DASH score at 12 months or more than those with 2- and 3-part fractures, this difference was not significant. In addition, time to healing was comparable between groups. However, a significant difference was noted for active forward elevation and external rotation, with patients with 4-part fractures reporting decreased range of motion. Pairwise comparisons showed that those with 4-part fractures still differed significantly from those with 2- and 3-part fractures in terms of active forward elevation (*P*<.0005 and *P*<.0005, respectively) and external rotation (*P*=.021 and *P*=.025, respectively). Although passive forward elevation did not differ significantly between groups, patients with 4-part fractures had the smallest range of motion.

Based on the AO/OTA system, the study group included 42 (25.6%) type 11-A fractures, 62 (37.8%) type 11-B fractures, and 60 (36.6%) type 11-C fractures (**Table 2**). Body mass index differed significantly between groups (*P*=.007), with those with type 11-C fractures having higher body mass index than those with type 11-A or -B fractures on pairwise comparisons (*P*=.010 and *P*=.039, respectively). Groups did not differ in terms of age, age-adjusted Charlson Comorbidity Index, race, sex, marital status, education level, employment status, complication rate, or time to healing. Although patients with type 11-C fractures had higher DASH scores by an average of 5 points at 12 months or more, this difference was not statistically significant. Range of motion, as assessed by active and passive forward elevation and external rotation, was significantly decreased for type 11-C fractures. Pairwise comparisons showed that patients with type 11-C fractures showed a significant difference from those with type 11-A or -B fractures on active forward elevation (*P*=.002 and *P*=.043) and external rotation (*P*=.012 and *P*=.027, respectively), but only differed significantly from those with type 11-A fractures on passive forward elevation (*P*=.002). Functional outcomes (DASH scores, time to healing, and range of motion) also were examined for AO/OTA fracture classification subgroups (11-A1, -A2, -A3; 11-B1, -B2, -B3; 11-C1, -C2, -C3). The most common fracture type by subgroup was type 11-B1 (22.6%). Time to healing and DASH scores at 12 months or more did not differ significantly between these subgroups (**Table 3**). However, active and passive forward elevation and external rotation were significantly worse in all type 11-C subgroups compared with type 11-A and -B subgroups.

Patients also were classified by varus, valgus, or neutral coronal angulation of the humeral head. Of the fractures, 54 (32.9%) had varus angulation, 66 (40.2%) had valgus angulation, and 44 (26.8%) had neutral angulation. Patients did not differ in terms of fracture angulation across any of the variables reported in this analysis, although trends were seen toward more complications and worse DASH scores for those with varus angulation and better scores for those with neutral angulation (**Table 4**).

Overall, 38 patients (29%) had a total of 48 complications, with 4 patients experiencing 2 complications and 3 patients experiencing 3 complications. The most frequent complication was screw penetration (33.3% of reported complications). The rate of osteonecrosis was 14.6%, and the rate of nonunion was 4.2%. A complete list of complications is shown in **Table 5**. The complication rate was higher in patients with Neer 4-part fractures, AO/OTA type 11-C fractures, and varus angulation. However, no statistically significant difference was found for the complication rate between those with Neer 2-, 3-, and 4-part fractures (*P*=.470); AO/OTA type 11-A, -B, and -C fractures (*P*=.145); and varus, valgus, or neutral angulation (*P*=.170).

Table 2

Patient Demographics According to the AO/OTA Classification

	AO/OTA Classification			
Characteristic	**11-A (n=42)**	**11-B (n=62)**	**11-C (n=60)**	***P***
Age at injury, mean±SD, y	56.64±17.0	61.90±12.4	60.27±11.2	.144
Body mass index, mean±SD, kg/m^2	26.39±6.6	27.59±6.3	31.22±9.6	.007
Age-adjusted CCI, mean±SD	3.09±2.1	3.18±1.6	3.13±1.6	.966
White	71.4%	79.0%	71.7%	.569
Female	76.2%	64.5%	66.7%	.429
Married	44.1%	57.9%	54.8%	.434
College degree	45.7%	66.0%	47.1%	.080
Employed	36.4%	48.2%	41.2%	.526
DASH score at 12+ mo, mean±SD	20.21±20.8	19.60±21.6	25.51±22.1	.274
Complications	19.0%	17.7%	31.7%	.145
Time to healing, mean±SD, mo	4.55±4.2	4.44±2.5	3.93±2.1	.589
Final active forward elevation, mean±SD	149.67°±28.2°	139.67°±29.1°	126.73°±32.9°	.007
Final passive forward elevation, mean±SD	160.00°±23.5°	147.76°±25.6°	136.22°±30.4°	.006
Final external rotation, mean±SD	51.60°±15.1°	49.07°±14.6°	41.41°±17.9°	.019

Abbreviations: CCI, Charlson Comorbidity Index; DASH, Disabilities of the Arm, Shoulder and Hand; OTA, Orthopaedic Trauma Association.

Discussion

At their best, fracture classification systems allow surgeons to systematically conceptualize the pathoanatomy, optimal management, and prognosis of a given injury. The dominant classifications available for fractures of the proximal humerus—the Neer system and the AO/OTA classification—do not always accomplish this goal. They have poor reliability and reproducibility and omit key considerations.[10,13,19-22] Given the limitations of the current proximal humerus classification systems, Resch et al[23] recently proposed a new classification system based on pathomorphologic analysis, and this system has shown high inter- and intraobserver reliability and has influenced surgical decision-making more than the Neer classification.[24] The patients analyzed in the current study represent a preselected group for whom there was no indication for nonoperative treatment, minimally invasive surgery, or arthroplasty. Therefore, some of the least severe and most severe fractures were excluded. Nevertheless, the study group included a wide range of fracture patterns, as demonstrated by the fact that 23 of 27 AO/OTA subgroups were represented. This multivariate analysis did not find a statistically significant predictive value for either the Neer system or the AO/OTA classification. Although both the Neer system and the AO/OTA classification identified patients with decreased range

Table 3

DASH Scores by the AO/OTA Subgroup Classification

		Mean±SD				
AO/OTA Fracture Classification With Subgroups	**Patients With Fracture Type**	**DASH Score at 12+ mo**	**Time to Healing, mo**	**Final Active Forward Elevation**	**Final Passive Forward Elevation**	**Final External Rotation**
11-A1	0	-	-	-	-	-
11-A2	9.8%	15.75±16.6	3.35±1.7	168.89°±13.6°	174.29°±9.8°	58.89°±11.7°
11-A3	15.9%	23.88±22.8	5.18±5.0	138.29°±28.8°	151.79°±25.4°	46.67°±15.7°
11-B1	22.6%	17.69±19.4	4.33±2.6	140.93°±28.3°	151.89°±22.5°	48.70°±12.6°
11-B2	12.2%	24.75±25.3	4.46±2.7	135.71°±30.8°	140.83°±29.6°	50.00°±19.1°
11-B3	3.7%	13.83±21.2	5.25±1.7	145.00°±35.1°	140.00°±42.4°	48.75°±16.5°
11-C1	15.2%	26.24±24.5	3.58±1.6	133.75°±31.4°	140.34°±26.6°	50.00°±15.3°
11-C2	14.6%	25.83±21.9	4.00±1.6	128.00°±33.7°	137.50°±36.5°	36.25°±17.0°
11-C3	6.1%	22.90±17.5	4.45±3.2	114.09°±32.8°	127.78°±26.8°	36.67°±19.8°
P	-	.555	.792	.013	.039	.014

Abbreviations: DASH, Disabilities of the Arm, Shoulder and Hand; OTA, Orthopaedic Trauma Association.

of motion at final follow-up, these limitations in shoulder range of motion were not captured by DASH scoring, which did not differ significantly based on any classification system. It is possible that the barrier to predicting outcomes lies in the functional assessment tool as opposed to the fracture classification system. Further investigation is needed to determine whether different functional scoring systems would produce different results. However, it is unclear whether other outcome assessment tools would show a different result as to which classification is more effective in predicting functional outcomes.

Other studies have shown significant differences in outcomes between groups of patients with proximal humerus fractures, but not within groups defined according to either the Neer system or the AO/OTA classification. Previous studies showed that proximal humerus fractures with varus angulation had higher complication rates compared with those with valgus fracture patterns, yet the reported long-term functional outcomes for varus-angulated proximal humerus fractures are varied and show conflicting results for functional ability.[5,23,25-29] The poor prognosis associated with varus angulation is likely caused in part by increased disruption of the medial vascular supply to the humeral head.[5] Humeral head angulation is considered for some AO/OTA classes, although it is only a branch point at the subgroup level. The Neer system does not consider varus angulation, and although neither system quantifies impaction, it can be difficult to account for impaction in a reproducible way.[23] However, Solberg et al[25] reported that the degree of metaphyseal impaction was a strong predictor of osteonecrosis after open reduction and internal fixation, and Hertel et al[30] showed that displacement of the medial hinge was most commonly associated with vascular compromise. However, neither of these studies correlated these radiographic findings with worse functional outcomes. Although radiographic findings such as varus angulation and metaphyseal impaction have been associated with increased complication rates, they have not been correlated with reduced range of motion or worse functional outcomes.[5,15] Therefore, it is unclear whether greater consideration of fracture angulation and metaphyseal impaction would improve the utility of the Neer system and the AO/OTA classification.

Limitations

This study had several limitations. Given the low interoperator agreement of these classification systems, it is likely that others may have classified many of the patients in this analysis differently. A single traumatologist performed the classification for this analysis, and no interobserver analysis was performed. The anatomy of proximal humerus fractures is often difficult to assess on plain radiographs, given the presence of multiple fracture lines and overlapping shadows, with the axillary view often particularly misleading, although the reliability of classification based on computed tomography scans also has been shown to be poor.[20,31] Additionally, although the current patient population was relatively homogenous demographically, a significant difference in body mass index was noted within the Neer 2-, 3-, and 4-part fracture groups and the AO/OTA type 11-A, -B, and -C fracture groups. Both patients with Neer 4-part fractures and those with AO/OTA type 11-C fractures had the highest DASH scores compared with their respective classification groups (ie, 2- and 3-part fractures, and type 11-A and -B fractures,

Table 4

Patient Demographics According to Fracture Angulation

Characteristic	Fracture Angulation Varus (n=54)	Valgus (n=66)	Neutral (n=44)	*P*
Age at injury, mean±SD, y	60.19±13.4	61.00±11.2	58.07±16.3	.528
Body mass index, mean±SD, kg/m^2	27.14±6.6	30.28±9.3	28.05±7.1	.105
Age-adjusted CCI, mean±SD	2.90±1.9	3.47±1.3	2.95±1.9	.168
White	81.5%	65.2%	79.5%	.082
Female	66.7%	68.2%	70.5%	.923
Married	48.9%	60.0%	50.0%	.492
College degree	58.8%	45.3%	60.0%	.272
Employed	43.1%	41.8%	44.1%	.976
DASH score at 12+ mo, mean±SD	24.81±23.3	22.00±21.9	18.16±18.8	.318
Complications	31.5%	21.2%	15.9%	.170
Time to healing, mean±SD, mo	4.84±3.6	3.85±2.0	4.11±2.7	.231
Final active forward elevation, mean±SD	133.51°±35.4°	138.16°±29.4°	138.21°±31.6°	.759
Final passive forward elevation, mean±SD	144.38°±30.7°	147.93°±29.2°	145.42°±24.1°	.862
Final external rotation, mean±SD	45.42°±18.0°	45.31°±15.0°	49.83°±17.3°	.450

Abbreviations: CCI, Charlson Comorbidity Index; DASH, Disabilities of the Arm, Shoulder and Hand.

respectively). Although this difference was not significant for either classification system, it is possible that patients with higher body mass index were prone to worse functional outcomes, which would slightly skew the results. Further, this analysis was limited by a relatively small sample size. It is possible that trends in the data would become statistically significant with a larger sample size. In addition, analysis based on the full 16-type Neer system and the 27-type AO/OTA classification may have shown some trends, but the full depth of these classifications is rarely used in clinical practice and subclassification of the fractures would have further limited the statistical power of the study. Earlier studies reported that AO/OTA type 11-C fractures had significantly higher complication rates and worse functional outcomes, as assessed by the Constant Shoulder Score.[5,32] The Neer system provides the basic framework that many orthopedic traumatologists use to approach proximal humerus fracture management. The Neer system is intuitive and simple, requiring only 1 diagram for explanation. Also, unlike the AO/OTA classification, the Neer system includes a definition of displacement (>1 cm, >45° rotation), which is important because fracture displacement is the main indication for surgery. However, this definition is somewhat arbitrary. The AO/OTA classification considers valgus and varus displacement, which has been shown to have a large influence on outcomes.[5,15,25] Finally, some fractures fit better into 1 of the 2 systems.[10] Thus, despite their well-documented lack of reliability and their shortcomings in differentiating between fractures of similar clinical severity, both systems have utility.

Conclusion

The current findings showed that neither the number of Neer fracture parts nor the AO/OTA type or subtype correlated significantly with postoperative DASH scores or complications. However, range of motion was significantly decreased with Neer 4-part and AO/OTA type 11-C fractures. Additionally, poorer functional outcomes were seen for patients with AO/OTA type C (intra-articular) fractures, and higher complication rates were seen

Table 5

Complications

Complication	Frequency in Total Complication Rate (n=48)
Screw penetration	33.3%
Osteonecrosis	14.6%
Infection	12.5%
Heterotopic ossification	8.3%
Malunion	8.3%
Removal of hardware	8.3%
Hardware failure	6.3%
Nonunion	4.2%
Osteoarthrosis	2.1%
Postoperative capsular contracture	2.1%

for patients with Neer 4-part and AO/OTA type C fractures. These results suggest that, for practical purposes, all displaced fractures that show indications for open reduction and internal fixation with a locked plate have a relatively similar prognosis, despite a wide range of categorizations according to the Neer system and the AO/OTA classification. However, more complex fracture patterns may show decreased range of motion in the affected shoulder. Neither classification system proved to be more reliable than the other, and although the Neer system is more familiar to most treating surgeons and is reported more often in the literature, it has problems with inter- and intraobserver reliability. Fracture severity within the system is likely more important than the classification system for predicting prognosis. Additional functional assessment tools are needed to better predict outcomes after proximal humerus fracture.

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