



# How do surgeons decide when to treat proximal humerus fractures with operative versus nonoperative management?

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## Abstract

**Purpose** The objective of this study was to determine the underlying factors that drive the decision for surgeons to pursue operative versus nonoperative management for proximal humerus fractures (PHF) and if fellowship training had an impact on these decisions.

**Methods** An electronic survey was distributed to members of the Orthopaedic Trauma Association and the American Shoulder and Elbow Surgeons Society to assess differences in patient selection for operative versus nonoperative management of PHF. Descriptive statistics were reported for all respondents.

**Results** A total of 250 fellowship trained Orthopaedic Surgeons responded to the online survey. A greater proportion of trauma surgeons preferred nonoperative management for displaced PHF fractures in patients over the age of 70. Operative management was preferred for older patients with fracture dislocations (98%), limited humeral head bone subchondral bone (78%), and intraarticular head split (79%). Similar proportions of trauma surgeons and shoulder surgeons cited that acquiring a CT was crucial to distinguish between operative and nonoperative management.

**Conclusion** We found that surgeons base their decisions on when to operate primarily on patient's comorbidities, age, and the amount of fracture displacement when treating younger patients. Further, we found a greater proportion of trauma surgeons elected to proceed with nonoperative management in patients older than the age of 70 years old as compared to shoulder surgeons.

**Keywords** Proximal humerus · Fracture · Shoulder · Elbow · Trauma · Management

## Introduction

Proximal humerus fractures (PHFs) are one of the most common fragility fractures following hip, spine, and distal radius fractures [1]. They account for around 5% of all adult

fractures and are more prevalent in the elderly as result of low energy falls [2]. The incidence of PHFs is anticipated to triple by 2030 due to the increase in the geriatric population, further exacerbating healthcare costs [1]. The ideal treatment for PHFs depends on multiple patient and fracture factors.

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There are also multiple treatment options for PHFs including nonoperative management, open reduction and internal fixation, hemiarthroplasty, and reverse shoulder arthroplasty. While the majority of the literature has focused on operative treatments, many fractures can be successfully treated nonoperatively [3–9]. Historically, up to 80% of proximal humeral fractures have been managed nonoperatively [10, 11].

There is a substantial amount of debate as to whether an operative versus nonoperative approach is superior in PHF management. While some randomized control trials support ORIF or arthroplasty over nonoperative management [8], others have concluded that there is little or no functional benefit for operative management [12–17]. A 2015 Cochrane Review comparing operative to nonoperative management for PHFs ultimately concluded that there was insufficient evidence supporting one strategy over the other [10]. Further, the PROFHER study evaluated the clinical- and cost-effectiveness of surgical versus nonsurgical intervention for displaced PHF and reported that neither management route was superior [12]. Given the controversy surrounding PHF management and mixed results reported in the literature, it is unclear what factors surgeons consider to determine operative versus nonoperative management of PHFs. Trauma and shoulder surgeons are among those that treat the highest volume of PHFs, and differences in their training may influence which patient and fracture characteristics they most consider when determining their management strategy.

Therefore, the purpose of this study was to determine what underlying factors drive the decision to pursue operative versus nonoperative management. Secondly, we aimed to uncover if any are based on fellowship training. We hypothesized that patient and fracture characteristics along with surgeon subspecialty training would influence the decision to pursue operative versus nonoperative management for PHFs.

## Methods

The primary investigator emailed a voluntary electronic survey to all members of the American Shoulder and Elbow Surgeons Society (ASES) and Orthopaedic Trauma Association (OTA) via their registered email addresses. The survey was also posted to the online ASES and OTA sites. Responses were recorded from 250 fellowship trained orthopaedic surgeons (78 orthopaedic trauma surgeons vs 172 shoulder and elbow surgeons) to assess differences in patient selection for operative vs non-operative management of PHFs. Eleven trauma surgeon respondents had also completed a shoulder fellowship and four had completed a sports fellowship. We considered both of these subsets of respondents to be in the shoulder surgeon group for the

purposes of this study. Participation was noncompensated, voluntary, and anonymous.

## Survey instrument

The authors of this study constructed a survey regarding age differences, radiographic modalities used, displacement characteristics, and patient functional status to determine preferences regarding the management of PHFs. A 27 close-ended-question survey was developed based on expert-opinion-based face validity using multiple episodes of consensus development between authors (see supplementary material). The study was approved by the institutional review board at the senior author's institution. Survey responses were collected between January and March, 2021. No compensation for involvement was provided. The survey was administered using REDCap which is a secure web application for building and managing online surveys and databases [18, 19]. The survey was displayed as a web link on the Orthopaedic Trauma Association website for a total of 4 months. Survey questions consisted of unforced responses and non-respondent answers were simply omitted from data analysis without data imputation.

## Survey questions

Basic demographic questions were asked for each respondent including their fellowship training, board certification, practice setting, years in practice, number of PHFs treated per year, and if they supervised trainees. All respondents were surveyed on their preferred use of imaging to evaluate PHFs and which underlying factors prompted the surgeons to obtain computed tomography (CT) scans. In order to assess which factors surgeons consider when proceeding with operative over nonoperative management, respondents were asked specifically about the patient's functional status including age, comorbidities, job type, pre-injury function, recreational activities, and their ability to participate in outpatient therapy. Further, respondents were asked about consideration of patients age and ASA scores when considering nonoperative management for displaced fractures. For medically ill patients, respondents were asked about the amount of shaft displacement required to pursue operative management. When assessing the factors considered for operative management in young patients, hand dominance, fracture displacement, tuberosity involvement, polytrauma, and occupation were queried. Lastly, surgeons were asked whether operative, nonoperative, or referral was the most appropriate choice in management based on common patient and fracture characteristics. These characteristics included: an (1) elderly or (2) young patient with a fracture dislocation, an (3) elderly or (4) young patient with a head-split fracture, an (5) elderly or (6) young patient with limited

humeral head subchondral bone, (7) a low functioning geriatric patient with a significantly displaced fracture, (8) a low functioning patient with a non-reconstructible injury, (9) a patient with pre-existing moderate to severe glenohumeral arthritis with an intact rotator cuff, and (10) a patient with a preexisting rotator cuff tear.

## Statistical methods

All statistical analyses were performed using R Software (version 3.6.3, R Core Team, Vienna, Austria). Chi-square and Mann–Whitney rank sum tests were used to compare responses between trauma surgeons and shoulder surgeons for categorical and continuous variables, respectively. Significant interactions were followed by a Bonferroni post hoc test for multiple pairwise comparisons. Significance was set at an alpha of 0.05.

## Results

### Demographics

Survey results from 78 fellowship trained trauma surgeons and 172 fellowship trained shoulder surgeons were analyzed. A greater proportion of trauma surgeons were more likely to work in an academic setting as compared to shoulder

surgeons who were more commonly working as hospital-based employees or in private practice ( $P < 0.001$ ). Trauma surgeons treated fewer PHFs per year compared to shoulder surgeons ( $26.9 \pm 24.8$  vs.  $46.6 \pm 42.2$ ,  $P < 0.001$ ) (see Table 1).

### Radiographic assessment for PHF management

The use of imaging modalities to decide between operative and nonoperative management did not differ between trauma and shoulder surgeons. Most trauma surgeons (94%) and shoulder surgeons (88%) responded that obtaining AP radiographs of the scapula was their main preference for radiographic analysis. Both trauma surgeons (59%) and shoulder surgeons (65%) commonly cited that acquiring a CT was crucial to distinguishing between operative and nonoperative management for PHFs. Notably, inadequate X-rays were also a commonly cited indication for obtaining CT scans for PHFs. A small percentage of trauma surgeons (5%) and shoulder surgeons (6%) responded that a CT scan was indicated for every patient presenting with a PHF (see Table 2).

### Patient/fracture characteristics influencing PHF management

The evaluation of patient functional status was most commonly established through comorbidities (86%), normal vs

**Table 1** Demographics of respondents

Characteristic	All respondents (N = 250)	Shoulder (N = 172)	Trauma (N = 78)	<i>p</i> value
Practicing physician	99% (247)	99% (171)	97% (76)	0.087
Board certified	85% (212)	83% (142)	90% (70)	0.202
Fellowship training				<b>&lt; 0.001</b>
Trauma	36% (89)	6% (11)	100% (78)	<b>&lt; 0.001</b>
Shoulder/elbow	69% (172)	100% (172)	0% (0)	<b>&lt; 0.001</b>
Sports medicine	8% (19)	10% (18)	1% (1)	<b>0.023</b>
Other	1% (3)	2% (3)	0% (0)	0.585
Years in practice				0.459
0–5	32% (79)	33% (57)	28% (22)	
6–10	26% (64)	27% (46)	23% (18)	
11–15	18% (46)	19% (32)	18% (14)	
15+	24% (61)	22% (37)	31% (24)	
Primary practice setting				<b>&lt; 0.001</b>
Academic	48% (119)	34% (59)	77% (60)	<b>&lt; 0.001</b>
Hospital employed	17% (42)	22% (38)	5% (4)	<b>0.005</b>
Private practice	36% (89)	44% (75)	18% (14)	<b>&lt; 0.001</b>
Supervise trainees	75% (188)	67% (116)	92% (72)	<b>&lt; 0.001</b>
# Of PHFs <sup>1</sup> treated per year	30 (20–50)	30 (20–50)	20 (12–30)	<b>&lt; 0.001</b>

% (N) or Median (IQR)

Bold values indicate statistical significance

<sup>1</sup>PHF: proximal humerus fracture

**Table 2** Use of imaging to determine whether to manage PHFs operatively

Characteristic	All respondents	Trauma	Shoulder	<i>P</i> value
Radiographical assessment for all patients				–
AP radiograph of the scapula	90% (225)	94% (73)	88% (152)	0.295
Axillary radiograph	65% (163)	71% (55)	63% (108)	0.296
Velpeau axillary	32% (81)	26% (20)	35% (61)	0.164
CT scan	29% (72)	24% (19)	31% (53)	0.372
CT scan indications				
Every patient	6% (14)	5% (4)	6% (10)	1
Inadequate x-rays	47% (118)	53% (41)	45% (77)	0.314
Involvement of either tuberosity	25% (63)	23% (18)	26% (45)	0.716
Operative only cases	20% (49)	15% (12)	22% (37)	0.338
Distinguish between operative and nonoperative	63% (157)	59% (46)	65% (111)	0.483

All values presented as % (N)

PHF: Proximal humerus fracture

impaired pre-injury function (77%), age (72%), recreational activities (67%), and sedentary vs manual work (59%). Sixty nine percent of respondents felt that low functioning patients, regardless of age, were best treated with nonoperative management. Interestingly, a greater proportion of trauma surgeons preferred nonoperative management for treating displaced PHF fractures in patients over the age of 70 and 80 compared to shoulder surgeons (24 vs. 6%,  $P < 0.001$  and 56 vs. 37%,  $P = 0.005$ ). Similar proportions of trauma and shoulder surgeon preferred nonoperative management in patients over the age of 90 and in patients with an ASA score of 3 or 4. 47% of surgeons responded that nonoperative management was indicated for all medically ill patients regardless of the amount of shaft displacement. However, 43% of surgeons responded that 100–150% of shaft displacement was enough to warrant surgical management in medically ill patients. Only 9% felt that an operative approach was necessary when managing 50–99% displacement in these patients. When treating young patients, respondents felt that the following factors were the most influential characteristics for a surgeons' choice for operative management and included fracture displacement (91%), tuberosity involvement (78%), polytrauma (63%), and occupation (60%) (see Table 3).

### Common PHF presentations indicating operative management

Operative management was preferred for older patients with fracture dislocations (98%), limited humeral head subchondral bone (78%), and/or an intraarticular head split. In elderly patients with an intraarticular head split, a greater proportion of shoulder surgeons choose to proceed with surgical management as compared to trauma surgeons (95 vs. 50%). Similar preferences were seen in older patients with fracture dislocations (98 vs. 62%) and limited humeral head subchondral bone

(95 vs. 40%). The rate of referral out by trauma surgeons was higher in all of these scenarios. In younger patients, operative management was preferred in patients with an intra-articular head split (95%), fracture dislocation (87%), and/or limited humeral head subchondral bone (95%) with similar percentages amongst trauma and shoulder surgeons. A greater number of both trauma and shoulder surgeons responded that patients with preexisting rotator cuff injuries and preexisting glenohumeral arthritis with an intact cuff needed operative management for PHFs. However, a greater proportion of shoulder surgeons felt that surgical treatment was warranted for both preexisting conditions (see Fig. 1).

### Common PHF presentations indicating nonoperative management

Low functioning patients that presented with a nonreconstructible injury had a higher overall rate of non-operative management in both groups (56%), despite a greater proportion of trauma surgeons electing to proceed with nonoperative treatment (50%) and a greater proportion of shoulder surgeons choosing surgical treatment (12%). Low functioning patients with significantly displaced fractures also had a higher overall rate of non-operative management (59%), however, a significantly greater proportion of shoulder surgeons chose operative management in these patients (46 vs. 13%). Notably, a greater number of trauma surgeons referred out in all patient cohorts except the patients under the age of 50 with intraarticular head split and fracture dislocations (see Fig. 1).

## Discussion

PHFs are one of the most common fractures in orthopaedics and the incidence is increasing as the population ages [20]. While most PHFs are treated non-operatively, it is unclear

**Table 3** Patient and fracture characteristics influencing operative versus nonoperative management for PHFs

Characteristic	All respondents	Trauma	Shoulder	P value
<b>Deterministic factors of functional status</b>				
Age	72% (181)	69% (54)	74% (127)	0.547
Ability to participate in outpatient therapy	39% (98)	42% (33)	38% (65)	0.591
Sedentary work vs manual labor	59% (148)	60% (47)	59% (101)	0.928
Normal vs impaired pre-injury function	77% (192)	72% (56)	79% (136)	0.271
Comorbidities	86% (216)	87% (68)	86% (148)	0.966
Recreational activities	67% (168)	72% (56)	65% (112)	0.370
<b>Nonoperative management for displaced fractures</b>				
Over the age of 70	12% (30)	24% (19)	6% (11)	<b>&lt;0.001</b>
Over the age of 80	43% (107)	56% (44)	37% (63)	<b>0.005</b>
Over the age of 90	54% (134)	50% (39)	55% (95)	0.528
ASA 3	10% (26)	14% (11)	9% (15)	0.286
ASA 4	54% (135)	53% (41)	55% (94)	0.865
Low functioning regardless of age	69% (172)	68% (53)	69% (119)	0.962
Displacement threshold indicating operative management in medically-ill patients				0.271
100,150% shaft displacement	43% (100)	36% (26)	47% (74)	
5099% shaft displacement	9% (22)	10% (7)	9% (15)	
Nonoperative management only	47% (110)	55% (40)	44% (70)	
<b>Factors indicating operative management in young patients</b>				
Hand dominance	24% (59)	15% (12)	27% (47)	0.058
Fracture displacement	91% (227)	90% (70)	91% (157)	0.878
Tuberosity involvement	78% (195)	76% (59)	79% (136)	0.659
Polytrauma	63% (158)	72% (56)	59% (102)	0.079
Occupation	60% (151)	56% (44)	62% (107)	0.466

All values presented as % (N)

Bold values indicate statistical significance

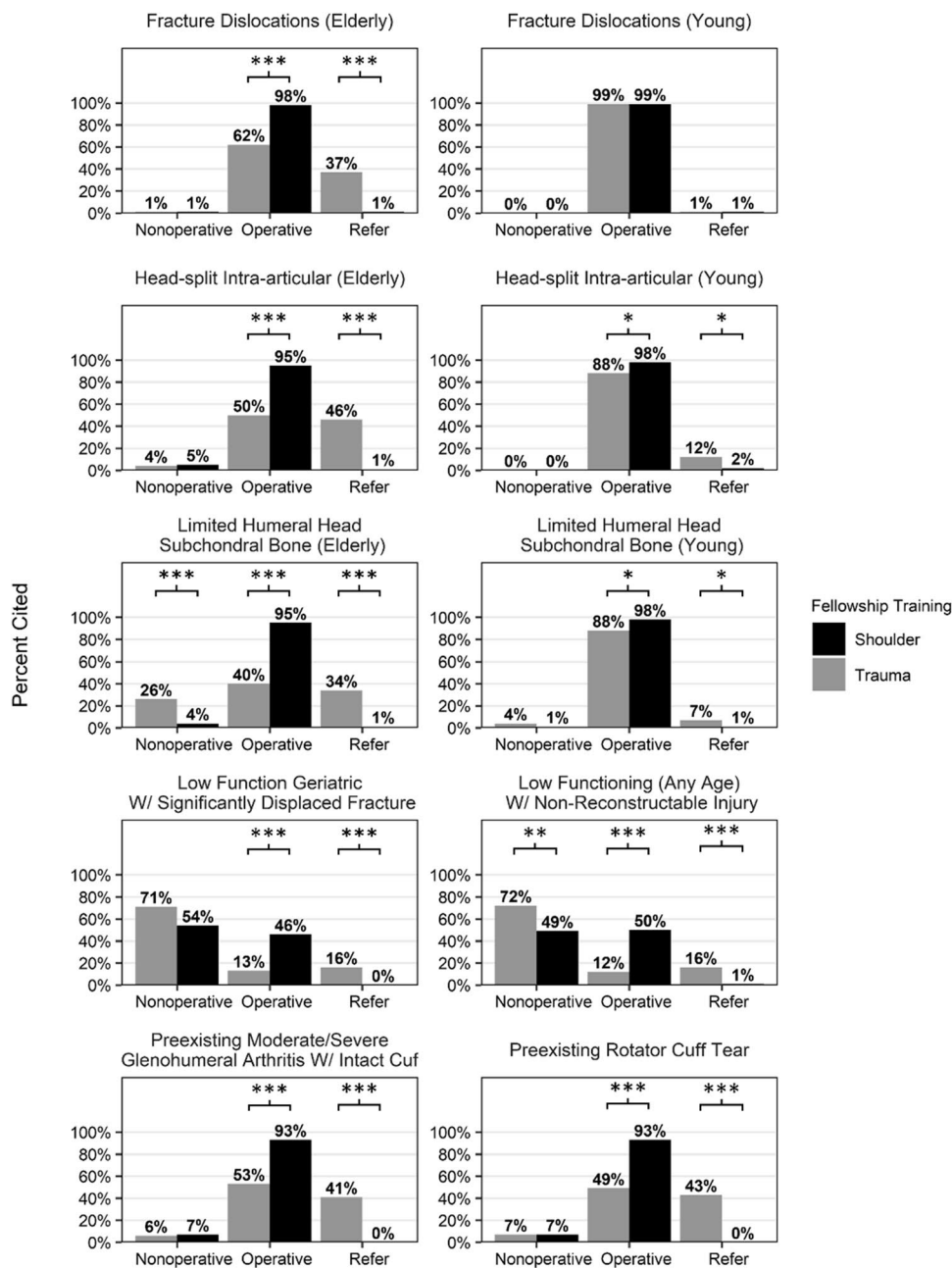
PHF: Proximal humerus fracture

when surgical management provides patients with a better outcome [8, 10, 12, 21, 22]. These mixed results make it unclear which underlying factors surgeons consider when deciding to recommend surgical management of PHFs. In this survey, we found that surgeons base their decision on when to operate on PHFs primarily on patient's comorbidities, age, and the amount of fracture displacement when treating younger patients. Furthermore, we found a greater proportion of trauma surgeons elected to proceed with nonoperative management in patients between 70 and 90 years old more often than shoulder surgeons.

The PROFHER trial found no difference in clinical outcomes between operative and non-operative treatment for

adults with displaced PHFs [12]. This might lead some to consider more non-operative treatment of PHFs. Conversely, Handoll et al. found in a systematic review of 31 RCTs that insufficient evidence exists to determine if operative treatment is better in two-part greater tuberosity fractures, high energy fractures, fracture dislocations, or head splitting fractures [10]. However, in contrast to this, our study's findings suggest that age, fracture severity, functional expectations, and subspecialty training seem to drive the decision for operative versus nonoperative management of PHFs [10]. The current study found that older patients with lower functional status were less likely to be considered for surgery whereas surgery was still recommended for younger patients with

**Fig. 1** Proportion of shoulder and trauma surgeons that prefer operative management, nonoperative management, or choose to refer patients with common PHF presentations



displaced fractures. The present study also found that elderly patients with injury characteristics such as an intra-articular head split, fracture dislocations, and minimal humeral head subchondral bone were preferentially managed operatively by shoulder surgeons and nonoperatively by trauma surgeons (Fig. 1). These studies together bring up the point that although there is insufficient evidence to guide decision-making in the current literature surgeons are basing decisions off these underlying factors.

Despite the current controversy around treatment recommendations for PHFs, our study aligns with previous studies concluding that shoulder surgeons are more likely to manage

PHFs with surgical management than trauma surgeons [23, 24]. Ansari et al. conducted a survey for all subspecialties of orthopedic surgeons and discovered that shoulder surgeons were more likely to operate on a two-part PHF in an older individual as compared to other orthopedic subspecialties [23]. Another study conducted by Okike et al. also found that a greater proportion of shoulder surgeons decided to proceed with surgical management for displaced proximal humerus fractures than trauma surgeons [24]. Patient age seemed to have the most effect on treatment decisions between these two subsets of surgeons. Our study found that given the same fracture characteristics (e.g., fracture

dislocation and intraarticular head split fracture), a greater proportion of shoulder surgeons responded that they would undertake operative management in older patients where as in younger patients, trauma and shoulder surgeons had similar treatment recommendations. This can be accounted for by the option for arthroplasty in older patients, leading some trauma surgeons to refer these fractures to a shoulder specialist (see Fig. 1) [25, 26].

The optimal treatment of PHF has been a topic of controversy for decades and high-quality evidence has yet to demonstrate firm surgical versus nonsurgical management recommendations [10]. This is likely due to significant heterogeneity among studies of PHF patient cohorts (including patient age, fracture patterns, and fracture displacement) and treatment options making it difficult to transfer into clinical practice. Additionally, there is a disproportionate amount of literature focusing on surgical PHF management (85%) compared to the less than 5% on non-surgical PHF management [27]. Limited high-quality evidence is available, but there are several studies that demonstrate acceptable results with nonoperative management [28–31]. The sparse literature on non-surgical treatment of PHF makes these findings difficult to generalize and the understanding of which patient and fracture factors that are best managed nonoperatively remains challenging.

High-quality evidence focusing on displaced PHF have been unable to demonstrate superiority of surgery compared to non-surgical management [10, 12]. However, benefits of surgical treatment in complex (i.e., three- and four-part) fractures has been shown to reduce malunion and stiffness of the shoulder [32–34] and Neer II [35] recommended operative management of most three- and four-part displaced PHFs. In the present study, both shoulder and trauma surgeons recommend surgical management in younger patients with fracture dislocations, intra-articular head split patterns, and those with limited humeral head subchondral bone. The consensus to recommend surgical intervention in these patients is likely taken out of precaution to preserve the native joint and maximize long-term shoulder function. Further, trauma surgeons may offer higher rates of non-operative management in the older subsets of patients as compared to shoulder surgeons who may opt for arthroplasty in this population based on training bias.

Despite the widespread disagreement among surgeons on the optimal management of PHF, the authors of this study advocate for a holistic determination of functional status, rather than age alone, when making the decision on operative intervention. Both trauma and shoulder surgeons agreed that consideration of patient-related factors such as ability to participate in outpatient therapy, pre-injury functional status, medical comorbidities, and recreational activities affect their recommendations when

planning management. Patient characteristics, along with a surgeon's preferences [36], may influence the decision to operate and when combined with differences in subspecialty training may offer insights into the variation amongst trauma and shoulder surgeon's decision-making process.

We acknowledge the limitations of cross-sectional survey research to summarize conclusions. The first limitation has a potential volunteer bias in those who choose to complete the survey. The individuals who completed this survey may have more interest in this topic and may have stronger opinions about treatment recommendations. Further, we were unable to record the response rate or if the respondents answered all of the questions since the survey was posted to online platforms and was voluntary. Another limitation of survey research is the terminology and organization of the survey that can potentially introduce selection bias. In order to address this potential limitation, we provided access to a copy of the survey that was developed by multiple individuals of different training backgrounds and with specific experience in survey research and development. Additionally, geographical variations may play a role in response bias as well as individual bias; however, this was not included through our surveys.

Despite the limitations inherent to survey research, we believe our results highlight potential driving factors for differences in management preferences and provide insight into surgeon's decision-making process when managing PHFs. Trauma surgeons are more likely than shoulder surgeons to treat elderly patients nonoperatively regardless of fracture characteristics. This might be due to training bias or unfamiliarity with shoulder arthroplasty, but until clear indications for operative and nonoperative management are defined, surgeon characteristics will play a role in the recommendation for operative management.

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## Declarations

**Conflict of interest** Joseph J. King is a consultant for Exactech, Inc. Catherine Fedorka is a consultant for Stryker. The other authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

## References

- Court-Brown CM, Caesar B (2006) Epidemiology of adult fractures: a review. *Injury* 8:691–697
- Horak J, Nilsson BE (1975) Epidemiology of fracture of the upper end of the humerus. *Clin Orthop Relat Res* 112:250–253
- Vachtsevanos L, Hayden L, Desai AS et al (2014) Management of proximal humerus fractures in adults. *World J Orthop* 5:685–693
- Yahuaca BI, Simon P, Christmas KN et al (2020) Acute surgical management of proximal humerus fractures: ORIF vs. hemiarthroplasty vs. reverse shoulder arthroplasty. *J Shoulder Elb Surg* 7S:S32–S40
- Chalmers PN, Slikker W 3rd, Mall NA et al (2014) Reverse total shoulder arthroplasty for acute proximal humeral fracture: comparison to open reduction-internal fixation and hemiarthroplasty. *J Shoulder Elb Surg* 2:197–204
- Chivot M, Lami D, Bizzozero P et al (2019) Three- and four-part displaced proximal humeral fractures in patients older than 70 years: reverse shoulder arthroplasty or nonsurgical treatment? *J Shoulder Elb Surg* 2:252–259
- Ferrel JR, Trinh TQ, Fischer RA (2015) Reverse total shoulder arthroplasty versus hemiarthroplasty for proximal humeral fractures: a systematic review. *J Orthop Trauma* 1:60–68
- Gupta AK, Harris JD, Erickson BJ et al (2015) Surgical management of complex proximal humerus fractures—a systematic review of 92 studies including 4500 patients. *J Orthop Trauma* 1:54–59
- Solberg BD, Moon CN, Franco DP et al (2009) Surgical treatment of three and four-part proximal humeral fractures. *J Bone Jt Surg Am* 7:1689–1697
- Handoll H H G, Brorson S (2015) Interventions for treating proximal humeral fractures in adults. *Cochrane Database Syst Rev* CD000434
- Helmy N, Hintermann B (2006) New trends in the treatment of proximal humerus fractures. *Clin Orthop Relat Res* 442:100–108
- Rangan A, Handoll H, Brealey S et al (2015) Surgical vs nonsurgical treatment of adults with displaced fractures of the proximal humerus: the PROFHER randomized clinical trial. *JAMA* 313(10):1037–1047
- Huttunen TT, Launonen AP, Pihlajamäki H et al (2012) Trends in the surgical treatment of proximal humeral fractures—a nationwide 23-year study in Finland. *BMC Musculoskelet Disord* 13:261
- Fjalestad T, Hole MØ, Jørgensen JJ et al (2010) Health and cost consequences of surgical versus conservative treatment for a comminuted proximal humeral fracture in elderly patients. *Injury* 1(6):599–605
- Launonen AP, Sumrein BO, Reito A et al (2016) Operative versus non-operative treatment for 2-part proximal humerus fracture: a multicenter randomized controlled trial. *PLoS Med* 7:e1002855
- Brorson S, Olsen BS, Frich LH et al (2009) Effect of osteosynthesis, primary hemiarthroplasty, and non-surgical management for displaced four-part fractures of the proximal humerus in elderly: a multi-centre, randomised clinical trial. *Trials* 10(1):1–5
- Beks RB, Ochen Y, Frima H et al (2018) Operative versus non-operative treatment of proximal humeral fractures: a systematic review, meta-analysis, and comparison of observational studies and randomized controlled trials. *J Shoulder Elb Surg* 8:1526–1534
- Harris PA, Taylor R, Thielke R et al (2009) Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform* 2:377–381
- Harris PA, Taylor R, Minor BL et al (2019) The RED Cap consortium: building an international community of software platform partners. *J Biomed Inform* 95:103208
- Karl JW, Olson PR, Rosenwasser MP (2015) The Epidemiology of Upper Extremity Fractures in the United States, 2009. *J Orthop Trauma* 8:e242–e244
- Baudi P, Campochiaro G, Serafini F et al (2014) Hemiarthroplasty versus reverse shoulder arthroplasty: comparative study of functional and radiological outcomes in the treatment of acute proximal humerus fracture. *Musculoskelet Surg Suppl* 1:19–25
- Gradl G, Knobe M, Pape H-C et al (2015) Decision making in displaced fractures of the proximal humerus: fracture or surgeon based? *Int Orthop* 2:329–334
- Ansari U, Adie S, Harris IA et al (2011) Practice variation in common fracture presentations: a survey of orthopaedic surgeons. *Injury* 4:403–407
- Okike K, Lee OC, Makanji H et al (2013) Factors associated with the decision for operative versus non-operative treatment of displaced proximal humerus fractures in the elderly. *Injury* 4:448–455
- Walters JM, Ahmadi S (2020) High-energy proximal humerus fractures in geriatric patients: a review. *Geriatr Orthop Surg Rehabil* 11:2151459320971568
- Dillon MT, Inacio MCS, Burke MF et al (2013) Shoulder arthroplasty in patients 59 years of age and younger. *J Shoulder Elb Surg* 10:1338–1344
- Slobogean GP, Johal H, Lefavre KA et al (2016) A scoping review of the proximal humerus fracture literature. *BMC Musculoskelet Disord* 112:1–10
- Hodgson SA, Mawson SJ, Saxton JM et al (2007) Rehabilitation of two-part fractures of the neck of the humerus (two-year follow-up). *J Shoulder Elb Surg* 2:143–145
- Lefevre-Colau MM, Babinet A, Fayad F et al (2018) Immediate mobilization compared with conventional immobilization for the impacted nonoperatively treated proximal humeral fracture: a randomized controlled trial. *J Bone Jt Surg Am* 12:2582–2590
- Court-Brown CM, Cattermole H, McQueen MM (2004) Impacted valgus fractures(B1.1) of the proximal humerus: the results of non-operative treatment. *J Bone Jt Surg* 84(4):504–508
- Martínez R, Santana F, Pardo A et al (2021) One versus 3-week immobilization period for nonoperatively treated proximal humeral fractures: a prospective randomized trial. *J Bone Jt Surg Am* 103(16):1491–1498
- Leyshon RL (1984) Closed treatment of fractures of the proximal humerus. *Acta Orthop Scand* 55(1):48–51
- Murray IR, Amin AK, White TO et al (2011) Proximal humeral fractures: current concepts in classification, treatment and outcomes. *J Bone Jt Surg Br* 93(1):1–11
- Brorson S, Alispahic N, Bahrs C et al (2019) Complications after non-surgical management of proximal humeral fractures: a systematic review of terms and definitions. *BMC Musculoskelet Disord* 20(1):91



35. Neer CS (1974) Displaced proximal humeral fractures: part II treatment of three-part and four-part displacement. *J Bone Jt Surg Am* 52(6):1090–1103
36. Teunis T, Janssen SJ, Guitton TG et al (2010) Surgeon personality is associated with recommendation for operative treatment. *Hand* 10(4):779–784

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