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Acute surgical management of proximal humerus fractures: ORIF vs. hemiarthroplasty vs. reverse shoulder arthroplasty

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Background: Proximal humerus fracture treatment varies by surgeon preference and patient factors. This study compares patient and fracture characteristics, with outcomes between current surgical treatment options.

Methods: Between 1999 and 2018, 425 proximal humerus fractures underwent acute surgical management: open reduction internal fixation (ORIF, n = 211), hemiarthroplasty (HA, n = 108), or reverse shoulder arthroplasty (RSA, n = 106). Patient and fracture characteristics included age, American Society of Anesthesiologists physical status classification (ASA), and fracture classification. Postoperative motion at 3, 6, and minimum 12 months (avg 20 ± 21 months), radiographic outcomes, and postoperative falls were analyzed.

Results: Average age for treatment groups was 65 ± 13 years (range: 18-93 years). Fractures were classified as 2- (11%), 3- (41%), or 4-part (48%). Age, ASA, and fracture classification were associated with selected surgical management ($P < .0001$, $=.001$, $<.0001$, respectively). Outcomes showed a significant improvement in forward flexion from 3 months to 6 months in all groups ($P < .0001$). No difference in final motion was seen between groups. Radiographic union was higher in ORIF (89%), and similar between HA (79%) and RSA (77%, $P = .005$). Rate of reoperation was RSA 6.6%, ORIF 17.5%, and hemiarthroplasty 15.7% ($P = .029$). Postoperatively, 23% patients had at least 1 fall, of which 73% resulted in fractures.

Conclusion: Older patients with high ASA were treated with arthroplasty, and younger patients with lower ASA were treated with ORIF. All groups showed improvements in motion. At minimum 1 year of follow-up, there was no difference in motion between groups. ORIF and HA showed significantly more reoperations compared with RSA. Patients should be counseled about reoperation, fall risk, and prevention.

Investigation performed at Florida Orthopaedic Institute and Foundation for Orthopaedic Research and Education (FORE), Tampa, FL, USA.
This study was determined to be exempt from review by the Western Institutional Review Board (WIRB).

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Level of evidence: Level III; Retrospective Cohort Comparison; Treatment Study

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Proximal humerus fractures (PHFs) account for 4%-5% of all adult fractures and 50% of all humerus fractures.[27,29,32,37] The incidence is 114 and 47 per 100,000 person-years in females and males, respectively, and increases with older age groups.[37] The characteristics of patients who sustain these injuries vary in age, sex, comorbidities, and mechanism of injury.[37] The variation of patient age has been described as a bimodal distribution, with younger patients having a high-energy injury with less comorbidities compared with low-energy injuries in older patients with more comorbidities. The American Society of Anesthesiologists physical status classification (ASA) has been used to evaluate the general health status of patients, and as a risk factor to evaluate in orthopedic studies.[2,35,36] In fact, ASA has also been shown to be a predictor for mortality after a PHF in the elderly. In addition, this fracture has been found to increase the risk of subsequent hip fractures and mortality.[9,13,32,43] There is also an effect of these subsequent falls or fractures on the emotional, social, and economic well-being of patients and their families. Therefore, a better understanding of the patient characteristics, methods of surgical treatment, and outcomes after the surgical treatment of this injury may potentially benefit the patient and society.

The decision for operative intervention must consider the nature of the fracture, as well as patient characteristics. Most PHFs may be treated nonoperatively. However, recent literature does support operative intervention in cases of displaced 3- and 4-part fractures.[8] If the decision is made for operative intervention, the surgeon must determine what device to employ. This can be difficult, even for experienced surgeons. LaMartina et al noted the complex nature of treatment selection, showing agreement between fellowship-trained shoulder surgeons only two-thirds of the time.[28] Recently, a treatment algorithm has been described to aid in this decision. It takes into account living situation, activity level, age, bone quality, and health status.[44] Historically, these fractures were treated with open reduction internal fixation (ORIF) in the young patient and hemiarthroplasty (HA) in the older patient.[38-40,42] However, reverse shoulder arthroplasty (RSA) has been growing in popularity.[39,40] The use of ORIF has remained stable over the years, whereas we have seen both a substantial decrease in HA use and a meteoric rise in RSA use.[23] Acevedo et al[1] described that RSA may be particularly useful in the elderly patient population. Other than age, factors such as a patient's health status and fracture type may play a role in decision making as well.[33,34]

There have been multiple studies evaluating 1 or 2 of the surgical options.[4,5,12,14,15,16,18,31,38,39,40,42,46] Yet, there is a paucity of evidence comparing the outcomes of all 3 surgical options.[7,20,23] Chalmers et al evaluated RSA, ORIF, and HA for 3-part and 4-part PHFs.[7] Their study included a total of 27 patients with a minimum follow-up of 1 year. Patients who underwent RSA had a higher range of motion and cost savings to Medicare compared with HA and ORIF. There was no significant difference in functional scores. In addition, there has been no study to date evaluating the relationship between the patient's preoperative health status (ASA) and complexity of fracture (Neer class) with surgical intervention (ORIF, HA, or RSA) and outcomes for PHFs. Therefore, it would be helpful to better understand what factors influence selection of surgical options to treat PHFs and to determine the outcomes of these different methods of treatment.

The purpose of this study is to evaluate the effect of patient and fracture characteristics on selection of surgical management and outcomes of treatment. We hypothesize that a patient with a higher age, ASA score, and fracture type (Neer 3 and 4) is more likely to undergo arthroplasty than ORIF. Age and treatment types will affect range of motion, fracture healing, and reoperation rate. In addition, patients who sustain a PHF are likely to sustain a subsequent fall, with or without fracture.

Methods

This study is a retrospective review of 425 shoulders in 419 patients who sustained a PHF between 1999 and 2018 and underwent ORIF, HA, or RSA (Fig. 1). Inclusion criteria were serial clinical and radiographic examinations with a minimum of 12 months of follow-up. We evaluated patient characteristics (age and ASA score), fracture classification (Neer type), surgical management (ORIF, HA, or RSA), and outcomes (reoperation, union, postoperative range of motion, and subsequent falls). Exclusion criteria were age <18 years, insufficient follow-up (<1 year), lack of appropriate postoperative radiographs, segmental fractures, and concomitant ipsilateral extremity fractures.

Preoperative radiographs and clinical documentation were evaluated for fracture classification. These fractures were graded using Neer's original classification.[6,26,33] Postoperative radiographs included a true anteroposterior (AP), a lateral Y view, and an axillary view. These radiographs were taken at increments

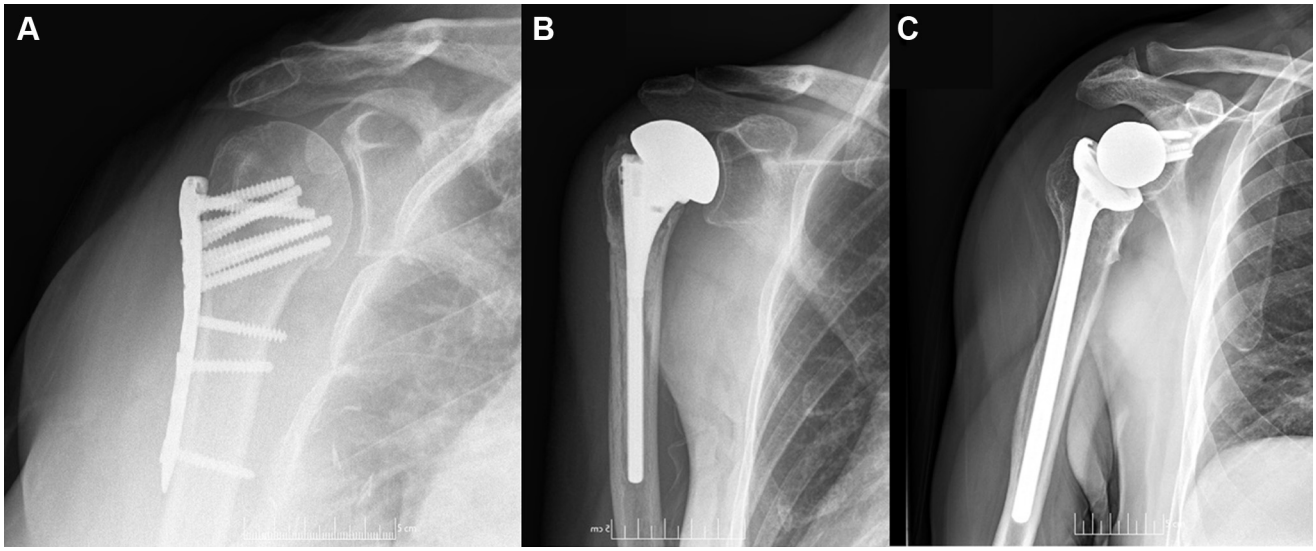

Figure 1 Examples of successful reconstruction. (**A**) 57-year-old woman's 14-month status after open reduction internal fixation for a 3-part proximal humerus fracture with radiographic union. (**B**) 57-year-old man's 6-month status after hemiarthroplasty for a 4-part proximal humerus fracture with union of the greater tuberosity. (**C**) 74-year-old man's 3-year status after reverse shoulder arthroplasty for a 4-part proximal humerus fracture with union of the greater tuberosity.

approximately 2-3 weeks, 6 weeks, 3 months, 6 months, 1 year, and annually thereafter. Radiographs were evaluated with specific attention to fracture union, nonunion, malunion, and hardware complication. A malunion of the greater or lesser tuberosity, articular surface, or articular segment was documented based on Beredjiklian's definitions.[3] A nonunion was considered to be present if the fracture was not clinically or radiographically united after 6 months from definitive fixation or sooner if there was displacement of the fracture due to implant failure. Available ASA scores were recorded from preoperative anesthesiology record. Patients with ASA scores of 1 and 2 were grouped as low, whereas those with ASA scores of 3 and 4 were grouped as high.[24,25]

For all groups, forward flexion (FF) was used as an outcome measure at 3 months, 6 months, and the final follow-up of 1 year or more. FF was then compared amongst treatment groups and further evaluated for differences based on patient characteristics and fracture type. FF was used because it is a more reliable measurement than external or internal rotation.[8,11] All patients who underwent repeat surgeries on the ipsilateral shoulder were documented. Clinical notes were evaluated for postoperative falls and resultant fractures. Fracture location and time from surgical management of the PHF to the fall were recorded.

Statistical analysis

Statistical analysis was conducted using SPSS 24.0 (IBM, Armonk, NY, USA). Continuous variables were reported as mean and standard deviations and evaluated using either a paired *t*-test or the Wilcoxon rank-sum test where appropriate. The difference between study groups was evaluated using either analysis of variance or the Kruskal-Wallis test. Categorical variables were evaluated using the chi-square or Fisher's exact test. Significance was determined by alpha set to 0.05.

Results

Demographics

In a total of 425 shoulders that met the inclusion criteria, there were 211 (49.6%) ORIF, 108 (25.4%) HA, and 106 (24.9%) RSA. The patients were predominantly female, 326 of 425 (76.7%). Each type of surgical management consisted of at least 70% females: 162 of 211 (76.8%) ORIF, 77 of 108 (71.3%) HA, 87 of 106 (82.1%) RSA. However, there was no difference between sex and type of surgical management ($P = .176$). The average age at the time of surgery was 65 ± 13 years (range: 18-93 years). There was a significant age dependence with respect to the types of surgical management: ORIF 62 ± 13 years, HA 65 ± 12 years, and RSA 73 ± 9 years ($P < .0001$) (Table I).

ASA scores were available for 267 of 425 shoulders (63%). There was a significant association between the types of surgical management and ASA score ($P = .001$; Table I). A higher percentage of patients who underwent RSA had high ASA score, when compared with HA and ORIF: RSA (79%), HA (66%), and ORIF (55%) ($P = .001$). Overall, patients who were treated with arthroplasty (75% of HA and RSA patients) had a significantly higher ASA than those who underwent ORIF (55% of ORIF patients, $P < .0001$) (Table II).

Fracture characteristics and surgical management selection were strongly associated, with 2- and 3-part PHFs more likely to undergo ORIF (41 of 44, 93% and 104 of 162, 64%, respectively) and 4-part PHFs more likely to undergo RSA (74 of 190, 39%) ($P < .0001$; Table I).

Table I Patient and fracture characteristics

	Surgical management						*P* value
	ORIF		HA		RSA		
ASA score*	137	100%	35	100%	95	100%	.001
Low (1 or 2)	62	45%	12	34%	20	21%	
High (3 or 4)	75	55%	23	66%	75	79%	
Age (yr)	61.6 ± 12.9		64.7 ± 12.2		73.0 ± 8.6		<.0001
Neer fracture classification†							<.0001
2	41	93%	2	5%	1	2%	
3	104	64%	30	19%	28	17%	
4	56	29%	60	32%	74	39%	

ASA, American Society of Anesthesiologists physical status classification; *ORIF*, open reduction internal fixation; *HA*, hemiarthroplasty; *RSA*, reverse shoulder arthroplasty.
Data represent number of shoulders or fractures and percentage, unless otherwise indicated.
* Missing values (ASA score not available for 158 patients).
† Missing values (fracture classification not available for 29 patients).

Range of motion

All groups showed significant improvements in FF from 3 to 6 months (HA: $P < .0001$; ORIF: $P < .0001$; RSA: $P = .001$) and 6 to last visit (1 year plus, for all groups: $P < .01$). The resultant FF at 6 months was significantly better in ORIF and RSA, compared with HA ($P < .0001$ and $P = .005$, respectively). At the final follow-up (1 year plus: average 20 ± 21 months; ORIF average 15 ± 15 and range 11.4-126 months; HA average 21 ± 22 and range 11.8-145 months; and RSA average 29 ± 26 and range 12-116 months), there was only a significant difference between ORIF and HA ($P = .002$; Table III; Fig. 2). Further analysis showed that patients older than 65 years who were treated with ORIF or RSA had significantly better FF than HA patients at 6 months ($P = .001$ and $P = .01$, respectively) and at last visit ($P = .02$ and $P = .036$, respectively). We also found that patients who underwent ORIF and RSA for 4-part PHFs had better FF than HA at 6 months ($P = .01$ and $P = .024$, respectively).

Radiographic outcome

Malunion, nonunion, and/or hardware complications were present in 25% of ORIF, 30% of HA, and 15% of RSA. Tuberosity union was significantly associated with patient age group: younger patients (≤65 years old) had increased rate of unions compared with older patients (>65 years old) ($P = .011$; Table IV). Based on surgical management, tuberosity or fracture union at the time of final radiographic follow-up was significantly higher in the ORIF group, and similar between the HA and RSA group ($P = .002$; Table IV).

Table II ASA scores vs. surgical management

	Surgical management				*P* value
	ORIF		Arthroplasty		
ASA score*	137	100%	130	100%	.0001
Low (1 or 2)	62	45%	32	25%	
High (3 or 4)	75	55%	98	75%	

ASA, American Society of Anesthesiologists physical status classification.
Data represent number of shoulders and percentage.
* Missing values (ASA score not available for 158 patients).

Reoperation

Reoperation rates were significantly different between the types of surgical management: RSA 6.6%, HA 15.7%, and ORIF 17.5% ($P = .029$, Fig. 3). ASA score was not correlated with reoperation ($P = .882$).

Subsequent falls

Postoperatively, 97 of 419 (23%) patients had at least 1 fall after the treatment for their PHFs. In the group that fell, there were 80 identified fractures in 71 patients. The most common fractures were the distal radius (22 of 80, 28 %), proximal humerus (12 of 80, 15%), and hip (11 of 80, 14%; Table V). The average time from the PHF surgical management to the fall was 38 ± 35 months. Females (84%) fell more often than males, but it was not statistically significant ($P = .063$). There was no significant difference in age ($P = .198$). Sixty-seven percent of patients who fell had a high ASA score; however, it did not reach statistical significance ($P = .747$, Table VI).

Discussion

In our series, age was associated with type of surgical management. Patients ≤65 years old and >65 years old were more likely to undergo ORIF and arthroplasty, respectively. Gupta et al had similar findings in their

Table III Forward flexion results

	Surgical management					
	HA		ORIF		Reverse	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Forward flexion at 3 mo	87	29	98	31	96	30
Forward flexion at 6 mo	97	33	125	33	113	34
Forward flexion at 1 yr plus	112	44	130	41	124	41

HA, hemiarthroplasty; *ORIF*, open reduction internal fixation.

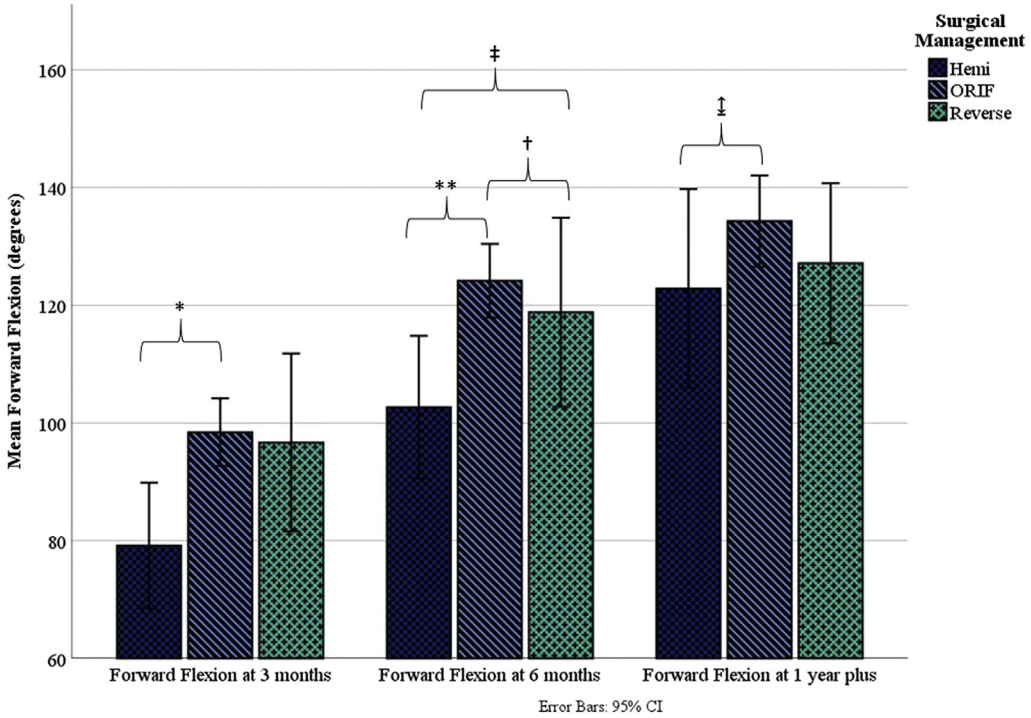

Figure 2 Mean active forward flexion at 3 months, 6 months, and at least 1-year follow-up for each cohort. *$P = .01$; **$P < .0001$; ‡$P = .005$; †$P = .018$; ↕$P = .02$. *ORIF*, open reduction internal fixation; *CI*, confidence interval.

Table IV Tuberosity union by age and type of surgical management

	Tuberosity union		*P* value
	Yes	No	
	n (%)	n (%)	
Age group			
≤65 yr	178 (88)	24 (12)	.011
>65 yr	176 (79)	47 (21)	
Surgical management			
HA	85 (79)	23 (21)	.002
ORIF	189 (90)	22 (10)	
Reverse	80 (75)	26 (25)	

HA, hemiarthroplasty; *ORIF*, open reduction internal fixation.

systematic review of studies comparing ORIF, HA, and RSA for PHFs.[20] The decision for RSA in older patients is likely influenced by studies reporting worse outcomes with ORIF in this patient population. Hardeman et al showed worse functional outcomes and higher reoperation rate in older patients treated with ORIF for displaced PHFs.[21] They attributed their findings to poorer bone quality in the older population. Similarly, we showed increased reoperation rate with ORIF and found that nonunion was greater in patients >65 years old vs. those ≤65 years old who underwent ORIF.

Patients with higher ASA scores were more likely to undergo arthroplasty for PHFs in our cohort. However, there was no association between ASA score and FF, radiographic outcomes, reoperation, or postoperative falls. There have been no studies to date evaluating ASA

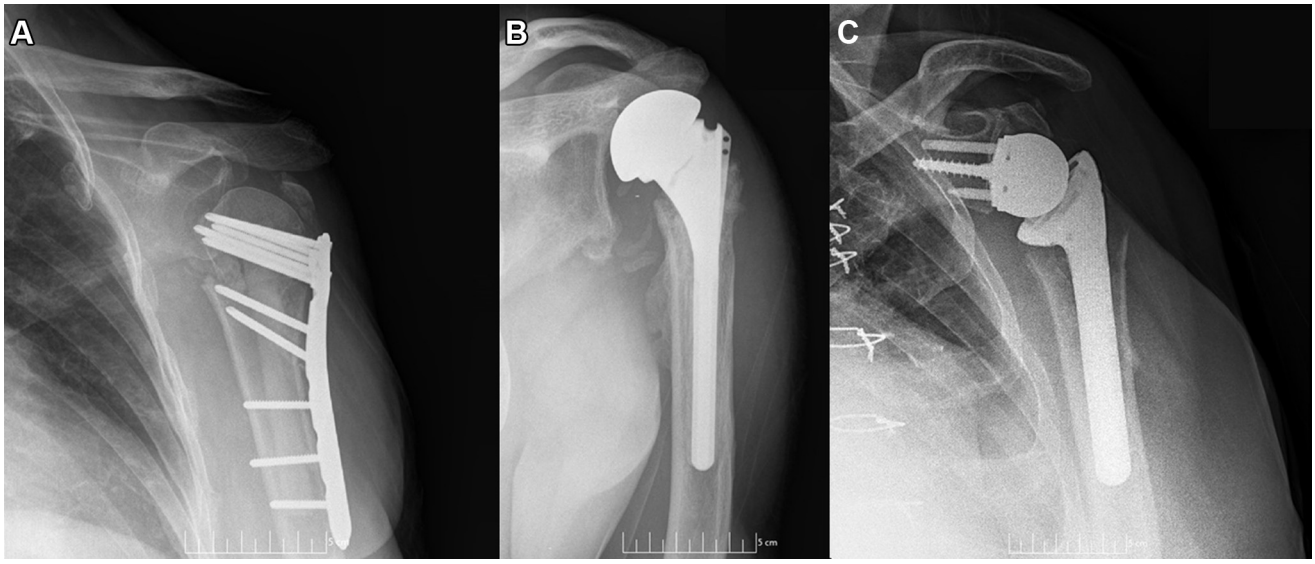

Figure 3 Examples of failed reconstruction. (**A**) 65-year-old woman's 3-month status after ORIF for a 4-part proximal humerus fracture with humeral head collapse and failed greater tuberosity repair. (**B**) 26-year-old man's 12-month status after hemiarthroplasty for a 4-part proximal humerus fracture with nonunion of the greater tuberosity and anterior, superior escape. (**C**) 75-year-old man's 6-month status after reverse shoulder arthroplasty for a 4-part proximal humerus fracture with nonunion of the greater tuberosity. *ORIF*, open reduction internal fixation.

scores with surgical management of PHFs. Johnson et al showed that higher ASA scores were associated with surgical complications and prosthetic failure in patients who underwent shoulder arthroplasty.[25] In their cohort, only 7 patients underwent arthroplasty for a PHF. Similar findings on complications have been shown in the hip and knee arthroplasty literature.[24] Even though our study did not show similar associations, ASA scores are important in predicting postoperative complications and outcomes.

Table V Fracture types due to postoperative fall

Fracture type	n
Distal radius	22
Proximal humerus	12
Hip	11
Clavicle	5
Ankle	4
Periprosthetic (shoulder)	4
Periprosthetic (femur)	3
Pelvic	3
Scapula	2
Olecranon	2
Tibia	2
Facial	1
Vertebral compression	1
Distal humerus	1
Coronoid	1
Radial neck	1
Ulna	1
Finger	1
Distal femur	1
Patella	1
Proximal fibula	1
Total	80

We found a significant difference in type of surgical management based on Neer's fracture classification. Two- and three-part PHFs were more likely to be treated with ORIF, and four-part PHFs were more likely to be treated with RSA. Good outcomes with ORIF depend on adequate mechanical stability and preservation of the humeral head vascularity.[10,17] This is likely the reason why the majority of 2-part PHFs underwent ORIF. The optimal treatment for 3-part PHFs, however, can be difficult to determine. The treatment is based on multiple factors: patient variables, neurovascular examination, potential vascularity of the humeral head, bone quality, and time from injury to clinic presentation. Many of these factors were not evaluated in our study; therefore, it is difficult to determine the reason why more patients underwent ORIF rather than HA or RSA for 3-part PHFs, although 4-part PHFs were more likely to be treated with arthroplasty.

Studies have found mixed results when comparing surgical options for PHFs. Gupta's systematic review of surgical management for 3- and 4-part PHFs showed that ORIF had better range of motion than HA.[20] Similarly, other studies have shown poor outcomes with HA.[12,14,40,42,46] In contrast, Cai et al[5] showed that hemiarthroplasty had better outcomes than ORIF for 4-part PHFs. RSA has been shown to have improved motion than HA in many studies.[1,12,16,38,39] Only 1 other

Table VI Postoperative fall vs. ASA scores

Postoperative fall	ASA score*			*P* value
	Low (1 and 2), n (%)	High (3 and 4), n (%)	Total	
Yes	18 (33)	36 (67)	54	.747
No	76 (36)	137 (64)	213	
Total	94 (35)	173 (65)	267	

ASA, American Society of Anesthesiologists physical status classification.
* Missing values (ASA score not available for 158 patients).

study has attempted to compare outcomes of all 3 types of surgical management. Chalmers showed that 3- and 4-part PHFs had improved early range of motion and decreased cost with RSA, when compared with ORIF and HA.[7] Our study found a significant improvement in FF within all groups. When comparing final motion between groups, we found higher averages in the ORIF and RSA groups but the only significant difference was when comparing ORIF with HA. These closely grouped outcomes may be explained by the experience of the surgeons in our cohort.

Reoperation rate is an important factor in decision making for PHFs. Gupta et al noted a higher reoperation rate with ORIF, in their systematic review of surgically treated complex PHFs. They noted a reoperation rate of 12.7% in ORIF and a reoperation rate of 5% in RSA.[20] Similarly, we found a significant difference with ORIF 17.1% and RSA 6.6%. In their review, HA had a low reoperation rate of 4.9%, but we found a much higher rate of reoperation of 15.7%. Reoperation needs to be a point of discussion when deciding about the optimal treatment. Previous literature has shown that primary RSA for PHFs outperformed a revision from another device to RSA.[12] This is very important for a patient, as it increases not only morbidity but also health care cost.

Lastly, 97 of 419 (23%) of our cohort had a postoperative fall with resultant fracture in 71 patients. To our knowledge, this is the only study to investigate the association of falls and fractures specifically after surgical management of PHFs. Subsequent fractures after the PHF, in general, have been reported in other studies in both men and women.[9,13] These studies looked particularly at hip fractures after the PHF and showed an increased hazard risk.[9] Tinetti et al noted a fall rate of 49.5% (381 of 770) and 9% (71 of 770) fractures in their 3-year study of community-dwelling older patients.[45] This study did not consider surgically treated PHFs. In our population, we found that 23% of the patients sustained a postoperative fall, and 19% of patients sustained a subsequent fracture. Breakdown of the fractures showed that, of the 80 fractures, only 14% had a subsequent hip fracture, but over 27.5% sustained a distal radius fracture, and 15% with a contralateral PHF. Although the risk of periprosthetic fracture is low, 5%, previous studies have found that greater comorbidities increased the risk for periprosthetic fracture.[41] We also noticed this finding but did not reach significant values in our analyses. These injuries are a tremendous burden to the patient. Over the last 20 years, there has been increasing mortality associated with falls amongst older adults in the United States.[22] Patient counseling about fall risk, as well as fall prevention, must be undertaken. The American Academy of Orthopaedic Surgeons, in conjunction with American Geriatrics Society and British Geriatrics Society, has fall prevention guidelines available to help counsel patients.[19] Also, a home-based strength and balance retraining exercise program has been shown to significantly reduce the rate of subsequent falls compared with usual care.[30] Patients who sustain a PHF should have a multidisciplinary approach to fall prevention, bone density management, and comorbidity management.

The study has its limitations. Most are related to the inherent weaknesses of a retrospective review, including loss to follow-up particularly in the trauma population. This affected the proportion of patients who had all their postoperative FF values, follow-up radiographs, and instances of subsequent falls. There were 29 patients who did not have preoperative radiographs, and their injury could not be classified based on their notes. These patients were not excluded, as they maintained necessary postoperative data. There were 158 patients who did not have ASA scores available. This was due to the longevity of our study, as both the hospital electronic medical record and the anesthesia group electronic medical record had transitioned. This made the early ASA scores unattainable. The data available provided only short-term clinical outcomes for many patients. Because of this short-term follow-up, the number of subsequent falls with or without fracture is likely underestimated. Another limitation is the selection bias with treatments; given that the majority of 2-part PHFs were treated with ORIF, there may be a bias giving ORIF better outcomes secondary to the decreased complexity of the fracture.

Conclusion

This is the first study to not only compare ORIF, HA, and RSA but also evaluate comorbidities, fracture complexity, postoperative falls, and fractures. ORIF was performed in younger patients with lower ASA scores and less complex fractures. RSA was performed in older patients with higher ASA scores and more complex fractures. Our primary hypothesis that a patient with a higher age, ASA score, and fracture type (Neer 3 and 4) is more likely to undergo arthroplasty than ORIF was confirmed.

ORIF had better final range of motion than HA. ORIF vs. RSA and RSA vs. HA did not show a significant difference. ORIF did show a higher fracture union rate than RSA and HA. However, this should be carefully interpreted as nearly all 2-part PHFs were treated with ORIF. ORIF and HA have a higher reoperation rate than RSA. This is important information when discussing surgical treatment options with patients.

An important aspect of this study was the demonstration of postoperative fractures in this population. Our hypothesis that surgically treated PHFs are likely to sustain a repeat fracture was confirmed. Twenty-three percent of patients with an acute surgically managed PHF had at least 1 subsequent fall. Approximately 73% of these falls sustained a fracture. This is an extremely important public health concern. Patients need proper counseling after PHF treatment to prevent future falls and fractures that can potentially hinder functional status and quality of life.

Disclaimer

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