RESEARCH ARTICLE

Impact of Age on Functional Outcome After Reverse Shoulder Arthroplasty Performed for Proximal Humerus Fractures or Their Sequelae

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Abstract

Background: The use of reverse shoulder arthroplasty (RSA) to treat displaced, unstable 3- and 4-part proximal humerus fractures (PHFs) has traditionally been reserved for patients over 70 years old. However, recent data suggest that nearly one-third of all patients treated with RSA for PHF are between 55-69 years old. The purpose of this study was to compare outcomes for patients younger than 70 versus patients older than 70 years of age treated with RSA for a PHF or fracture sequelae.

Methods: All patients who underwent primary RSA for acute PHF or fracture sequelae (nonunion, malunion) between 2004 and 2016 were identified. A retrospective cohort study was performed comparing outcomes for patients younger than 70 versus older than 70. Bivariate and survival analyses were performed to evaluate for survival complications, functional outcomes, and implant survival differences.

Results: A total of 115 patients were identified, including 39 patients in the young group and 76 cases in the older group. In addition, 40 patients (43.5%) returned functional outcomes surveys at an average of 5.51 years (average age range: 3.04-11.0 years). There were no significant differences in complications, reoperation, implant survival, range of motion, DASH (27.9 vs 23.8, P=0.46), PROMIS (43.3 vs 43.6, P=0.93), or EQ5D (0.75 vs 0.80, P=0.36) scores between the two age cohorts.

Conclusion: At a minimum of 3 years after RSA for a complex PHF or fracture sequelae, we found no significant difference in complications, reoperation rates, or functional outcomes between younger patients with an average age of 64 years and older patients with an average age of 78 years. To our knowledge, this is the first study to specifically examine the impact of age on outcome after RSA for the treatment of a proximal humerus fracture. These findings indicate that functional outcomes are acceptable to patients younger than 70 in the short term, but more studies are needed. Patients should be counseled that the long-term durability of RSA performed for fractures in young, active patients remains unknown.

Level of evidence: III

Keywords: Age, Arthroplasty, Function, Outcome, Shoulder fracture

Introduction

Proximal humerus fractures account for more than 5% of all adult fractures and the incidence is increasing with the aging of the US population. [1] Nearly 275,000 ED visits for proximal humerus fractures are expected in 2030. [2] The optimal management of proximal humerus fractures remains controversial. [3,4]

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Nonoperative management is indicated in the majority of cases. [5,6] When surgery is indicated, many factors may influence the choice of the implant including patient functional status and expectations, patient age, degree of comminution, bone quality, surgeon preference, and the presence of dislocation, head split fracture or neurologic compromise. [3-5] There is currently no consensus on surgical indications or technique, but surgery may be considered for displaced, unstable 3- and 4-part fractures. 3 Options include open reduction and internal fixation (ORIF), hemiarthroplasty (HA), and reverse total shoulder arthroplasty (RSA). [3,6,7]

Young patients who would normally be candidates for ORIF may require arthroplasty due to poor bone quality, fracture-dislocation, or head split fracture patterns. The RSA has traditionally been reserved for patients older than 70 years. [8] However, surgeons may be using RSA for fracture in younger patients due to unpredictable results with HA 8 and high complication rates after ORIF, particularly with poor bone quality or a large amount of comminution. [3,9] The use of RSA for the surgical treatment of complex PHFs increased from 2% in 2005 to 38% in 2012, and multiple studies have shown that RSA for the treatment of PHFs has now surpassed that of HA for this indication. [8,11-14] Satisfactory results for pain control and functional outcomes after RSA for PHFs have been documented in elderly patients, and RSA is a viable option for young patients with massive rotator cuff tears. [10,15-18] It has been suggested that outcomes of the various surgical treatments for PHF may be dependent on age, but little is known about the outcomes of younger patients after RSA for PHF or fracture sequelae. [3, 8,9,10, 19]

The purpose of this study was to compare complications and functional outcomes for patients younger than 70 versus older than 70 years of age treated with RSA for a PHF or fracture sequelae.

Materials and Methods

Institutional Review Board approval was obtained for the conduction of this study. A retrospective comparative cohort study was performed to analyze complications and functional outcomes for consecutive patients undergoing RSA for proximal humerus fracture at two levels :one trauma center and one academic community hospital between 2004 and 2016. Patients were included if they underwent RSA as the primary management of an ipsilateral PHF or fracture sequelae (nonunion, malunion). Patients were excluded if they had undergone any prior surgery to address the PHF before RSA.

Patient medical records were retrospectively reviewed to collect data on patient demographics, date, and mechanism of injury, preoperative diagnoses and indications for surgery, date of surgery, complications, postoperative active forward elevation (AFE), and active external rotation (AER) reported in clinical notes, patient-reported pain at last follow-up visit, and length of clinical follow-up. Operative notes were reviewed for approach, intraoperative complications (neurovascular injury or fracture), and implant manufacturer when available.

The "young" group was defined as having an age of fewer than 70 years, while the "old" group was defined as having an age of greater than 70 years at the time of the index procedure based on a pre-existing assumption in the literature that patients older than 70 are indicated for RSA. [3,8,20] Complications including dislocation, deep infection, a medical complication such as PE or sepsis, new postoperative neurologic deficit, and return to the operating room for any reason were compared between the young and old cohorts for all patients meeting inclusion criteria. Clinical outcomes (e.g., AFE, AER, subjective pain) were documented and compared for patients with at least one year of clinical follow-up. Patients were contacted to obtain minimum 3-year functional outcomes using DASH (Disabilities of the Arm, Shoulder, and Hand), PROMIS (Patient Reported Outcome Measurement Information System) Short Form v2.0 - Physical Function 10b, and EQ5D scores. To assess for additional complications treated at other healthcare facilities, contacted patients were asked if they had ever been told they had an infection in their shoulder, and whether they had any complications related to their shoulder or any additional surgeries on their shoulder since their index procedure. In order to account for the possibility of selection bias in the choice of surgical treatment, the Charleson Comorbidity Index (CCI) was compared between young and old patients with functional outcomes.

Final follow-up radiographs were available from within 30 days of the last clinical visit for 81 patients (70.5%). All available final x-rays were evaluated by a musculoskeletal radiologist and an orthopedic surgeon for tuberosity healing as well as any evidence of complication not identified in clinical notes such as fracture or loosening.

Bivariate analyses using Fisher's exact test for categorical variables and independent t-tests for continuous variables were performed for comparisons between the young and old patient cohorts. Implant survival was compared between the two groups using a univariate analysis of survival data by the logrank test (Mantel-Cox). All statistical analyses were performed using IBM SPSS V23.

Results

An initial query yielded 178 patients. A total of 115 patients met the inclusion criteria [Figure 1]. Of the 115 eligible patients, 39 patients were younger than 70 (mean 64.0 years, SD 4.52) and 76 were older than 70 years of age (mean 78.7 years, SD 6.15) at the time of the index operation. A total of 58 patients (50.4%) had at least one year of clinical follow-up. A total of 23 patients were deceased and unable to complete functional outcomes scores. Furthermore, 40 patients (43.5%) completed functional outcomes surveys at a minimum of 3 years and an average of 5.51 years postoperatively (average age range: 3.04-11.0 years, SD 2.15).

There was no significant difference in baseline

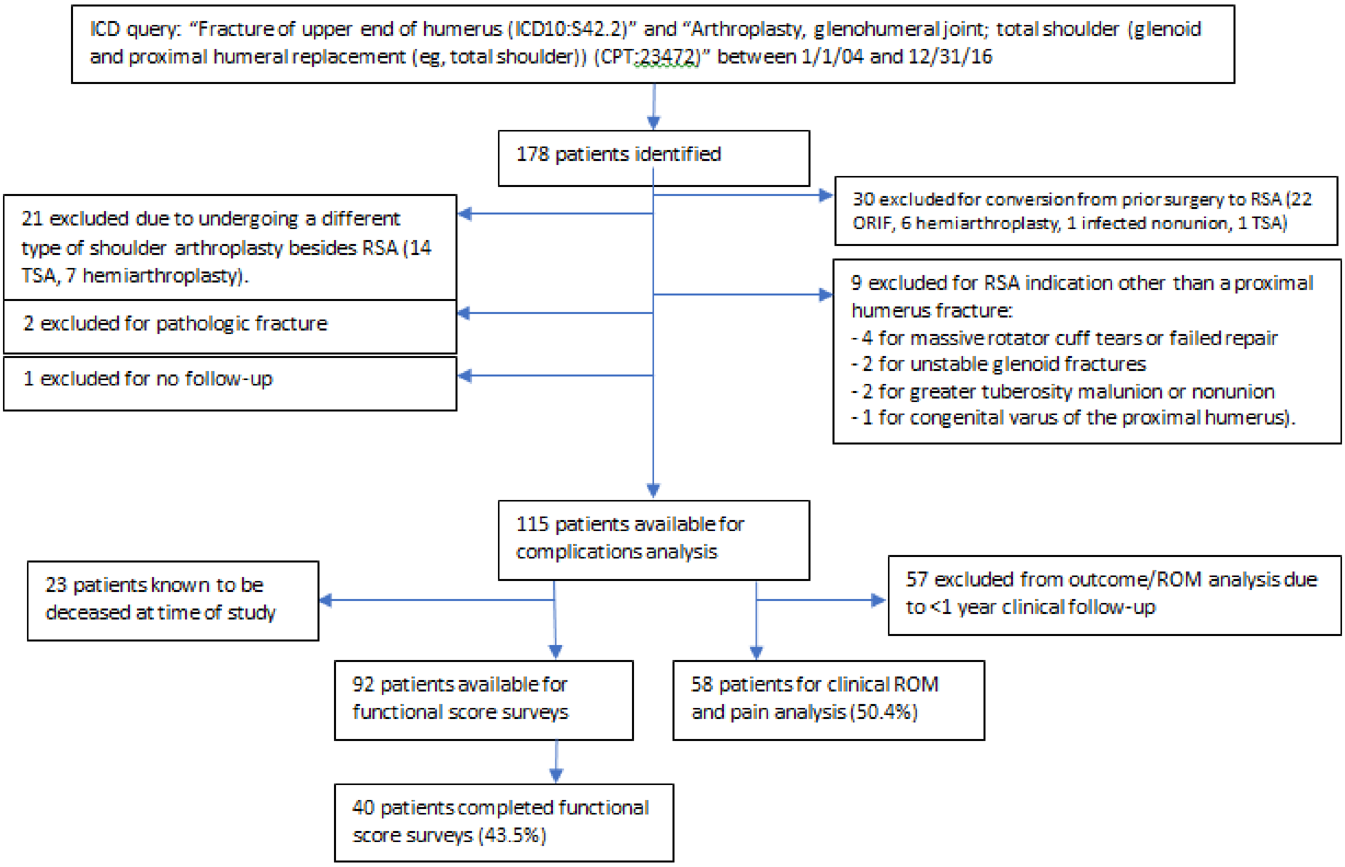

Figure 1. Initial database query and exclusions.

characteristics for the two age cohorts besides age and comorbidities [Tables 1A; 1B]. There was no difference in baseline characteristics between patients with functional outcomes and patients lost to follow-up except for age and ASA score [Appendix 1]. The average time from injury to surgery was 112 days (range: 1 day to 4.5 years) for the under-70 cohort and 109 days for the over-70 cohort (range: 0 days to 3.4 years). A similar proportion of patients in each group underwent acute surgical management within 4 weeks of injury: 28 of 39 patients (71.8%) in the younger group and 55 out of 76 patients (72.4%) in the older group. There was a significant difference in both ASA and CCI between the two age cohorts among included patients, suggesting that patients in the under-70 cohort were physiologically as well as chronologically younger in general. [Table 1A; Table 5]. A summary of injury mechanism by age is also provided [Table 2]. The most common indication for the choice of RSA in both groups was comminution and/or subjective assessment of poor bone quality for reconstruction. In the under-70 group, the next most common indication was a head-split pattern while in the over-70 group it was fracture-dislocation.

All patients underwent RSA through a deltopectoral approach. Iatrogenic humerus fracture or fracture propagation managed with cerclage wiring and/or cement was documented in the operative note for three patients (2.6%), all in the over-70 group. The humeral component was cemented more often in the older group (60.5%) than in the younger group (43.6%). There was no significant difference in complication or reoperation rates between the two cohorts [Table 3]. There was no significant difference in range of motion (AFE, AER) or reported pain for patients with minimum one-year clinical follow-up data [Table 4].

There were 20 patients under 70 and 20 patients over 70 years of age who returned functional outcomes surveys. Among patients who returned functional outcomes, 80% of younger patients were treated with surgery acutely compared to 65% of older patients. Bivariate analysis revealed that the older cohort had significantly more comorbid conditions at the time of surgery according to the CCI, but there was no significant difference in DASH, PROMIS, or EQ5D scores at an average of 5.51 years postoperatively [Table 5]. Patients were subdivided into four groups according to age (<65, 65-70, 70-75, >75) but there was no significant difference in outcome scores between any

Table 1A. Comparison of baseline characteristics for under-70 and over-70 patient cohorts (all included patients)

Variable		**<70 years (N=39)**	**>70 years (N=76)**	***P value***
Age of patient (mean (SD))		63.97 (4.52)	78.65 (6.15)	<0.001*
Sex	Female	33	62	0.682
	Male	6	14	
1-yr clinical follow-up		26 (66.7%)	32 (42.1%)	0.018*
Operation duration (minutes)		137.90 (45.45)	138.44 (48.11)	0.966
Blood loss (mean, SD)		286.36 (137.66)	320.33 (202.05)	0.391
BMI		29.97 (7.15)	27.01 (5.79)	0.035*
Smoker	Never	35	65	
Former	3	11		0.217
Current	1	0		
Diabetes		11	11	0.086
Dementia		1	8	0.168
Neer class	2	5	6	
3	6	22		0.198
4	24	37		
Tuberosity Healing	No	10	21	0.650
Yes	24	38		
ASA class	1	1	0	
2	26	41		0.044*
3	9	34		
4	1	1		
Pre-op nerve injury	None	38	71	
Axillary	0	0		0.801
Radial	0	3		

Table 1B. Comparison of baseline characteristics for under-70 and over-70 patient cohorts (patients returning functional outcomes)

Variable		**<70 years (N=20)**	**>70 years (N=20)**	***P value***
Age of patient (mean (SD))		64.35 (5.54)	75.47 (6.68)	<0.001*
Sex	Female	18	16	0.661
	Male	2	4	
1-yr clinical follow-up (%)		15 (75%)	12 (60%)	0.501
Operation duration (minutes)		136.75 (50.45)	159.29 (50.66)	0.268
Blood loss (mean, SD)		310.00 (161.08)	299.41 (213.91)	0.865
BMI		29.97 (5.60)	27.74 (5.94)	0.242
Smoker	Never	20	18	
Former	0	2		0.487
Current	0	0		
Diabetes		6	4	0.716
Dementia		1	2	>0.999
Neer class	2	1	1	
3	2	8		0.090
4	14	8		
Tuberosity Healing	No	4	5	>0.999
Yes	14	13		
ASA class	1	1	0	
2	14	15		0.695
3	3	5		
4	1	0		
Preop nerve injury	None	20	18	
Radial	0	1		0.487
Ulnar	0	1		

of these groups [Table 6].

Six patients in the young cohort (30%) and two patients in the older cohort (10%) reported that they were working at the time of the survey. The employed younger patients worked as a hair stylists, executive chefs, kitchen staff at a school, investment advisors, artist, and homemakers. The older patients worked in real estate and as textbook writers/editor. The average DASH score for employed younger patients was 21.6 (SD 18.8), with an average score on the work module of 22.9 (SD 39.7). The average DASH score for employed older patients was 2.5 (SD 3.5), with an average score on

Table 2. Mechanism of injury for patients with documented mechanism

	Fall from standing	**Fall > standing**	**Seizure**	**MVC**	**Ped struck**	**Total**
Age <70	29	5	2	2	1	39
	74.4%	12.8%	5.1%	5.1%	2.6%	
Age >70	67	2	3	1	0	73
	91.8%	2.7%	4.1%	1.4%	0.0%	

Table 3. Comparison of complications between patients in the two age cohorts

Variable	<70 years (N=39)	>70 years (N=76)	*P value*
Complication	6 (15.4%)	7 (9.2%)	0.359
Dislocation	2 (5.1%)	4 (5.3%)	>0.999
Infection	1 (2.6%)	0 (0%)	0.339
Revision	3 (7.7%)	4 (5.3%)	0.688
Medical	1 (2.6%)	2 (2.6%)	>0.999
Reoperation	3 (7.7%)	5 (6.6%)	>0.999
New post-op nerve palsy	2 (5.1%)	0 (0%)	0.113

Table 4. Comparison of clinical outcomes for patients with minimum 1-year clinical follow-up according to age.

Outcome		Age < 70 Mean (SD) (N=26)	Age > 70 Mean (SD) (N=32)	*P value*
AFE		126.52 (36.63)	126.72 (34.67)	0.984
AER		31.11 (17.54)	29.58 (18.82)	0.790
Pain > 0	No	11 (44.0%)	16 (51.6%)	0.571
	Yes	14 (56.0%)	15 (48.4%)	

Table 5. Comparison of patients providing functional outcomes scores at an average of 5.51 years (range 3.04-11.0, SD 2.15) according to age. (CCI = Charleson Comorbidity Index)

Variable	Younger than 70 Mean (SD) (N=20)	Older than 70 Mean (SD) (N=20)	*P value*
CCI	2.5 (1.24)	4.2 (1.15)	<.0001*
DASH	27.93 (17.52)	23.84 (16.93)	0.457
PROMIS	43.29 (10.26)	43.58 (10.56)	0.930
EQ-5D	0.75 (0.14)	0.80 (0.16)	0.356

Table 6. Subgroup analysis of functional outcomes according to age an average of 5.51 years (range 3.04-11.0, SD 2.15) (CCI = Charleson Comorbidity Index)

Variable	Age (y)	N	Mean	Std. Deviation	*P value*
CCI	<65	8	2.3750	1.50594	0.001*
	65-70	12	2.5833	1.08362	
	70-75	12	4.0833	.99620	
	>75	8	4.3750	1.40789	
PROMIS	<65	8	41.3625	12.90426	0.568
	65-70	12	44.5667	8.45441	
	70-75	12	45.9667	10.36860	
	>75	8	39.9875	10.43968	
DASH	<65	8	34.8096	16.70696	0.387
	65-70	12	23.3429	17.18870	
	70-75	12	21.8966	17.61394	
	>75	8	26.7444	16.57412	
EQ-5D	<65	8	.7180	.19570	0.605
	65-70	12	.7719	.10048	
	70-75	12	.8145	.13451	
	>75	8	.7673	.20387	

the work module of 0 (SD 0). There was no significant difference in implant survival at 5 years between the young cohort (90.6%) and the old cohort (94.4%) (χ^2 2.73, df = 3, *P = 0.44*). Implant manufacturer data are provided in Appendix 2.

Discussion

The indications for RSA after fracture are expanding, and the use of RSA for surgical management of PHFs has now surpassed the use of hemiarthroplasty for this indication. [13,14] Surgeons may be utilizing RSA for the surgical treatment of PHFs in the acute or delayed setting for increasingly younger patients, 8 yet the impact of age on outcomes after RSA for PHF or fracture sequelae remains unclear. We examined outcomes for a cohort of young patients (average age 64 years) undergoing RSA for PHF and compared them to those of their older counterparts traditionally recommended for RSA after PHF. In this retrospective cohort study, there was no statistically significant difference between younger and older patients with regards regard to reoperation rate, complications, or clinical outcomes (AFE, AER, pain) after RSA for PHF. For patients with functional outcomes scores available (43.5%), there was no difference between younger and older patients in DASH, PROMIS, or EQ5D scores at a minimum of 3 years and an average of 5.51 years (average age range: 3.04-11.0 years, SD 2.15) postoperatively.

The RSA has traditionally been reserved for patients over the age of 70 years, (3,8,20) due to concerns for higher functional demands of younger patients. [14] Age has been shown to affect outcomes after knee arthroplasty but there have been no studies specifically examining the impact of age on outcome after RSA for fracture. [9,3,21] Prior studies on RSA for fracture have consistently evaluated cohorts of patients with a mean age of greater than 75 years. [22,23] However, in a recent large registry study, Dillon et al demonstrated that patients aged 55-69 years represented nearly one-third of all patients treated with RSA for PHF in the US from 2009 to 2016. Spross et al found increasing utilization of RSA for the 65-70 years old age group which they attributed to more reliable results with RSA than HA and good long-term data for primary RSA. [8] HA is technically demanding, with less consistent results than RSA likely due to the need for anatomic tuberosity healing. [22] RSA is an acceptable alternative to HA for the surgical treatment of PHFs. [8,24,25] Some surgeons may feel they can offer more consistent results, even for physiologically younger patients, with RSA compared to HA. [8] Therefore, younger patients appear to represent a stable and possibly growing portion of the population treated with RSA for PHF, but little is known about the outcomes of these younger patients after the procedure.

The average age of younger patients with functional outcomes in this study was 64 years with an average follow-up of 5 years. Physiologically younger patients may have higher post-operative expectations of motion and function. [14] To account for possible selection bias that could result in "physiologically older" young patients being preferentially selected for RA rather than HA or ORIF, we calculated the Charleson Comorbidity Index (CCI) for patients with functional outcomes. There was a significant difference in CCI between the two age cohorts, suggesting that patients in the young cohort were physiologically as well as chronologically younger at the time of surgery.

Surgical fixation of PHFs was previously thought to offer a superior range of motion compared to RSA(3) but a recent RCT comparing ORIF with RSA demonstrated better motion after RSA. [9] On average, our study subjects achieved comparable AFE and AER to what has been reported in the literature, but there was no difference between the younger and older groups at one year. [16,26] The average AFE of 120 degrees and AER of 30 degrees are less than in a native shoulder, and it is important to counsel younger active patients that their motion is an unlikely to return to pre-injury levels. Complication and revision rates in our study are comparable to those reported in RSA for rotator cuff deficiency in young patients and to those previously reported after RSA for fracture. [9, 18] Lastly, the longevity of the implant may be a concern in younger patients with greater functional demands. Our results demonstrated >90% implant survival at an average of 5 years for patients with adequate follow-up, but the long-term durability of RSA implants in young, active patients remains unknown.

There was no significant difference in functional scores between patients in the younger and older cohorts, and DASH scores were similar to prior studies of patients undergoing RSA for PHF. [17, 27] These findings that RSA after fracture may be functionally acceptable to younger patients are consistent with those of a recent multicenter RCT comparing ORIF and RSA for the treatment of displaced PHFs. The authors sub-stratified patients into two age groups of 65-74 and 75-85 years and found superior Constant scores for RSA compared to ORIF in both groups. [9] We performed a subgroup analysis according to 5-year age groups (<65, 65-70, 70-75, >75) to evaluate for any impact of the extremes of age on functional outcome. There was no statistically significant difference between the groups, but the average DASH score for patients <65 years old was more than 10 points worse than for patients in the years65-70- and 70–75-year-old age groups. Although this difference exceeds the minimum clinically important difference (MCID) for the DASH, the worst score of 34.8 is better than the average DASH score reported after RSA for fracture in the literature. [28] The difference could relate to these youngest patients having a higher expectation of their functional results after RSA, but this question requires further investigation with larger numbers of patients. This study is likely underpowered for such a subgroup analysis and conclusions are limited by the low number of patients and high standard deviation of DASH scores.

RSA is a reliable procedure for pain relief and restoration of function in the elderly population after PHF. 9,20,22 In the older cohort, our results are consistent with previous studies in this regard, offering pain relief and satisfactory function. The complication rates in this cohort were compared favorably with the literature on patients of similar ages. [3,22] Primary RSA after PHF has historically been associated with overall complication rates as high as 20%, but reoperation was significantly higher for ORIF than RSA in one recent systematic review of 4500 PHFs. [3,24] The authors of this review attempted to analyze patient outcomes according to age, but the available studies did not provide adequate information about the ages of enrolled patients. They concluded that RSA may be more cost-effective than ORIF for patients older than 70 due to the low reoperation rate. [3] The ability to reliably perform a definitive procedure is important for older patients with PHFs, whom have had a one-year mortality rate between 5% and 22%. [29] Mortality in this study was approximately 20% at an average of 5 years after surgery, with 95% of deaths occurring among patients in the older age group.

Strengths of this study include its comparative nature and the number of patients, as studies that include an analysis of the impact of age on functional outcomes are sparse. We were able to obtain functional outcomes in a representative sub-cohort at a minimum of 3 years and an average of 5.5 years postoperatively. Despite these strengths, there are several important limitations. These include the retrospective nature of the study, the significant loss to follow-up (approximately 50% at one year), and the relatively small number of patients providing functional outcomes (approximately 43.5%). A comparison of baseline characteristics between patients with functional outcomes and non-responders revealed significant differences only in age and ASA class. Therefore, younger patients generally responded to the functional surveys, while older patients were lost to follow-up at least partly due to mortality. Another important limitation is the inclusion of patients undergoing both acute and delayed reconstruction. This study is the first to compare outcomes by age, and the decision to include all patients was made toof assess the impact of patient age on the functional acceptability of RSA as a primary procedure for managing PHF in either the acute or delayed setting. Although the proportion of patients in each group undergoing acute and delayed reconstruction was similar, the results must be interpreted with this limitation in mind and future studies on age should consider stratifying by time to surgery. In addition, the literature guided the decision to use 70 years as the cutoff between young and old but is ultimately arbitrary. Despite the significant difference in CCI between the two cohorts, there is still the potential for unidentified selection bias in the cohort of younger patients who underwent RSA instead of ORIF or HA. We must suggest caution when considering RSA in younger patients. Ours follow-up is only 5 years and the long-term durability of RSA implants in young, active patients is unknown.

At a minimum of 3 years after primary RSA for a complex PHF or fracture sequelae, we found no significant difference in functional outcome between young patients with an average age of 64 years and older patients with an average age of 78 years. There was no significant difference in complication or reoperation rates between groups. In a limited subgroup analysis, patients under 65 years old had worse DASH scores compared to older patients, although this difference did not reach statistical significance. The trend toward worse DASH scores in the youngest patients may be useful to counsel younger patients undergoing RSA for PHF to help set reasonable expectations for function. To our knowledge, this is the first study to specifically examine the impact of age on outcome after RSA for the treatment of a proximal humerus fracture. These findings indicate that functional outcomes are generally acceptable to patients younger than 70 years in the short term, but more studies are needed. Patients should be counseled that the long-term durability of RSA performed for fractures in young, active patients remains unknown. Further studies are needed to determine the optimal age cutoff to consider RSA after PHF.

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Appendix 1. Comparison of baseline characteristics between patients who returned functional scores and those who did not

Variable		**Non-responders** (N=75)	**Patients with Functional Scores** (N=40)	***P value***
Age of patient (mean (SD))		75.68 (9.05)	69.91 (7.57)	0.001*
Sex	Female	61	34	0.797
	Male	14	6	
1-year clinical follow-up (%)		31 (41%)	27 (67.5%)	0.011*
Operation duration (minutes)		131.21 (43.40)	148.88 (50.85)	0.138
Blood loss (mean, SD)		310.53 (181.94)	305.14 (184.55)	0.889
BMI		27.63 (6.79)	28.86 (5.81)	0.354
Smoker	Never	62	38	
Former	12	2		0.167
Current	1	0		
Diabetes		12	10	0.320
Dementia		6	3	>0.999
Neer class	2	9	2	
3	18	10		0.575
4	39	22		
ASA class	1	0	1	
2	28	29		
3	35	8		0.006*
4	1	1		
Tuberosity healing	No	22	9	0.259
Yes	35	27		
Preop nerve injury	None	71	38	
Axillary	1	0		
Radial	2	1		0.702
Ulnar	0	1		

Appendix 2. Implant manufacturer information for patients in the two age cohorts

Implant Manufacturer	**Young cohort (N (%))**	**Old cohort (N (%))**
Tornier	5 (13)	10 (13)
Dupuy	15 (38)	26 (34)
Arthrex	5 (13)	14 (18)
Zimmer	5 (13)	10 (13)
Wright Medical	1 (2.5)	0 (0)
Not available	8 (20)	16 (21)
N (total)	39	76