Title: Comparing Radial Head Fracture Surgical Outcomes in Patients Younger and Older Than Forty

Running head title: Radial Head Fractures in Younger Patients: ORIF versus RHA

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Conflict of Interest Statement:

Statement of Human and Animal Rights:

This study did not involve any physical interaction with human or animal subjects. Questionnaires were completed in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. The Institutional Review Board approved the study of Mass General Brigham, Protocol Number 2022P001719.

Statement of Informed Consent:

Informed consent was not needed for this study.

ABSTRACT

OBJECTIVES: To compare the results of radial head arthroplasty(RHA) and open reduction internal fixation (ORIF) for radial head fracture treatment based on patient age.

METHODS

Design: Retrospective cohort study

Setting: Two academic Level 1 Trauma centers

Patient Selection Criteria: Included were patients treated with RHA or ORIF for a radial head fracture (OTA/AO 2R1A/B/C) between January 2015 and September 2022.

Outcome Measures and Comparisons: Postoperative surgical outcomes, including reoperations, final elbow range of motion (ROM), and radiographic features were collected. The outcomes of RHA and ORIF in patients above and below 40 years were compared using bivariate and multivariable regression analyses.

RESULTS

The study cohort included 161 operative radial head fractures sustained in 160 patients of which 47% were male (n=75). Thirty-two patients were included in the RHA <40 years group (mean age 31 years, standard deviation (SD) 5; 72% were male (n=23)), 96 patients in the RHA ≥40 years group (mean age 60 years, SD 11; 34% were male (n=33)), and 22 patients in the ORIF <40 years group (mean age 27 years, SD 6; 64% were male (n=14)). In patients <40 years old, RHA versus ORIF had comparable flexion-extension (125° versus 128°, p=0.79) prono-supination (145° versus 140°, p=0.16), and reoperation rate (22% versus 14%, p=0.50). Rates of post-traumatic arthritis were higher for RHA versus ORIF in this age group (57% versus 27%, p=0.047), although the follow-up period for radiographic assessment in the RHA <40 years group was slightly longer than the ORIF <40 years group (12.7±10.4 months versus 7.6±4.6 months, p=0.04). When comparing patients ≥40 years old with those <40 years old, outcomes of RHA had comparable flexion-extension (125° versus 125°, p=0.93) prono-supination (145° versus 150°, p=0.07), reoperation rate (22% versus 15%, p=041), and post-traumatic arthritis rate (57% versus 64%, p=0.34). Younger patients exhibited a lower frequency and severity of stem radiolucency than older patients (53% versus 67%, p=0.01).

CONCLUSIONS

For patients under 40 years, ORIF and RHA yielded comparable outcomes. RHA had a higher risk of post-traumatic arthritis, favoring ORIF for younger patients if technically feasible. Older patients should be aware of the increased risk of stem lucency when undergoing RHA.

KEY WORDS: radial head fracture, reoperations, arthritis, stem lucency, erosion, heterotopic ossification, radial head arthroplasty, radial head replacement

LEVEL OF EVIDENCE: Level III, retrospective cohort study

Introduction

Radial head fractures are the most common elbow fractures, accounting for approximately 1.5% to 4% of all fractures.[1,2] Surgical management – open reduction internal fixation (ORIF), radial head arthroplasty (RHA), or radial head excision – is often indicated for unstable elbow fractures and fractures with a mechanical block to motion.[3] Conventional teaching is that radial head fractures with more than 3 fragments are best treated with RHA, although recent studies have demonstrated similar results between ORIF and RHA.[4–6]

Deciding between ORIF or RHA in younger patients, especially those under 40 years old, is challenging. Dunn et al. reported a good DASH score and return to upper extremity activity after RHA for Mason III radial head fractures, terrible triad injuries, and fracture dislocation in an active-duty military population.[7] Yet, Sinha et al. reported favorable outcomes for ORIF regarding patient-related outcomes compared to RHA or radial head excision.[8] Other authors have reported similar contrasting results when assessing clinical, functional, and radiographic outcomes of ORIF versus RHA by age. Notably, the complication profiles between the two surgical treatments differed.[9] Most recently, in younger patients aged less than 30, Walsh et al. found no difference in clinical outcomes or reoperation rates after ORIF for radial head fractures with >2 fragments versus <2 fragments.[10]

The constellation of these studies has made it challenging to decide when to perform ORIF versus RHA for surgically indicated radial head fractures. It is also unclear if younger patient age is associated with differences in surgical results after ORIF or RHA, or if outcomes of either technique vary in older versus younger patients. This study aimed to compare the results of RHA and ORIF in patients above and below an age threshold of 40. The primary outcome was the need for subsequent surgeries at a mid-term follow-up. The secondary outcomes were range

of motion (ROM) and radiographic indicators, including the stage of heterotopic ossification (HO), grade of arthritis, stem lucency, and capitellar erosion at short-term follow-up.

Material and methods

Study design and setting

This was a retrospective cohort study approved by the institutional review board of ████ ████████████. The institutional database was searched and all charts were manually reviewed to identify potential patients with radial head fractures treated (OTA/AO 2R1A/B/C) with RHA (uncemented prosthesis) or ORIF (plating and/or screw fixation) between January 2015 and September 2022 in 2 academic Level 1 trauma hospitals. The study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines. To ensure data accuracy, all data was manually collected by two independent researchers. A consensus was reached for all differences between the two independent researchers and two board certified orthopaedic hand and upper extremity surgeons.

Data collection

The institutional electronic medical record was searched for relevant current procedural terminology codes (Supplemental Table S1). Study data were collected and managed using REDCap electronic data capture tools hosted at ████████████████████████.

Subject selection criteria and independent variables

Patients who received treatment with either RHA or ORIF were included. Radial head fractures were typically indicated for surgical management when they were associated with elbow instability or a mechanical block to motion. Patients who were below 18 years of age, pregnant, had a previous ipsilateral elbow fracture, pathological fractures, insufficient documentation, radial head fractures prior to January 2015, those who underwent conservative

treatment or other surgical treatment, and those with a follow-up period of less than 3 months specifically for the elbow issue were excluded from the study (Figure 1). Sex, race, and hand dominance were also collected. At the time of surgery, age, smoking status, occupation, diagnosis of diabetes mellitus, diagnosis of inflammatory arthritis, and American Society of Anesthesiologists physical status were collected. The trauma mechanism was defined according to the Advanced Trauma Life Support guidelines.[11] Patients who did not meet the criteria for having sustained high-energy trauma were considered to have sustained low-energy trauma. Additionally, other injuries of the ipsilateral arm, radial head fracture type based on the modified Mason classification,[12] and concomitant lateral and medial collateral ligament injuries were collected. The characteristics of other fractures around the elbow and forearm, including proximal ulna fracture, coronoid fracture, terrible triad, Essex-Lopresti, and distal humerus fracture were also recorded.

Outcome measures

The primary clinical outcome was reoperation. The secondary outcomes were ROM and the radiographic indicators measured on the most recent radiograph. These included the stage of HO, the grade of arthritis, stem lucency, and capitellar erosion. The details of these classifications were described as follows:

The stages of HO were defined based on the classification system reported by Hastings et al.[13] Stage I involved elbow or forearm HO that could be demonstrated radiographically without functional limitation. Stage II was characterized by limitation in elbow extension-flexion and/or forearm rotation. Stage III referred to ankylosis of the particular articulation, whether the forearm, elbow, or both.

The severity of arthritis was determined based on the Broberg and Morrey grading system[14]: Grade 0, normal elbow joint; Grade 1, slight joint-space narrowing with minimum osteophyte formation; Grade 2, moderate joint-space narrowing with moderate osteophyte formation; and Grade 3, severe degenerative change with gross destruction of the joint.

The stem radiolucency was based on the number of zones around the stem[15.] No radiolucency referred to no radiolucent line in any zone. Mild radiolucency was defined as radiolucent lines occupied in one or two zones; moderate radiolucency was characterized as three to six involved zones; severe radiolucency was defined as seven involved zones (Figure 2).

Capitellar erosion was classified as present or not present. ROM, measured with a goniometer by the treating surgeon, was collected from the most recent visit note related to the elbow problem. Lastly, as not all reoperations affected the treatment outcome, the reoperations were divided by two independent hand surgeons into 2 groups: one where the reoperation may have negatively affected ROM and/or radiographic outcomes and a second group where the reoperation likely would not have had a significant effect on ROM or radiographic outcomes. Statistical analyses were performed on the first group. The follow-up interval for reoperations was defined as the most recent visit with any provider in the ▬▬▬▬▬▬▬▬▬ ▬▬▬, assuming that patients did not transfer care to another hospital. Missing data were described in the tables.

Statistical analysis

Data was reported as means ± standard deviations (SD) for normally distributed data, medians and interquartile ranges (IQR) for non-normally distributed data, and frequencies and percentages for categorical data. The normality of the data was assessed using histograms and

quantile-quantile plots. The cohort was subdivided into two groups: under 40 years old and greater than or equal to 40 years old based on empirical optimal cutpoint analysis (Supplemental Digital Content 1). The empirical optimal cutpoint for age was calculated using Liu's method.[16] To statistically compare the outcomes of the two surgical treatments in patients younger than 40 years and to analyze the differences in RHA between patients younger than 40 years and those 40 years and older, an Independent Samples t-test and one-way ANOVA for parametric data, Mann-Whitney U for non-parametric data, and Chi-square test for categorical variables were utilized. Multivariable regression analysis was performed to evaluate the independent associations between predictor variables (age, sex, smoking status, manual labor, diabetes mellitus, proximal ulnar fracture, terrible triad fracture, severity of radial head fracture, collateral ligament injury, hand dominance, and duration of follow-up) and the primary and secondary outcomes. Adjusted odds ratios, confidence intervals, and p-values were calculated for each variable in the model. A p-value of <0.05 was considered statistically significant. Analyses were performed only for groups consisting of at least 6 patients. The analysis was performed using Stata Statistical Software: Release 16 (StataCorp. 2019, College Station, TX: StataCorp LLC).

Results

Study Population Characteristics

The study included 32 patients in the RHA <40 years group (mean age 31 years, SD 5; 23 male), 96 in the RHA ≥40 years group (mean age 60 years, SD 11; 33 male), and 22 in the ORIF <40 years group (mean age 27 years, SD 6; 14 male)., with a mean age of 49±17 years. The patient characteristics are displayed in Table 1. There was no statistically significant difference in Mason fracture classification distribution between the 4 groups (Table 1, p>0.05). For this cohort of patients, the follow-up period with detailed documentation of joint range of motion was 11.1±11.9 months, while the follow-up period for radiographic assessment was 12.8±12.6 months.

Reoperations and Complications: Total cohort

For patients requiring reoperation, the time to reoperation occurred at 30.3±26.1 months. The most common reasons for reoperation affecting motion or imaging findings were mechanical locking or elbow stiffness (Table 2). Otherwise, the most common reason for reoperation was cubital tunnel release with or without anterior transposition (Supplemental Tables S2 and S3).

Patients who underwent arthroplasty (21/128, 16%) did not have a higher reoperation rate than those treated with ORIF (6/33, 18%) (p=0.104). There was no significant age difference between patients needing reoperation and those who did not, with mean ages of 47±16 and 50±17 years, respectively (p=0.983). Smokers showed a 4.48 times higher likelihood of reoperation when compared to non-smokers (p=0.035), patients with ulnar collateral ligament (UCL) injuries had 9.47 times higher odds of reoperation compared to those without UCL

injuries (p=0.033), and males had 5.35 times higher odds of reoperation compared to females (p=0.017) (Supplemental Digital Content 2).

RHA vs. ORIF in Patients <40 Years Old

<u>Reoperation rate:</u> In patients less than 40 years of age, the reoperation rate was 22% for RHA (n=7) and 14% for ORIF (n=3) (p=0.502). (Table 3). Among patients treated with RHA, one required revision due to stiffness from prosthesis overstuffing. Among patients treated with ORIF, one underwent an anconeus interposition arthroplasty due to arthritis, and one patient had a radial head resection due to symptomatic radial head deformity.

<u>ROM:</u> The ROM was comparable between the RHA and ORIF groups in patients < 40 years old with a median flexion-extension arc of 125° (108-135°) and 128° (110-135°) (p=0.79) and a median prono-supination of 145° (140-150°) and 150° (140-160°) (p=0.16), respectively.

<u>Post-traumatic arthritis:</u> Arthritis was more common in patients who underwent RHA (n=18, 57%) than those who underwent ORIF (n=6, 27%) (p=0.047) (Table 3). The follow-up period for radiographic assessment in the RHA <40 years group was 12.7±10.4 months, and in the ORIF <40 years group, 7.6±4.6 months (p=0.019). Subgroup analysis for modified Mason type 4 fractures showed a statistically significant difference in the presence of arthritis among patients younger than 40 years old: in the RHA group, 13 out of 21 patients (62%) developed arthritis, compared to only 1 out of 8 patients (13%) in the ORIF group (X^2(1)=5.66, p=0.017). Multivariable regression controlling for demographic factors, comorbidities, fracture characteristics, and follow-up duration, identified age as a significant predictor: each additional year of age was associated with a 2.79% increase in the odds of progressing to a higher grade of arthritis.. This result was marginally significant (p=0.052), indicating a potential age-related

influence on the progression of postoperative arthritis. Furthermore, the sex variable exhibited a statistically significant association with the progression of arthritis. Males had approximately 2.9 times higher odds of advancing to a higher grade of arthritis than females (p=0.002). When accounting for the types of occupations held by patients, specifically manual labor jobs, the odds ratio for gender decreased from 3.89 to 3.18, which represents an 18% reduction. This indicated that engaging in manual labor jobs served as a significant confounding variable in the association between sex and the progression of arthritis (Supplemental Digital Content 2). Furthermore, a subgroup analysis of patients with more than one year of follow-up for posttraumatic arthritis identified that a higher proportion of grade 1 or grade 2+3 arthritic changes was observed in the RHA group compared to the ORIF group (70% vs. 25%), although the difference did not reach statistical significance (Table 3).

RHA in Patients <40 versus ≥40 Years Old

Reoperation rate: The reoperation rate after radial head arthroplasty was not statistically different in the <40-year group (n=7, 22%) and the ≥40-year group (n=14, 15%) (p=0.41) (Table 4). Regarding the reason for reoperation, in the <40-year group, one patient had a revision of an RHA due to stiffness caused by overstuffing. In the ≥40-year group, one patient had an RHA revision due to overstuffing, and three patients had an RHA removal (two patients due to infection and one patient due to elbow deformity secondary to instability requiring lateral collateral ligament reconstruction) (Table 2).

ROM: The ROM was comparable between the groups with a median flexion-extension arc of 125° (108-135°) versus 125° (105-135°) (p=0.93) and a median prono-supination of 145° (140-150°) versus 150° (140-160°) (p=0.07), respectively.

<u>Stem lucency and post-traumatic arthritis:</u> Stem lucency was statistically significant in patients ≥40 years old (n=64, 67%) compared to patients <40 years old (n=17, 53%) (p=0.01). The rate of mild stem radiolucency in the <40 and ≥40-year groups was 53% and 50%, respectively. However, moderate and severe stem lucency rates in the <40 and ≥40-year groups were 0% and 17% (p=0.01), respectively.

Discussion

In this study, no significant differences were observed in the rate of reoperation after treatment with RHA or ORIF for an operative radial head fracture in patients above and below 40 years of age. Regarding secondary outcomes, for patients under 40 years, RHA was associated with a higher incidence of post-traumatic arthritis compared to ORIF (57% versus 27%, p=0.047), although it was possible that this was related to injury severity rather than treatment choice. Among those treated with RHA who were 40 years of age or older, the incidence of stem radiolucency was significantly higher compared to those who were younger (67% versus 53%, p=0.01). Based on these results, if a radial head fracture can be surgically repaired, ORIF may be a preferable treatment to RHA for younger patients. When a radial head fracture cannot be surgically repaired, older age patients treated with RHA showed a higher chance of stem radiolucency compared to younger patients, but outcomes were otherwise similar among all groups.

Postoperative complications and secondary surgeries are frequently associated with the concomitant injuries accompanying radial head fractures, rather than being directly influenced by the choice between RHA or ORIF as the surgical option.[10,17,18] For example, elbow stiffness and HO are associated with the severity of elbow trauma.[19,20] Similarly, in this study, reoperation was not independently associated with the choice of ORIF versus RHA, and no relation between reoperation and the choice of surgical treatment was identified in multivariable regression analyses.

Functional ROM for daily activity is defined as an elbow flexion-extension arc of 30-130° and forearm pronation-supination of 50-50°.[21] A recent systematic review by Davey et al. found that most patients regained functional ROM after RHA by a mean follow-up of 117

months.[22] Similarly, Ring et al. identified similar results, a mean arc of elbow motion of 119° (range, 75° to 140°) in Mason type 2 fractures and a mean arc of elbow motion of 111° (range, 40° to 130°) in Mason type 3 fractures after ORIF at an average follow-up of 58 months after injury.[23] In this study, most patients regained functional ROM regardless of age or choice of ORIF versus RHA.

Previous reported literature about short-term and mid-term outcomes has also shown that post-traumatic arthritis is a common complication after RHA.[18,24–27] However, these studies did not stratify by patient age, nor did they compare the outcomes of RHA to ORIF. The results of this study provided additional evidence suggesting that the incidence of postoperative arthritis may be comparable between patients under or over 40 years old treated with RHA, but rates of arthritis were higher in younger patients treated with RHA compared to ORIF.

Recent studies assessing stem lucency at long-term follow-up demonstrated that stem radiolucency was not associated with poorer clinical outcomes.[22,28,29] Even with cemented techniques, there was a high incidence of asymptomatic radiolucency.[30] Cemented techniques were also associated with a higher rate of complications.[31] The most likely reason for higher rates and grades of stem lucency in patients 40 years or older in this study was poorer bone quality.[32] Yet, stem radiolucency was not associated with ROM, reoperation rates, or post-traumatic arthritis. For this reason, radiographic findings such as stem radiolucency should be interpreted in the context of the patient's clinical symptoms to guide appropriate management. In addition, in cases where ORIF is not feasible, the results of this study support the use of RHA as a treatment modality.

This study had several limitations. First, there was a significant discrepancy in patient numbers between the groups, with most patients in the RHA group aged over 40. This may have

compromised the accuracy of detecting true effects or differences. Furthermore, due to the small sample sizes in the groups, all analyses between groups could not be performed. This imbalance potentially biased the interpretation of the results. Second, this was a retrospective study conducted at a tertiary trauma center. Patients with favorable recovery outcomes may have been lost to follow-up, potentially leading to incomplete data on elbow ROM and radiographic assessments. As a result, insufficient follow-up duration for some patients represented one of the major limitations of this study. For example, follow-up for RHA in patients younger than 40 years of age was slightly longer than for ORIF, and differential findings for post-traumatic arthritis may have been secondary to this. However, the overall size of difference in follow-up was small and therefore would be expected to have a smaller effect. Third, fractures that were more severely fragmented were treated with RHA, signifying selection bias. However, in younger patients, there appeared to be a preference for ORIF, as reflected in the findings. Fourth, preoperative evaluation of cartilage damage in the radiocapitellar joint was not routinely performed in patients with elbow trauma, and the condition of the capitellar cartilage was not consistently documented in surgical records. Consequently, it is unclear whether the increased incidence of postoperative arthritis or capitellar erosion in young patients who undergo RHA compared to those receiving ORIF was attributable to injury severity or long-term friction between the radial head prosthesis and the capitellum or if it existed preoperatively. Fifth, symptoms associated with stem lucency were not collected as these symptoms were difficult to characterize from the patient records and exam. Sixth, assessing elbow arthritis or stem radiolucency was difficult in cases of elbow stiffness, as the radiographs were not taken from 'ideal' angles. Considering that the rates of elbow ROM were similar between the two groups, systemic errors caused by the imperfect radiographs would have had a comparable impact on

both groups. Seventh, the recommendations based on the outcomes of this study must consider the surgeon's expertise, surgical technique, and the complexity of the fracture. Finally, the follow-up period for ROM and radiographic outcomes was approximately one year, following local practice patterns. However, extending the follow-up for physical examination and radiographic analysis presented implementation challenges.[21,33] However, with respect to reoperations, Laumonerie et al. recommended a minimum follow-up of 3 years,[34] which aligned with the follow-up timeframe of this study.

In conclusion, for patients younger than 40 years old, ORIF and RHA (based on surgeons' choice) demonstrated comparable outcomes regarding ROM, complications, and the need for reoperations. In younger patients, RHA was associated with a higher incidence of post-traumatic arthritis compared to ORIF, suggesting a preference toward treatment with ORIF in younger patients when surgical repair is achievable. In cases of radial head fractures where fragment salvage was unfeasible, patients treated with RHA, regardless of whether they were below or above 40 years of age, exhibited comparable short- and mid-term outcomes, but with an increased likelihood of stem radiolucency in older patients.

Supplement Table S1 --http://links.lww.com/JOT/C456

Supplement Table S2 --http://links.lww.com/JOT/C457

Supplement Table S3 --http://links.lww.com/JOT/C458

Supplemental Digital Content 1 --http://links.lww.com/JOT/C459

Supplemental Digital Content 2 --http://links.lww.com/JOT/C460

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Attachments

Figures

Figure 1 - Patient Flowchart Based on Inclusion and Exclusion Criteria

Figure 2 - Grading of Radiolucency Around the Stem According to the Number of Affected

Zones

Tables

Table 1 - Patient Characteristics

Table 2 - Reoperations That Compromised the Outcomes

Table 3 - Follow-Up Outcomes: RHA Treatment <40 Years and ORIF Treatment <40 Years

Table 4 - Follow-Up Outcomes: RHA Treatment <40 Years and RHA Treatment ≥40 Years

Supplements

Supplemental Table S1 - Current Procedural Terminology Codes

Supplemental Table S2 - Reoperations That Did Not Compromise the Outcomes

Supplemental Table S3 - Nonsurgical Complications

Supplemental Digital Content 1: Empirical Optimal Cutpoint

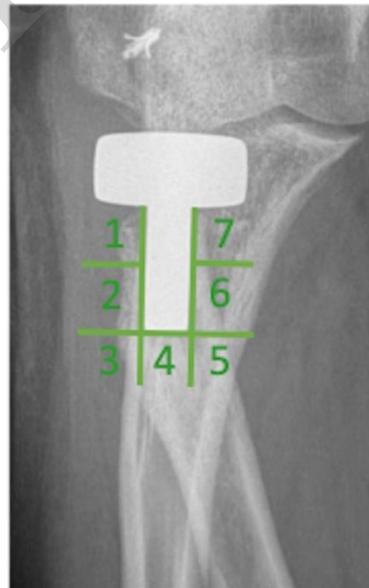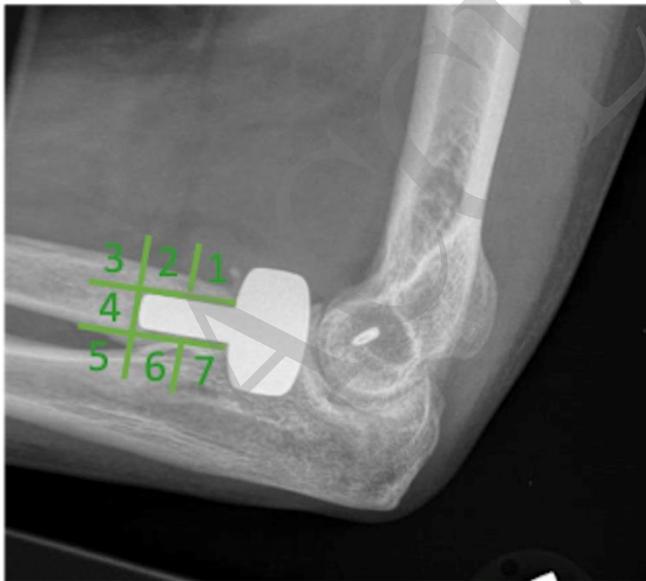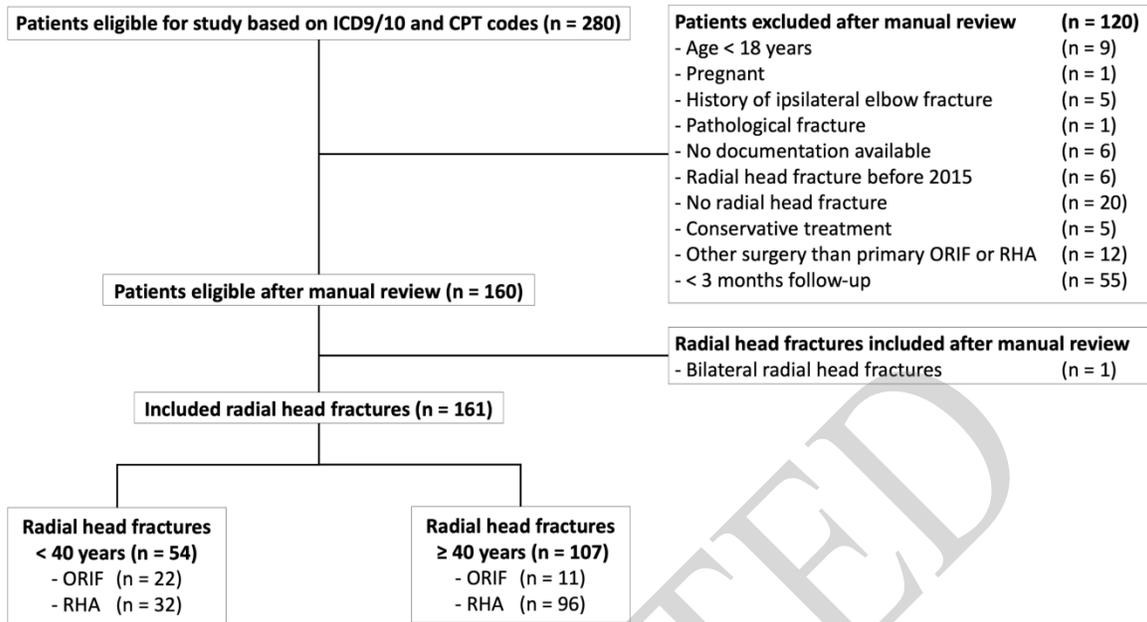Supplemental Digital Content 2: Multivariable Regression Analyses

	Total (n = 161)	RHA < 40 (n = 32)	RHA ≥ 40 (n = 96)	ORIF < 40 (n = 22)	ORIF ≥ 40 (n = 11)	P-value[#]*	P-value[§]*
Table 1 - Patient Characteristics							
Age (years), mean (SD)	49 (17)	31 (5)	60 (11)	27 (6)	54 (9)	**0.03**	**<0.01**
Male, n (%)	75 (47)	23 (72)	33 (34)	14 (64)	6 (55)	0.56	**<0.01**
Tobacco use, n (%)	20 (12)	4 (13)	13 (14)	2 (9)	1 (9)	**	**
Diabetes mellitus, n (%)	10 (6)	0 (0)	8 (8)	0 (0)	2 (18)	**	**
Inflammatory arthritis, n (%)	2 (1)	0 (0)	1 (1)	1 (5)	0 (0)	**	**
ASA classification, n (%)[a]							
1	34 (22)	18 (56)	8 (8)	7 (32)	1 (9)	0.10	**<0.01**
2	94 (59)	10 (31)	61 (64)	14 (64)	9 (82)	0.03	**<0.01**
3	30 (19)	4 (13)	24 (25)	1 (5)	9 (9)	**	**
Manual labor, n (%)[b]	34 (22)	9 (28)	14 (15)	7 (32)	4 (36)	1.00	0.11
Dominant hand affected n (%)[c]	67 (43)	14 (44)	39 (41)	10 (45)	4 (36)	1.00	0.84
Trauma mechanism, n (%)[d]						1.00	0.23
Low energy	123 (77)	22 (69)	76 (79)	15 (69)	10 (91)		
High energy	37 (23)	10 (31)	19 (20)	7 (32)	1 (9)		
Other trauma on ipsilateral hand, n (%)	19 (12)	2 (6)	14 (15)	3 (14)	1 (9)	**	**
Mason Classification, n (%)							
I	4 (2)	0 (0)	1 (1)	1 (5)	2 (18)	**	**
II	18 (11)	0 (0)	7 (7)	8 (36)	3 (37)	**	**
III	52 (32)	12 (38)	35 (36)	5 (23)	0 (0)	0.37	1.00
IV (associated with dislocation)	87 (54)	20 (63)	53 (55)	8 (36)	6 (54)	0.10	0.54
Isolated fracture	43 (27)	10 (31)	14 (15)	15 68	4 (36)	0.12	0.06
Isolated fracture + lateral collateral ligament injured	16 (10)	2 (6)	4 (4)	8 (36)	2 (18)	**	**
Terrible triad	74 (46)	19 (60)	44 (46)	6 (27)	5 (45)	0.28	0.22
Proximal ulna fracture	42 (26)	3 (9)	36 (38)	1 (5)	2 (18)	**	**
Coronoid fracture	24 (15)	2 (6)	20 (21)	1 (5)	1 (9)	**	**
Essex-Lopresti Injury	2 (1)	0 (0)	2 (2)	0 (0)	0 (0)	**	**
Additional distal humerus fracture	9 (6)	3 (9)	3 (3)	2 (9)	1 (11)	**	**
Lateral collateral ligament injured	93 (56)	20 (63)	52 (54)	13 (59)	8 (73)	1.00	0.54
Medial collateral ligament injured	8 (5)	4 (13)	2 (2)	1 (5)	1 (9)	**	**

Table 2 - Reoperations That Compromised the Outcome.*

Total missing number = 3[a], 6[b], 4[c], 1[d]; SD = standard deviation; RHA = radial head arthroplasty; ORIF = open reduction and internal fixation; [#]RHA < 40 years versus ORIF < 40 years; [§]RHA < 40 years versus RHA ≥ 40 years; *Chi-square test for categorical variables and independent samples T-test for continuous variables; **Groups too small for analysis

	RHA <40 (n = 32)		RHA ≥40 (n = 96)		ORIF <40 (n = 22)		ORIF ≥40 (n = 11)	
		N		N		N		N
Patients with one reoperation, n		6		14		5		4
Patients with two or more reoperations, n		2		3		0		0
Indications first reoperation, n	Locking/stiffness elbow	4	Locking/stiffness elbow	5	Locking elbow/stiffness elbow	5	Elbow subluxation/dislocation	2
	Heterotopic ossification	4	Elbow instability	2	Heterotopic ossification	1	Locking/stiffness elbow	1
	Elbow subluxation/dislocation	2	Coronoid malunion	2	Arthritis	1	Malunion radial head	1
	Coronoid malunion	1	Elbow subluxation/dislocation	2	Elbow instability	1	Malunion ulna	1
			Heterotopic ossification	1	Deformity radial head	1		
			Refracture ulna	1				
			Loose hardware proximal ulna	1				
First reoperation type, n	RHA Revision	1	RHA revision	1	Radial head removal	1	Revision and removal hardware ulna	1
	Capsulectomy	4	RHA removal	1	Anconeus interposition arthroplasty	1	RHA placement	1
	Excision heterotopic ossification	4	RHA replacement	1	Capsulectomy	3	Lateral collateral ligament repair	1
	IJS placement	2	Capsulectomy	4	Manipulation	1	Hardware removal radial head	1
	Lateral collateral ligament repair	2	Removal ORIF proximal ulna	4	Excision heterotopic ossification	1	ORIF Ulna	1
	ORIF coronoid	1	IJS placement	2	Lateral collateral ligament repair	1		
			IJS removal	2	Removal ORIF proximal ulna	1		
			Excision heterotopic ossification	1				
			Lateral collateral ligament repair	1				
			Ulna osteotomy	1				
			Revision ORIF of proximal ulna	1				
			Coronoid bone graft	1				
			External fixation	1				
			Medial collateral ligament repair	1				
			ORIF coronoid	1				

Table 2 - Reoperations That Compromised the Outcome (Continued).								
	RHA <40 (n = 32)		RHA ≥40 (n = 96)		ORIF <40 (n = 22)		ORIF ≥40 (n = 11)	
		N		N		N		N
Indications two or more reoperations, n	Elbow instability	2	Infection	3				

	Locking/stiffness	2	New distal humerus fracture	1				
	IJS failure	1	Elbow instability	1				
			Nonunion ulna	1				
			IJS failure	1				
Two or more reoperations type, n	IJS placement	2	RHA removal	2				
	IJS placement contralateral side	1	ORIF distal humerus	1				
	Lateral collateral ligament repair	1	Revision IJS	1				
	Removal ORIF proximal ulna	1	Lateral collateral ligament repair	1				
	IJS removal	1	ORIF ulna	1				
			IJS removal	1				
			Removal hardware ulna	1				

RHA = radial head arthroplasty; ORIF = open reduction and internal fixation; IJS = internal joint stabilizer; *negatively affected ROM and/or radiographic outcomes

Table 3 - Follow-Up Outcomes: RHA Treatment <40 Years and ORIF Treatment <40 Years				
	Total (n = 54)	RHA (n = 32)	ORIF (n = 22)	P-value**
Reoperations that compromised the outcome*, n (%)	10 (19)	7 (22)	3 (14)	0.50
Postoperative heterotopic ossification, n (%)	26 (48)	18 (56)	8 (36)	0.18
Postoperative heterotopic ossification with limitation in ROM, n (%)	4 (7)	4 (13)	0 (0)	0.14
Postoperative arthritis, n (%)				**0.047**
Grade 0	30 (56)	14 (44)	16 (73)	
Grade 1	19 (35)	13 (41)	6 (27)	
Grade 2 + 3	5 (9)	5 (16)	0 (0)	
Follow-up post-operative arthritis (years), mean (SD)	0.81 (0.75)	0.98 (0.87)	0.55 (0.38)	0.45
Postoperative arthritis with follow up >1 year, n (%)***				0.28
Grade 0	6 (43)	3 (30)	3 (75)	
Grade 1	6 (43)	5 (50)	1 (25)	
Grade 2 + 3	2 (14)	2 (20)	0 (0)	
Flexion-extension arc (degrees), median (IQR)	125 (110-135)	125 (108-135)	128 (110-135)	0.79
Prono-supination arc (degrees), median (IQR)[a]	150 (140-150)	145 (140-150)	150 (140-160)	0.16

[a]Missing number = 3; RHA = radial head arthroplasty; ORIF = open reduction and internal fixation; IQR = interquartile range; ROM = range of motion; * negatively affected ROM and/or radiographic outcomes; **Chi-square test for categorical variables and independent samples T-test for continuous variables; *** total = 14

	Total (n = 128)	RHA < 40 (n = 32)	RHA ≥ 40 (n = 96)	P-value**
Table 4 - Follow-Up Outcomes: RHA Treatment <40 Years and RHA Treatment ≥40 Years				
Reoperations that compromised the outcome*, n (%)	21 (16)	7 (22)	14 (15)	0.41
Postoperative heterotopic ossification, n (%)	63 (49)	18 (56)	45 (47)	0.41
Postoperative heterotopic ossification with limitation in ROM, n (%)	11 (9)	4 (13)	7 (7)	0.47
Post-operative arthritis, n (%)				0.34
Grade 0	46 (36)	14 (44)	32 (33)	
Grade 1	65 (51)	13 (41)	53 (55)	
Grade 2 + 3	16 (13)	5 (16)	11 (11)	
Follow-up post-operative arthritis (years), mean (SD)	0.98 (1.05)	0.98 (0.87)	0.99 (1.10)	0.27
Postoperative arthritis with follow up >1 year, n (%)***				0.71
Grade 0	9 (21)	3 (30)	6 (18)	
Grade 1	25 (58)	5 (50)	20 (61)	
Grade 2 + 3	9 (21)	2 (20)	7 (21)	
Postoperative stem lucency, n (%)				**0.01**
No	43 (34)	15 (47)	28 (29)	
Mild	65 (51)	17 (53)	48 (50)	
Moderate + severe	16 (13)	0 (0)	16 (17)	
Postoperative capitellar erosion, n (%)	31 (24)	5 (16)	26 (27)	0.24
Flexion-extension (degrees), mean/median (SD/IQR)[a]	123 (105-135)	125 (108-135)	125 (105-135)	0.93
Prono-supination arc (degrees), mean/median (SD/IQR)[b]	150 (140-150)	145 (140-150)	150 (140-160)	0.07

Total missing number = 4[a], 12[b]; RHA = radial head arthroplasty; SD = standard deviation; IQR = interquartile range; ROM = range of motion; * negatively affected ROM and/or radiographic outcomes; **Chi-square test for categorical variables and independent samples T-test for continuous variables; *** total = 43