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Outcomes after reverse shoulder arthroplasty for the treatment of glenohumeral osteoarthritis in patients under and over 70 years of age: a propensity score-matched analysis

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Introduction: As reverse shoulder arthroplasty (RSA) continues to grow in popularity for the treatment of glenohumeral osteoarthritis (GHOA) with an intact rotator cuff, it becomes increasingly important to identify factors that influence postoperative outcome. Although recent studies have demonstrated excellent postoperative range of motion and patient-reported outcome scores following RSA for GHOA, there continues to be surgeon hesitation to adopt RSA as a viable treatment in the younger patient population due to greater functional demands. In this study, we sought to determine the effect of age on clinical outcomes following RSA for GHOA through a comparison of patients over and under the age of 70.
Methods: A retrospective review of prospectively collected data from an institutional registry was performed. Propensity score matching was utilized to match patients under the age of 70 (U-70) to those over 70 (O-70) in a 1:1 ratio based on sex, body mass index (BMI), preoperative ASES score, preoperative active forward elevation (FE), Walch classification, and American Society of Anesthesiologists comorbidity score. Clinical outcomes obtained preoperatively and at a minimum of 2 years postoperatively consisted of Visual Analog Scale (VAS) for pain, Single Assessment Numeric Evaluation (SANE) score, and American Shoulder and Elbow Surgeons (ASES) score, as well as active (FE), internal rotation, and external rotation. Descriptive statistics and univariate analysis were performed to compare cohorts.
Results: After matching, each cohort consisted of 66 patients with similar mean follow-up periods (U-70, 28.1 $\pm$ 7.5 months vs. O-70, 27.4 $\pm$ 7.5 months; $P = .887$). Mean age of the U-70 cohort was 66.2 $\pm$ 3.3 while the O-70 cohort had a mean age of 75.3 $\pm$ 3.8. Both groups demonstrated significant improvement in VAS, SANE, and ASES scores, as well as active range of motion in all planes. The only significant difference between cohorts was greater postoperative FE in younger patients (143 $\pm$ 16° vs. 136 $\pm$ 15°; $P = .017$), though the baseline-to-postoperative improvement in FE was similar between cohorts (50 $\pm$ 29° vs. 43 $\pm$ 29°, $P = .174$).
Conclusion: RSA is a successful surgical treatment for GHOA regardless of age. Aside from greater postoperative FE in younger patients, there were no other differences in clinical outcomes between younger and older patients in this retrospective analysis, which compared patients who were matched by sex, BMI, and Walch classification, among other factors. Based on our results, 70 years of age should not be used as a threshold in preoperative counseling when determining whether a patient with GHOA with an intact rotator cuff is indicated for reverse shoulder arthroplasty.

This study received approval from the New England Baptist Hospital Institutional Review Board (Protocol #1853659).

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The incidence of shoulder arthroplasty has increased significantly in recent years and is expected to continue to increase over the next several years, beyond the projections for total hip and knee arthroplasty[32] Most of this increase can be attributed to reverse shoulder arthroplasty (RSA),[3,22,32] for which the incidence nearly tripled between 2012 and 2017, while the incidence of anatomic total shoulder replacement experienced only a 37% increase over the same period.[3]

RSA is increasingly being utilized for expanded indications beyond rotator cuff arthropathy (RCA), most commonly primary glenohumeral osteoarthritis (GHOA) with an intact rotator cuff.[5,15,18,21,31,33] As of 2017, 33% of RSAs were being performed for primary osteoarthritis, second only to RCA (44%).[3] Recent evidence has shown excellent results after RSA in patients with intact rotator cuffs, comparable to that of TSA.[13,18,21,31,33] Similar clinical outcomes have been especially evident between the 2 implant systems in patients over the age of 70.[34] Due to the comparable clinical outcomes between TSA and RSA for GHOA, coupled with the concern for anatomic glenoid component loosening and secondary rotator cuff failure[10,17,35] which may result in higher rates of revision surgery,[6,20,21] RSA is increasingly being considered in the setting of GHOA in older patients.

Some previous evidence suggests that RSA in younger patients does not achieve the same results as when performed in older patients. Otto et al,[19] reported a series of patients under 55 years of age, with an average postoperative American Shoulder and Elbow Surgeons (ASES) score of 58.6, lower than that generally reported for most cases of RSA.[26] However, this cohort involved a wide variety of diagnoses, including failed rotator cuff repairs and fractures, for which outcomes tend to be worse than those performed for GHOA.

There is currently limited clinical evidence to support age as a determining factor in the choice of shoulder arthroplasty. Surgeons seem to arbitrarily and anecdotally use age as a cutoff to decide between TSA and RSA when treating patients with primary GHOA, due to the notion that younger patients will have poorer outcomes. The purpose of this study was to evaluate outcomes and complications in a matched series of consecutive patients undergoing RSA for GHOA above or below the age of 70. We hypothesized that patients under the age of 70 would have similar patient-reported outcome measures (PROMs) and range of motion (ROM) as patients above the age of 70.

Methods

Patient selection

Following approval from the institutional review board (IRB), a retrospective review was performed using a prospectively maintained institutional database with greater than 75% overall follow-up [Outcomes Based Electronic Research Database (OBERD); Columbia, MO, USA]. Consecutive patients who had undergone primary reverse shoulder arthroplasty between 2015 and 2020 were identified. Patients were included if they underwent a primary RSA for the treatment of GHOA in the presence of an intact rotator cuff, had a minimum clinical follow-up of 2 years, had complete preoperative and postoperative functional outcomes scores, and had accessible preoperative computed tomography [CT] imaging to assess glenoid morphology according to the modified Walch classification system.[2] Patients were excluded if RSA was performed for reasons other than primary GHOA, there was a documented rotator cuff tear preoperatively or intraoperatively, they had incomplete clinical follow-up, or they had a history of ipsilateral shoulder surgery other than an arthroscopic debridement. All surgeries were performed by a single high-volume fellowship-trained shoulder and elbow surgeon.

Matching

The patients that met the inclusion and exclusion criteria were then propensity score-matched in a 1:1 ratio to produce 2 cohorts: patients 70 years of age or younger (U-70) and patients over 70 years of age (O-70). The propensity scores were generated with use of a logistic regression model method that incorporated sex, Walch glenoid morphology, American Society of Anesthesiologists (ASA) comorbidity score, body-mass index (BMI), preoperative ASES score, and preoperative forward elevation (FE) as covariates. The matching process was executed utilizing a greedy, nearest-neighbor matching algorithm, without replacement.[7] A caliper was specified for acceptable matches to eliminate the risk of making poor matches if the closest eligible neighbor was far away. The caliper was set as 0.2 times the standard deviation (SD) of the logit of the propensity scores among the entire population. Previously, 0.2 to 0.5 times the standard deviation of the logit of the propensity score has been experimentally demonstrated as an appropriate range for the caliper to effectively control for variance, with precision increasing alongside decreasing values.[7]

Surgical technique

The senior surgeon (A.J.) performed all RSAs, with the patient under general anesthesia in a beach chair position. An interscalene block was administered preoperatively for all patients. A deltopectoral approach was utilized in all cases. When intact, the biceps tendon was tenodesed to the pectoralis major tendon. The subscapularis was peeled in all cases and repaired using a combination of simple and Mason-Allen transosseous sutures. Intraoperative visual assessment of the rotator cuff was performed to confirm its integrity in all cases. All patients received the same prosthetic implant (AltiVate Reverse; DJO Surgical, Austin, TX, USA). Glenosphere size was 32 minus 4-mm lateralized for all female patients, while a 36-mm neutral lateralized glenosphere was used in all males as per the senior author's preference. An uncemented inlay standard length humeral component was implanted in all patients. Glenoid surface reaming was performed to match the backside of the glenoid component in all cases, with preferential reaming of the anterior glenoid for excessive posterior wear and to partially correct overall version. Glenoid bone grafting was not performed in any patient. Postoperative rehabilitation was similar for all patients, which involved restricted shoulder range of motion in a simple sling without an abduction pillow for the first six weeks with progressive range of motion and strengthening using a physician-directed home therapy protocol beginning at 2 weeks postoperatively. Active and active-assisted forward flexion began after 2 weeks, and external and internal rotation were permitted after 6 weeks. Strengthening and a progressive return to activities were typically permitted after 3 months.

Clinical outcome assessment

Basic patient demographics, including age, sex, and BMI, were retrieved from the electronic medical record. Clinical examination was performed at the patients' preoperative visit closest to the date of surgery and at the most recent postoperative visit by the senior author. Active shoulder ROM was assessed. FE and external rotation (ER) with the arm at the side were assessed using a goniometer. Internal rotation (IR) was measured by the highest vertebral level of the spine that the patient could reach with their thumb. Levels of IR were classified using a point system described by Triplet and colleagues: 0 for the buttocks/hip, 1 for the sacrum, 2 for L5, 3 for L4, and so on adding an additional point for each vertebrae reached.[12] PROMs, including the ASES score, Single Assessment Numeric Evaluation (SANE) score and visual analog scale (VAS) for pain, were prospectively collected at preoperative appointments and at the most recent follow-up. Complications and the need for revision surgery were prospectively recorded.

Radiographic evaluation

Preoperative true anteroposterior and axillary radiographs and CT imaging were available for all patients included in the final cohort. Preoperative glenoid morphology was assessed in a blinded fashion by 2 fellowship-trained shoulder and elbow surgeons following the modified Walch classification system.[2] In instances where consensus was not achieved by the 2 observers, the senior author (A.J.) determined final glenoid classification. The most recent postoperative radiographs at a minimum of 2 years after surgery were evaluated by the senior author for radiolucent lines around the hardware, gross component loosening, hardware fracture, and any other overt complications.

Statistical analysis

Descriptive statistics were performed for each cohort separately and expressed as mean and standard deviation (SD), median and interquartile range (IQR), or number and percentage of group when appropriate based on data type and distribution. Univariate analysis was performed to compare baseline demographics, comorbidities, and clinical outcomes between cohorts using T-test, Mann–Whitney U test, Chi-Squared test, and Fisher Exact test, as indicated by the data type and distribution. Improvements in ASES were assessed using the minimal clinically important difference (MCID) (10.3 $\pm$ 3.3) and substantial clinical benefit (SCB) (25.9 $\pm$ 2.9) thresholds, as calculated by Simovitch and colleagues.[27,28] All statistical analyses utilized an alpha-risk level of 0.05 to estimate significance. All statistical analyses were performed using R statistical software (version 4.2.2; R Foundation for Statistical Computing).

Results

The initial query identified 291 patients who had undergone RSA during the study period and met the inclusion and exclusion criteria, all of whom were included in subsequent propensity-score matching as outlined in the methods. The final matched cohort included 132 patients (66 in each group) with a mean duration of follow-up of 28.1 $\pm$ 7.5 months and 27.4 $\pm$ 7.5 months for the U-70 and O-70 cohorts, respectively (P = .887). Mean age of the U-70 cohort was 66.2 $\pm$ 3.3 while the O-70 cohort had a mean age of 75.3 $\pm$ 3.8. There were no significant differences in sex (female, U-70: n = 36, 54.5% vs. O-70: n = 43, 65.2%; P = .287), BMI (U-70: 32.0 $\pm$ 7.1 vs. O-70: 30.8 $\pm$ 5.7; P = .261), ASA comorbidity score (P = .682), Walch classification (P = .385), or history of prior surgery, all of which were arthroscopic debridements (P = .092). Aside from hypertension, which was more prevalent in the older group (n = 55, 83.3% vs. n = 34, 51.5%; $P < .001$), there were no other significant differences in comorbidity proportions ($P > .05$) (Table I).

No significant differences were found between cohorts in terms of baseline or final VAS scores (P = .435 and P = .667, respectively), ASES scores (P = .846 and P = .852, respectively) or SANE scores (P = .687 and P = .489, respectively). In addition, baseline-to-postoperative changes in PROMs did not significantly differ between groups (VAS, P = .441; ASES, P = .865; SANE, P = .206) (Table II). The MCID for ASES was achieved by 64 patients (97.0%) in the U-70 cohort and 65 patients (98.5%) in the O-70 cohort ($P > .999$). The SCB for ASES was achieved by 59 patients (89.4%) in the U-70 cohort and by 58 patients (87.9%) in the O-70 cohort ($P > .999$).

Baseline active ROM was similar between both cohorts in all planes measured. Both cohorts experienced statistically significant baseline-to-postoperative improvements in all planes of motion. Patients in the U-70 cohort had greater

Table I Demographics comparision between patients younger and older than 70

Parameter	U-70 $n = 66$	O-70 $n = 66$	P value
Age	66.2 ± 3.3	75.3 ± 3.8	<.001*
Female sex	36 (54.5%)	43 (65.2%)	.287
Glenoid Walch classification			
A1	23 (34.8%)	22 (33.3%)	.385
A2	7 (10.6%)	5 (7.6%)	
B1	5 (7.6%)	3 (4.5%)	
B2	14 (21.2%)	22 (33.3%)	
B3	13 (19.7%)	14 (21.2%)	
C	1 (1.5%)	0 (0%)	
D	3 (4.5%)	0 (0%)	
BMI	32.0 ± 7.1	30.8 ± 5.7	.261
ASA			
2	52 (78.8%)	49 (74.2%)	.682
3	14 (21.2%)	17 (25.8%)	
Follow-up (mo)	28.1 ± 7.5	27.4 ± 7.5	.887
History of prior ipsilateral shoulder surgery	18 (27.3%)	9 (13.6%)	.092
Complications	3 (4.5%)	4 (6.1%)	>.999
Smoking status			
Never	27 (40.9%)	33 (50%)	.183
Previous	32 (48.5%)	29 (43.9%)	
Current	5 (7.6%)	1 (1.5%)	
Diabetes			
None	56 (84.8%)	55 (83.3%)	>.999
Type 1	1 (1.5%)	1 (1.5%)	
Type 2	9 (13.6%)	10 (15.2%)	
Depression	22 (33.3%)	15 (22.7%)	.245
Hypertension	34 (51.5%)	55 (83.3%)	.001*
Hypercholesterolemia	17 (25.8%)	23 (34.8%)	.344
Rheumatoid arthritis/inflammatory arthritis	4 (6.1%)	3 (4.5%)	>.999
Thyroid disorder	10 (15.2%)	16 (24.2%)	.274

U-70 Cohort, 70 years old or younger; *O-70 Cohort*, over 70 years old; *BMI*, body mass index; *ASA*, American Society of Anesthesiologists comorbidity score.

$x \pm s$ represents mean ± standard deviation; n (%) represents number and percentage of group.

* Designates statistical significance with alpha risk set at 0.05.

postoperative active FE (143° ± 16 vs. 136° ± 15; $P = .017$). A total of 37 patients (56%) in the O-70 cohort achieved active FE over 135°, compared to 52 (78.8%) in the U-70 group ($P = .009$). Postoperative active ER (56° ± 17 vs. 53° ± 18; $P = .309$) and IR (2.7 ± 2.1 levels vs. 2.8 ± 2.1 levels; $P = .604$) did not significantly differ between the 2 groups, nor did the baseline-to-postoperative improvement in both (ER $P = .243$; IR $P = .877$) (Table II).

Complications occurred in 2 patients in the U-70 cohort (3.0%) and 4 patients in the O-70 cohort (6.1%) ($P > .999$). Complications in the older cohort included an acromial stress fracture, a greater tuberosity fracture discovered on the first postoperative visit, postoperative cubital tunnel, and an intensive care unit admission during their inpatient stay following surgery, while the younger cohort had an intraoperative glenoid fracture and a traumatic baseplate failure. The patient diagnosed with baseplate failure was the only patient in the entire study cohort with any radiolucent lines, gross component loosening, or hardware fracture evident on postoperative radiographs at final follow-up. No patients in either group included in the final matched cohort were revised after the initial procedure.

Discussion

The present study demonstrates that patients treated with RSA for GHOA have good outcomes, regardless of age. Both cohorts in this study, under and over 70 years of age, had similar improvement in terms of pain relief, ROM, and PROMs after a minimum follow-up of 2 years after surgery. Younger patients did have slightly greater FE at final

Table II Clinical outcomes comparision between patients younger and older than 70

Parameter	U-70	O-70	*P* value
	n = 66	*n* = 66	
Pain			
Preoperative	6.1 ± 2.4	6.4 ± 2.3	.435
Postoperative	0.8 ± 1.5	0.8 ± 1.6	.667
Change	−5.3 ± 2.6	−5.6 ± 2.4	.441
SANE			
Preoperative	31.5 ± 22.0	30.1 ± 19.8	.687
Postoperative	84.8 ± 21.2	89.5 ± 14.4	.489
Change	53.2 ± 32.6	59.4 ± 22.5	.206
ASES			
Preoperative	33.7 ± 16.2	33.2 ± 15.8	.846
Postoperative	84.9 ± 16.2	85.0 ± 14.8	.852
Change	51.2 ± 20.2	51.8 ± 20.8	.865
Forward elevation			
Preoperative	93 ± 24	93 ± 26	.932
Postoperative	143 ± 16	136 ± 15	.017*
Change	50 ± 29	43 ± 29	.174
External rotation			
Preoperative	26 ± 13	27 ± 15	.609
Postoperative	56 ± 17	53 ± 18	.309
Change	30 ± 18	26 ± 21	.243
Internal rotation			
Preoperative	0.6 ± 1.1	0.7 ± 1.1	.391
Postoperative	2.7 ± 2.1	2.8 ± 2.1	.604
Change	2.1 ± 1.8	2.1 ± 2.0	.877

U-70 Cohort, 70 years old or younger; *O-70 Cohort*, over 70 years old; *SANE*, Single Assessment Numeric Evaluation; *ASES*, American Shoulder and Elbow Surgeons score.
Data represented as mean ± standard deviation.
* Designates statistical significance with alpha risk set at 0.05.

follow-up compared to older patients, which was the only significant difference between the cohorts.

Improved designs and technique for implantation of RSA over recent years have significantly improved postoperative clinical outcomes and lowered complication incidence, especially with a preoperative diagnosis of primary GHOA.[18,21,33] Thus, the incidence of RSA increased in the USA from 7.3 to 19.3 cases per 100,000 persons between 2012 and 2017, a number that is expected to expand.[3] RSA utilization has grown at an exponential rate compared to that of TSA during this time, as well as hemiarthroplasties, which have decreased in use. Unsurprisingly, the number of surgeons preforming RSA has also increased at a similar rate.[6]

TSA is still considered by some the gold standard for treating GHOA, especially in the younger population.[8,14,29,30] While TSA has led to better postoperative ROM than RSA in select studies, especially internal rotation, PROMs tend to be very similar between the 2 surgeries.[13] Wright et al[34] did not observe any differences in PROMs or ROM between patients over 70-yearsold receiving RSA and TSA at short-term follow-up. We speculate that some surgeons continue to subscribe to the philosophy that RSA should be reserved for the older patient as a primary, conclusive procedure while initial TSA implantation is optimal for the younger patient with greater functional demand, which can more readily be revised to an RSA in the event of failure during the course of the patient's lifespan. Although this rhetoric is intuitive in thought, multiple studies have revealed a higher risk of revision in TSA, including a recent retrospective, matched cohort study performed by Polisetty and colleagues, which reported a cumulative revision rate of 2.4% for TSA compared to no revisions for RSA.[21] The 10-year revision-free survival rate for primary RSA was most recently reported by Chelli et al to be 91.0% within a group of 1282 shoulders. Of significance, the group studied had indication heterogeneity and just 8.9% of all patients were treated for GHOA. The current literature demonstrates superior clinical outcomes and a lower complication incidence after RSA for GHOA compared to other indications,[26] and it can therefore be postulated that RSA implanted into an osteoarthritic shoulder likely results in greater longevity compared to other indications. As such, surgeons have become less reluctant to treat younger patients with GHOA with RSA given its largely similar, if not greater survivorship compared to TSA for GHOA, which has been reported between 89 – 100% at 10-year follow-up in previous survivorship studies.[9,11,12,23,24,25]

There were few significant differences between the 2 cohorts in our study. We found patients in the U-70 cohort demonstrated significantly greater postoperative FE compared to those in the O-70 cohort (143° ± 16 vs. 136° ± 15; P = .017). McClatchy et al[16] observed lower FE in patients with RSA with lower deltoid muscle volume. Hence, the difference in postoperative FE between cohorts in our study could possibly be explained by the older patients having age-related muscle atrophy. Although statistically significant, this difference has questionable clinical significance as PROMs were very similar amongst the 2 cohorts. The baseline-to-postoperative improvement (U-70: 51.2 ± 20.2 vs. O-70: 51.8 ± 20.8; P = .865) and postoperative ASES (U-70: 84.9 ± 16.2 vs. O-70: 85.0 ± 14.8; P = .852) were nearly identical between cohorts. The ASES score is based on a validated questionnaire that incorporates both a patient's pain level and an assessment of their shoulder function through numerous survey questions, though the questions are standardized and cannot be tailored towards the individual's lifestyle. To control for this limitation, other methods for measuring clinical outcome are used, including the SANE score, which is a patient's subjective assessment of their function as a percentage of 100. Interestingly, the average SANE score was similar between cohorts (U-70: 84.8 ± 21.2 vs. O-70: 89.5 ± 14.4; P = .489), demonstrating that younger patients do not have an inferior perception of their postoperative state relative to that of older patients, even given their greater functional demands.

As noted above, there was no statistically significant difference between the complication rates of the younger and older cohorts. Despite a reported baseplate failure in the U-70 cohort, the patient decided against revision surgery. Age has been demonstrated in previous studies to have little to no effect on risk of baseplate failure. Bitzer and colleagues[4] reported a 3.0% rate of aseptic baseplate loosening through a review of 202 primary and revision RSAs and found no difference in age between the patients who failed and those who did not (P = .267). The only case of an acromial stress fracture was identified in the O-70 cohort in our study. Previous studies have determined that this complication, which is often associated with inferior results, is more common in the older population. It was reported by Mahendraraj et al[1] that the risk of acromial stress fracture increases by 2% for every year older a patient is at the time of surgery. To truly glean whether patients above or below a certain age threshold are more at-risk of postoperative complication, future studies should increase follow-up duration and expand sample sizes to more accurately assess patient final disposition and population incidence.

This study has several strengths. Unlike previous cohort studies that compare shoulder arthroplasty outcomes between different age groups, our study utilized propensity score matching to control for baseline differences using the following factors: sex, Walch glenoid morphology, ASA comorbidity score, BMI, preoperative ASES score, and preoperative FE. Even when matched by all the factors listed above, sample size in each cohort was greater than in previous publications investigating similar topics. Although this was a retrospective analysis, all clinical outcome data were collected prospectively, limiting recall bias. Lastly, observer biases were controlled for during radiographic evaluation by blinding the observers from clinical outcome data.

However, this study is not without limitations. This was a single surgeon's experience and therefore may not apply to the general population. Another important limitation was the minimum follow-up of only 2 years. As complications and the need for revision surgery are more likely to occur with time, longer follow-up is needed to determine true incidence and differences between younger and older patients. It should be acknowledged that since the senior author was the sole reviewer of postoperative imaging, there is a possible bias in reporting radiographic findings. Although clinical outcome data were collected prospectively, the retrospective nature of data curation using a patient registry may introduce selection biases, which we attempted to control through matching. Lastly, no a-priori power analysis was used to determine the sample size in this study. As such any differences that were not statistically significant could potentially exist as a result of limited statistical power.

We present a comprehensive analysis using a large consecutive series of patients under and over 70 years of age who have undergone RSA for GHOA. This is the only study, to the best of our knowledge, that directly compares those under and over 70 who have undergone RSA using 2 nearly identical cohorts, apart from age, as produced through propensity score matching. Our belief is that this study presents strong evidence that age should not be used in isolation of other factors when deciding if RSA is the correct surgical treatment for a patient with GHOA.

Conclusion

RSA is a successful surgical treatment for GHOA regardless of age. Aside from slightly greater postoperative FE in younger patients, there were no other differences in clinical outcomes between younger and older patients in this retrospective analysis, which compared patients who were matched by sex, BMI, and Walch classification, among other factors. Based on our results, 70 years of age should not be used as a threshold in preoperative counseling when determining whether a patient with GHOA with an intact rotator cuff is indicated for reverse shoulder arthroplasty.

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