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ORIGINAL PAPER

Decision making in displaced fractures of the proximal humerus: fracture or surgeon based?

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Abstract
Purpose The aim of this study was to analyse the factors that influence surgeon decision-making in the treatment of proximal humerus fractures that might be considered for arthroplasty or open reduction and internal fixation.
Methods A total of 217 surgeons evaluated radiographs and clinical vignettes of ten patients with fractures of the proximal humerus. In addition to radiographs, we provided patient age, sex, trauma mechanism, activity level (sedentary-vigorously active), and physical status (normal healthy-moribund). Observers were asked to: (1) choose open reduction and internal fixation or hemiarthroplasty (closed question, one option) and (2) to briefly describe the factors that led to their decision (open-ended question). We assessed interobserver reliability using the Fleiss generalized kappa and analysed factors that influenced decision-making according to treatment choice.
Results Internal fixation was the preferred treatment for the majority of fractures. The overall multirater agreement was fair (κ=0.30), with a 75 % proportion of agreement. When asked to describe the factors that influenced decision-making, surgeons favouring internal fixation described patient-based factors in 52 %, fracture morphology in 51 %, surgeon factors in 42 %, and bone quality in 11 %. In contrast, fracture morphology was the most common factor (67 %) described by surgeons recommending replacement. Patient age, sex, activity level, physical status and the presence of angular displacement were associated with a recommendation for internal fixation.
Conclusion There is substantial variation in recommendations for internal fixation vs. arthroplasty for fractures of the proximal humerus that arises in large part from patient and surgeon factors.

Keywords Proximal humerus fracture · Treatment · Decision-making · Arthroplasty

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Introduction

Surgery is considered for approximately 20 % of proximal humerus fractures [1].

Commonly cited indications for replacement of the humeral head are: 'head-splitting' fractures, multi-part fractures with delayed presentation (> four weeks post-injury), and some fractures where the head is deemed to be nonviable [2–4]. Despite these criteria, there are substantial variations in treatment strategy [5]. We were curious about which factors had more influence on decision-making: fracture, patient, or surgeon characteristics [6, 5, 7–9].

This study tests the primary null hypothesis that fracture, patient, and surgeon characteristics do not influence recommendations for arthroplasty rather than open reduction and internal fixation for fractures of the proximal humerus. We also addressed the influence of these factors on interobserver agreement.

Material and methods

We asked members of the Science of Variation Group to evaluate ten vignettes describing patients with three- and

four-part fractures of the proximal humerus in an Internet-based survey.

The Science of Variation Group is a collaborative of fully-trained surgeons from diverse countries and institutions. The objectives of the collaborative are to study variation in the definition, interpretation, and classification of injury and disease. The study was performed under a protocol approved by the institutional research board at the principal investigator's hospital.

Observers

A total of 681 independent board-certified orthopaedic shoulder/elbow, hand/upper extremity, and trauma surgeons from several countries were invited via e-mail to participate in the study. Other than an acknowledgment as part of the author collaborative in this report, no incentives were provided. Four weekly reminders to complete the online survey were e-mailed; 217 surgeons completed the study (Table 1).

Radiographs

Radiographs of ten consecutive patients fitting the inclusion criteria were selected from a list of all patients with three- and four-part fractures of the proximal humerus treated operatively by a senior investigator from January 2009 to December 2011. Inclusion criteria were the availability of good quality initial injury radiographs and the absence of associated injury (e.g. clavicle fracture, shoulder dislocation). Radiographs were de-identified by an independent research fellow and uploaded to the research group's website.

Table 1 Surgeon demographics

Characteristic	Value, *n*
All questions answered	217
Sex	
Male	204
Female	13
Area of practice	
United States	106
Europe	61
Other	50
Years of independent practice	
0–10 years	118
More than ten years	99
Specialty	
Trauma & orthopaedic	89
Shoulder & elbow	50
Hand and wrist	66
Other	12

n number of surgeons

Vignettes

Each set of radiographs was accompanied by a vignette containing five attributes: patient age, sex, trauma mechanism, activity level, and physical status in varying and randomly assigned degree or severity (Table 2).

On logging into the website, surgeons were asked to provide the following demographic and professional information: (1) sex, (2) location of practice, (3) years in independent practice, (4) training of surgical trainees, (5) number of proximal humerus fractures treated per year, and (6) subspecialty.

Observers were asked to: (1) choose open reduction and internal fixation or hemiarthroplasty (closed question, forced choice) and (2) to briefly describe the factors that led to their decision (open-ended question). All questions had to be completed to continue with the next case, and observers could comment on each case. The observers completed the study at their own pace.

Statistical analysis

The coding of responses to the open-ended question was based on a content analysis [10]. A coding manual was developed in advance and readjusted during analysis of the survey. We also analysed the comments surgeons made regarding the relative influence of patient factors, fracture characteristics (number of fragments, comminution, displacement), their estimation of bone quality, and surgeon factors (surgeon beliefs and biases). Two experienced orthopaedic trauma surgeons and one research fellow independently categorized all surgeon comments into one of those four categories. All discrepancies were discussed until a consensus was reached.

The multirater agreement of the dichotomous variable (ORIF/arthroplasty) was calculated with the Fleiss generalized kappa [11, 12]. This is a statistical chance-corrected measure for assessing multirater agreement with binary ratings. The kappa values were interpreted according to the guidelines of Landis and Koch [11] as follows: 0.01 through 0.20 represent slight agreement, 0.21 to 0.40 fair agreement, 0.41 to 0.60 moderate agreement, 0.61 to 0.80 substantial agreement, and above 0.80 almost perfect agreement.

Factors associated with a recommendation for operative treatment were sought from among the following explanatory variables: patient factors (age, sex, trauma mechanism, activity level, and physical status) and radiographic factors (surgical neck vs. valgus impaction; angular displacement vs. impaction or minimal displacement). All factors with $P<0.1$ were then entered into a backward stepwise logistic regression model to determine the best predictors of a recommendation for surgery.

Comments about factors that influenced decision-making were analysed according to treatment choice.

Table 2 Vignette cases

Vignette number	Age (years)	Sex	Activity level	Trauma mechanism	Physical status	Radiographic appearance of fracture
1	71	Female	Vigorously active	High energy	Normal healthy	Surgical neck fracture: axial impaction, no angulation
2	37	Male	Extremely inactive	Low energy	Mild systemic disease	Valgus impaction fracture: head facing upwards
3	70	Female	Moderately active	Low energy	Severe systemic disease	Surgical neck fracture: valgus angulation
4	80	Female	Sedentary	Low energy	Moribund	Surgical neck with greater tuberosity fracture. Part of the articular surface is on the tuberosity fragment
5	56	Female	Sedentary	High energy	Mild systemic disease	Surgical neck fracture: translated
6	58	Female	Moderately active	Low energy	Normal healthy	Valgus impaction fracture: mild displacement
7	65	Male	Moderately active	Low energy	Normal healthy	Surgical neck fracture: valgus angulation
8	36	Male	Vigorously active	Low energy	Normal healthy	Surgical neck fracture: axial impaction, no angulation, nondisplaced greater tuberosity fracture
9	48	Female	Moderately active	High energy	Normal healthy	Valgus impaction fracture: moderate displacement
10	50	Male	Sedentary	High energy	Normal healthy	Surgical neck fracture: varus angulation

Results

Factors affecting recommendation for arthroplasty rather than ORIF

Hand and wrist surgeons were more likely to recommend arthroplasty (30 %) than orthopaedic (23 %), trauma (21 %), and shoulder and elbow surgeons (19 %).

The primary influence on surgeons favouring internal fixation was patient factors, while for surgeons favouring arthroplasty it was fracture morphology (Table 3). Bone quality had the least influence (11 %) on decision-making in both groups.

Open reduction and internal fixation was the preferred treatment for the majority of fractures (Table 4). Patient age, sex, activity level, physical status and the presence of angular displacement were significant predictors for the recommendation of internal fixation (Table 5). Prosthetic arthroplasty was clearly preferred in only one case (patient 4: an 80-year-old infirm woman with a comminuted articular fracture).

Many observers commented that they would prefer nonoperative treatment (Table 6). As for patient 3 (Fig. 1), for instance, 31 % of observers who opted for open reduction and internal fixation and 16 % who opted for arthroplasty commented that they would prefer nonoperative treatment (Table 6).

The advantages of arthroplasty were described as more predictable, shorter procedure time, and less risk of having to perform a reoperation. The advantages of internal fixation were described as less invasive, lower risk of infection, and shorter procedure time.

Table 3 Influencing factors

Vignette	Internal fixation group				Replacement group			
	Patient's general factors	Fracture morphology	Bone quality	Surgeon factors	Patients' general factors	Fracture morphology	Bone quality	Surgeon factors
1	45 %	63 %	22 %	25 %	74 %	89 %	32 %	16 %
2	87 %	24 %	10 %	29 %	51 %	74 %	10 %	26 %
3	14 %	60 %	13 %	36 %	68 %	24 %	0 %	52 %
4	33 %	33 %	10 %	48 %	63 %	55 %	11 %	39 %
5	47 %	54 %	4 %	50 %	58 %	62 %	24 %	38 %
6	40 %	68 %	9 %	45 %	0 %	100 %	0 %	0 %
7	47 %	66 %	12 %	48 %	24 %	88 %	18 %	53 %
8	63 %	52 %	19 %	42 %	100 %	0 %	0 %	0 %
9	74 %	41 %	7 %	55 %	16 %	88 %	3 %	48 %
10	65 %	52 %	8 %	43 %	31 %	87 %	13 %	38 %

% of surgeons

Table 4 Operative treatment choice

Vignette	Operative treatment (forced choice)			
	Reconstruction		Replacement	
	n	%	*n*	%
1	198	91 %	19	9 %
2	136	63 %	81	37 %
3	192	88 %	25	12 %
4	42	19 %	175	81 %
5	138	64 %	79	36 %
6	215	99 %	2	1 %
7	200	92 %	17	8 %
8	216	100 %	1	0 %
9	140	65 %	77	35 %
10	178	82 %	39	18 %

n number of surgeons

Table 6 Nonoperative treatment

Vignette	Internal fixation group	Replacement group
1	19 %	5 %
2	3 %	2 %
3	31 %	16 %
4	26 %	14 %
5	28 %	10 %
6	4 %	0 %
7	2 %	0 %
8	13 %	0 %
9	0 %	0 %
10	6 %	5 %

% of surgeons that wrote in a preference for nonoperative treatment

Factors affecting interobserver variation

The overall multirater agreement was fair (κ=0.30) with a 75 % proportion of agreement (Table 7). Shoulder and elbow surgeons were more likely to agree than other specialists, but the area of practice, more years of practice (> ten years), and a higher number of fractures treated per year did not influence agreement (Table 7).

Discussion

A recent Cochrane Review concluded that there is insufficient evidence to determine the most appropriate interventions for different types of proximal humeral fractures [13]. Complex fractures of the proximal humerus with marked displacement, fracture-dislocations, "head-splitting" fractures, and those at risk of developing avascular necrosis are commonly considered for arthroplasty. Despite these criteria, there is considerable variation in practice patterns for nonoperative and surgical treatment of proximal humeral fractures.

There are several limitations to this study. First, we forced participants to choose either ORIF or arthroplasty, so our results might be different from standard practice. Second, we used the initial injury radiographs collected retrospectively as opposed to standardized radiographs made prospectively. We believe that using radiographs of varying quality better reflects routine patient care, which facilitates the application of our findings to current practice. Third, we did not vary the parts of the scenario for each observer resulting in less variation and more limited ability to test the influence of each specific factor. The use of open-ended questions is a type of qualitative research that can be used to support future hypotheses [14], but is less objective and standardized.

Consistent with prior research, there is substantial variation in treatment recommendations for proximal humerus fractures. Petit et al. reported moderate interobserver agreement (weighted kappa=0.41) on treatment recommendations with no difference between trauma surgeons and shoulder surgeons [15].

Table 5 Patients' predictors for open reduction and internal fixation

Patient predictor		OR	95% CI		p-value
			Lower	Upper	
Age	continuous	0.92	0.89	0.94	<0.001
Sex	Male	31	18	51	<0.001
Activity	Moderately active vs. sedentary / extremely inactive	11	8	16	<0.001
	Vigorously active vs. sedentary / extremely inactive	2.7	1.4	5.3	0.004
Physical health	Mild systemic disease vs. moribund / severe systemic disease	0.005	0.001	0.021	<0.001
	Normal healthy vs. moribund / severe systemic disease	0.04	0.02	0.10	
Angular displacement	Present	0.006	0.002	0.015	<0.001

CI confidence interval, *OR* odds ratio

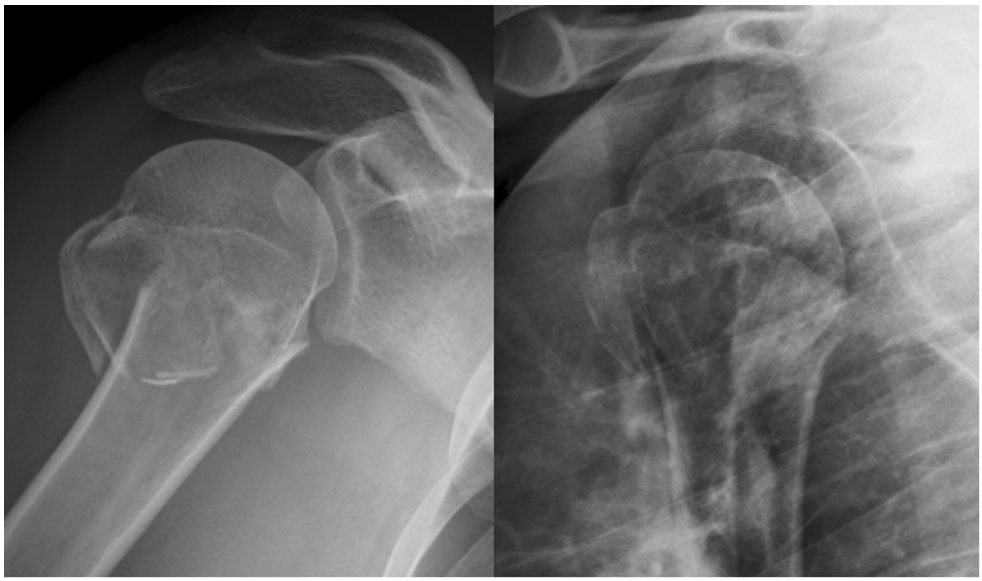

Fig. 1 Vignette case 3. A 70-year-old patient is taken to the hospital after she slipped on an icy patch on the way home from choir practice. The patient's BMI is 40 and her past medical history is remarkable for congestive heart failure, diabetes mellitus II and gout

The reasons for the substantial variations in treatment recommendations remain unaccounted for.

In line with other studies, surgeons favouring arthroplasty were mainly influenced by fracture morphology and patient factors such as age and physical status [16, 17]. Jain et al. [17] analysed the Nationwide Inpatient Sample (NIS) and found associations between surgeon and hospital volume and the proportion of patients undergoing hemiarthroplasty. Arthroplasty was also performed less frequently in patients younger than 50 years.

Primary arthroplasty is reported to be beneficial for pain relief, but functional results are less favourable.

In a recent matched-pair analysis of 25 patients treated with either reverse shoulder arthroplasty or the less invasive, semi-rigid Humerusblock, the functional outcome was superior in the Humerusblock group and patients reported less pain and disability [18].

A retrospective study investigating the effect of certain epidemiological and radiologic factors on the outcome of prosthetic replacement in acute proximal humerus fractures revealed that the most common complications were problems concerning the tuberosities (50 %), and they adversely affected the clinical outcome (p=0.002) [19]. Several techniques have been reported to avoid migration. Trabecular metal (TM) prostheses have the advantage of facilitating bone ingrowth by the tantalum porous layers around the components. Li reported on a consecutive series of 51 patients with complex proximal humeral fractures who underwent primary shoulder arthroplasties with the trabecular metal prosthesis. At the final follow up, postoperative radiographs exhibited an anatomically attached greater tuberosity in 39 of the 42 shoulders [20].

The emphasis our observers put on fracture morphology is debatable in light of several clinical studies describing little effect of fracture characteristics on functional outcome. In a 13-year observational cohort study of 138 patients treated with hemiarthroplasty for a proximal humeral fracture, Robinson et al. [2] identified patient factors (e.g. age, substance abuse) as significant predictors of shoulder function one year after

Table 7 Interobserver agreement on operative treatment choice

Multirater agreement	Description	Agreement	Kappa	PA (%)
Overall		Fair	0.30	75
Area of practice	United States	Fair	0.32	75
	Europe	Fair	0.29	75
	Other	Fair	0.25	74
Years of independent practice	0-10	Fair	0.30	75
	More than 10	Fair	0.29	74
Specialty	Trauma	Fair	0.27	76
	Shoulder & elbow	Fair	0.35	80
	Hand and wrist	Fair	0.32	71
	Orthopaedic	Slight	0.11	69

PA proportion of agreement

injury, whereas fracture severity or the presence of a subluxation or dislocation did not affect outcome.

Open reduction and internal fixation was the preferred treatment for the majority of fractures, and patient characteristics such as age, sex, activity level and physical status were significant predictors for the recommendation of internal fixation. There are numerous publications regarding the outcome of different fixation techniques including locking plates such as the frequently used PHILOS plate. Results of these studies however should be interpreted in light of several shortcomings such as heterogeneity of inclusion criteria and outcome parameters, and the exact indications remain unclear [21].

Open reduction and internal fixation with locking implants provides high primary stability and allows for early mobilisation. Expansive soft-tissue dissection however is associated with the risk for stiffness and avascular necrosis.

In light of these disadvantages, less invasive and percutaneous techniques have been described and results are comparable to those previously reported for other means of fixation for proximal humeral fractures [22–24].

There is considerable variation in treatment recommendations for proximal humeral fractures that cannot be explained by patient or surgeon factors or by injury characteristics. Future studies should address the influence of surgeon beliefs and biases of treatment recommendations. It would also be worthwhile to study whether decision aids (instructional material intended to help patients determine their values and preferences and have greater participation in treatment decisions) can decrease variation in treatment.

Conflict of interest The authors declare that they have no conflict of interest.

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