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Obesity is associated with improvement in functional outcome but lower internal rotation after reverse shoulder arthroplasty

Anup Shah, MD[a], Youssef Galal, BS[a,*], Brian C. Werner, MD[b], Reuben Gobezie, MD[c], Patrick J. Denard, MD[d], Evan Lederman, MD[a]

[a]*Banner University Medical Group, University of Arizona College of Medicine – Phoenix, Phoenix, AZ, USA*
[b]*Division of Sports Medicine, Department of Orthopedic Surgery, University of Virginia School of Medicine, Charlottesville, VA, USA*
[c]*Gobezie Shoulder Institute, Beachwood, OH, USA*
[d]*Oregon Shoulder Institute, Medford, OR, USA*

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Background: The role of obesity as an independent risk factor for increased complications following reverse shoulder arthroplasty (RSA) continues to generate debate. While no standardized body mass index (BMI) cutoff values for shoulder arthroplasty exist, many surgeons are concerned about the potential for poor outcomes and decreased range of motion (ROM) in patients with a high BMI. The purpose of this study was to compare functional outcomes in obese and nonobese patients preoperatively and at short-term follow-up after RSA.

Methods: A retrospective review was performed of a prospectively maintained, multicenter database of primary RSAs performed by 14 surgeons between 2015 and 2019 with minimum 2-year follow-up. A total of 245 patients met the study criteria, including 111 obese (BMI >30) and 134 nonobese (BMI <30) patients. Patient-reported outcomes (PROs) as well as ROM measurements were compared between the 2 groups.

Results: At baseline, obese patients had significantly lower American Shoulder and Elbow Surgeons (36.6 vs. 42.0, $P = .014$), Western Ontario Osteoarthritis of the Shoulder scores (33.1 vs. 37.8, $P = .043$), external rotation at 90° (19° vs. 28°, $P = .007$), internal rotation (IR) spinal level (L5 vs. L4, $P = .002$), and belly press strength ($P = .003$) compared to the nonobese cohort. There were no statistical differences in 2-year outcomes (PROs, ROM, and strength) other than a worse IR (spinal level) in the low BMI group (L4 vs. L3, $P = .002$). In linear regression analyses controlling for confounding variables, increasing BMI was negatively correlated with preoperative external rotation (B = −0.591, $P = .034$) and preoperative IR spinal level (B = 0.089, $P = .002$). Increasing BMI was not correlated with postoperative external rotation at 90° (B = 0.189, $P = .490$) but was associated with worse postoperative IR by spinal level (B = 0.066, $P = .043$).

Conclusions: Obese patients have greater restrictions in external and internal rotation as well as American Shoulder and Elbow Surgeons and Western Ontario Osteoarthritis of the Shoulder scores at baseline prior to RSA. However, there are no major differences in postoperative PROs or ROM measurements between obese and nonobese patients apart from a worse active IR by spinal level in the obese group (L4 vs. L3, $P = .002$). This study suggests that an RSA procedure does not need to be restricted solely based on BMI.

Reverse shoulder arthroplasty (RSA) is the fastest growing shoulder arthroplasty procedure in the United States.[5] With advancements in implant design, surgical technique, and more predictable outcomes, indications for RSA continue to expand, including RSA consideration in obese patients, defined as a body mass index (BMI) more than or equal to 30.[2,3,19,25] Using the BMI classification for obesity (BMI >30), approximately 42% of the US population is considered obese.[11,18] While no standardized BMI cutoff values for shoulder arthroplasty exist, many orthopedic surgeons are concerned about the potential for poorer functional and clinical outcomes for patients with a high BMI.

Institutional review board approval from South Oregon Institutional Review Board (SO IRB #15-001).

*Corresponding author: Youssef Galal, BS, Banner University Medical Group, University of Arizona College of Medicine – Phoenix, 755 E McDowell Rd, Second Floor, Phoenix, AZ 85006, USA.

E-mail address: yshg@email.arizona.edu (Y. Galal).

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The role of obesity as an independent risk factor for increased complications following shoulder arthroplasty continues to generate debate. Increased BMI poses intraoperative challenges to orthopedic procedures due to difficulties in surgical exposure, longer operative times, and increased blood loss.[10] However, whether these intraoperative shoulder arthroplasty challenges affect postoperative range of motion (ROM) and clinical outcomes in comparison to nonobese patients is unknown due to conflicting data in the literature.[1,8,12,23]

Internal rotation (IR) post-RSA has received increased attention with the evolution from the Grammont-style prosthesis to more lateralized systems. While pain and forward flexion are consistently improved with medialized center of rotation systems, several authors have noted loss of IR.[4,16,20] Recently, Werner et al demonstrated improved active IR at 1 year with 6-8 mm of glenoid lateralization compared to 2 mm or less.[22] Both preoperative BMI and IR pose interesting challenges that could potentially impact postoperative outcomes; however, there is limited information on BMI as an independent risk factor for predicting IR post-RSA.

The purpose of this study is to compare clinical and functional outcomes in obese and nonobese patients both before and after RSA. We hypothesized that obese patients would have less IR post-RSA but obtain similar patient-reported outcomes (PROs) and the other ROM metrics compared to the nonobese group. This hypothesis was formed based on findings from recent studies that suggest that BMI is an independent predictor of IR and inversely related to the degree of IR.[7]

Methods and materials

Database and study patients

A retrospective review was performed of a prospectively maintained, multicenter database of RSAs performed by 14 surgeons between 2015 and 2019. Institutional review board approval and informed consent were obtained as part of the prospective study. Inclusion criteria were primary generalized osteoarthritis, preoperative PRO and ROM datapoints, postoperative PRO and ROM datapoints, and a minimum postoperative follow-up of 2 years. Exclusion criteria were revision RSA, acute or chronic fractures, avascular necrosis, history of infection, and Walch type C glenoids. A total of 245 patients met the study criteria, including 111 obese (BMI >30) and 134 nonobese (BMI <30) patients.

Demographics, clinical outcomes, and functional outcomes

The following baseline data were obtained from the database for all patients: age, sex, BMI, whether surgery was performed on the dominant arm, tobacco use, and presence of diabetes mellitus. Glenoid morphology was defined by the Walch classification. The following preoperative and 2-year postoperative outcome scores were recorded and compared: visual analog scale (VAS) pain score, American Shoulder and Elbow Surgeons (ASES) score, Western Ontario Osteoarthritis of the Shoulder (WOOS) index score, Single Assessment Numeric Evaluation score, and Veterans RAND 12 mental score. The following ROM data were gathered across 5 different parameters of glenohumeral joint motion in degrees as follows: active forward flexion, active ER at the side, active external rotation at 90° of abduction (ER90), and active IR at 90°, as well as active IR estimated as the highest spinal level reached. In addition, data from the belly press strength test were collected with a dynamometer.

Surgical technique

A standard deltopectoral approach was used in all cases. A subscapularis peel or osteotomy was used followed by a 135° humeral head cut between 20° and 30° of retroversion. The glenoid was prepared and reamed, a baseplate was placed (Universal Glenoid or Modular Glenoid System; Arthrex Inc., Naples, FL, USA). Based on preoperative planning, soft-tissue tensioning, and surgeon preference, a standard or lateralized baseplate and glenosphere were used. Baseplate options included a 0-mm, +2-mm, or +4-mm option and the glenosphere was a 0-mm or +4-mm option, ranging from 0 to 8 mm of lateralization. Lateralization was based on the paleo-glenoid and patient characteristics. Glenoid version correction was based on the surgeon's discretion. Using advanced 3-dimensional imaging and software, the glenoid version was corrected to within −10°. The humeral component (Apex or Univers Revers; Arthrex Inc., Naples, FL, USA) was press fit with a goal of inlaying the humeral cup. Humeral retroversion was determined using an extramedullary guide and placed between 20° and 40° using the forearm as a reference. The appropriate polyethylene was implanted after trialing confirmed satisfactory soft-tissue tension. Postoperative rehabilitation was not standardized.

Statistical analysis

Comparisons of continuous variables (mean age, BMI, PROs, ROM) were performed using Student's *t*-tests. Comparisons of categorical variables (sex, dominant arm, tobacco use, diabetes mellitus, Walch classification, severity of glenohumeral arthritis, subscapularis management, satisfaction) were performed using Chi-squared tests. Student's *t*-test and Chi-squared analyses were performed using R version 4.2.2 (R Project; University of Auckland, Auckland, New Zealand). $P < .05$ was considered significant for all comparisons.

Linear regression analyses were used to control for additional confounding variables including BMI, age, sex, tobacco use, and dominant arm for both preoperative and postoperative outcome analyses. Glenosphere diameter, humeral lateralization, preoperative ROM and baseline ASES score were added for analyses of postoperative measures. All regression analyses performed using SPSS version 27 (IBM, Armonk, NY, USA). $P < .05$ was considered significant for all comparisons.

Results

Baseline data

Baseline demographics of the 2 cohorts are summarized in Table I. The mean BMI for the obese group was 35.4 kg/m^2 and 25.5 kg/m^2 for the nonobese group. There were otherwise no statistical differences between baseline demographics of the groups.

Baseline PROs and ROM data are summarized in Table II. Obese patients had significantly lower ASES (36.6 vs. 42.0, $P = .014$) and WOOS scores (33.1 vs. 37.8, $P = .043$). Additionally, obese patients had significantly decreased baseline ER90 (19° vs. 28°, $P = .007$) and IR spinal level (L5 vs. L4, $P = .002$) compared to the nonobese cohort. All other PRO and ROM metrics were similar. Baseline belly press strength was significantly lower in the obese group ($P = .003$).

Clinical outcomes

There were no statistical differences in 2-year functional outcomes (PROs, ROM, or strength) other than worse IR spinal level in the nonobese group (L4 vs. L3, $P = .002$) (Table III).

The differences between preoperative and postoperative scores for ROM and PRO were also analyzed (Table IV). The obese group experienced greater improvement in VAS pain ($P = .041$) and ASES score ($P = .014$), while all other PROs showed a similar change from preoperative to postoperative. The only ROM value that was

Table I
Demographic comparison of RSA patients in the obese and nonobese groups (N = 245).

Patient characteristics	BMI <30 (n = 134)	BMI ≥30 (n = 111)	*P*
Demographics			
Age: y, mean (SD)	70.0 (7.8)	68.0 (7.9)	.050
Sex: female, n (%)	67 (50.0)	52 (46.8)	.623
BMI: kg/m^2, mean (SD)	25.5 (2.9)	35.4 (5.2)	n/a
Dominant arm: yes, n (%)	79 (59.0)	65 (58.6)	.950
Tobacco use: yes, n (%)	8 (6.0)	9 (8.1)	.512
Diabetes mellitus: yes, n (%)	10 (7.5)	16 (14.4)	.079
Walch classification, n (%)			
A1	52 (38.8)	37 (33.3)	.375
A2	14 (10.4)	20 (18.0)	.088
B1	25 (18.7)	21 (18.9)	.958
B2	43 (32.1)	33 (29.7)	.691
Subscapularis management, n (%)			
Peel	115 (85.8)	94 (84.7)	.803
Osteotomy	19 (14.2)	17 (15.3)	

RSA, reverse shoulder arthroplasty; *BMI*, body mass index; *SD*, standard deviation.
Six different demographics were considered for patients receiving reverse shoulder arthroplasty including age, sex, BMI, dominant arm, tobacco use, and whether they had diabetes. The distribution of the patients in both the obese and nonobese group, in the 4 different Walch classification groups is also provided. Finally, the percentage of patients in each group that underwent a peel vs. an osteotomy for subscapularis management was also considered.

Table II
Comparison of baseline PROs and ROM (N = 245).

Pretreatment PROs and ROM	BMI <30 (n = 134)		BMI ≥30 (n = 111)		*P*
	Mean	Std. Dev.	Mean	Std. Dev.	
Baseline PROs					
VAS pain	5.5	2.7	6.0	2.1	.077
ASES	42.0	18.9	36.6	15.3	.014
WOOS	37.8	18.8	33.1	17.0	.043
SANE	33.9	24.1	30.9	23.8	.328
VR-12 Mental	50.9	12.8	51.3	11.6	.798
Baseline ROM					
Active FF (degrees)	92	34	90	35	.522
Active ER at side (degrees)	30	21	26	17	.068
Active ER at 90 (degrees)	28	28	19	25	.007
Active IR (spinal level)	L4	3	L5	2	.002
Active IR at 90 (degrees)	18	19	14	23	.228
Belly Press Test					
Strength	5.2	6.5	3.1	4.2	.003

ASES, American Shoulder and Elbow Surgeons; *BMI*, body mass index; *ER*, external rotation; *FF*, forward flexion; *IR*, internal rotation; *PROs*, patient-reported outcomes; *ROM*, range of motion; *SANE*, Single Assessment Numeric Evaluation; *Std. Dev.*, standard deviation; *VAS*, visual analog scale; *VR-12*, Veterans RAND 12; *WOOS*, Western Ontario Osteoarthritis of the Shoulder.
This table captures the data for both baseline patient-reported outcome data as well as baseline range of motion data preoperatively. The 5 different baseline patient-reported outcome metrics that were used include VAS pain, ASES, WOOS, Constant-Murley, and VR-12 Mental. The 5 different baseline range of motion metrics included active forward flexion, active external rotation at side, active external rotation at 90°, active internal rotation (based on spinal level), and active internal rotation at 90° (based on degrees). Baseline belly press strength test results were also recorded.

significant was the change in ER90 ($P = .017$). The difference in belly press strength was also significant ($P = .001$).

Linear regression

Increasing BMI negatively correlated with preoperative ER ($B = -0.591$, $P = .034$) and preoperative IR spine ($B = 0.089$, $P = .002$). Increasing BMI was not correlated with postoperative ER90 ($B = 0.189$, $P = .490$); the most significant factor in the regression correlating with postoperative ER90 was preoperative ER90 ($B = 0.275$, $P < .001$). Increasing BMI was associated with worse postoperative IR by spinal level ($B = 0.066$, $P = .043$); several other factors also had significant associations with postoperative IR by spinal level (gender, glenosphere diameter, and preoperative IR spine). BMI was not correlated with the change in ASES from baseline ($P = .181$) nor the change in VAS score from baseline ($P = .655$).

Table III
Comparison of 2-year outcomes (N = 245).

Final PROs and ROM	BMI <30 (n = 134)		BMI ≥30 (n = 111)		*P*
	Mean	Std. Dev.	Mean	Std. Dev.	
2-y PROs					
VAS pain	1.1	1.9	0.9	1.8	.408
ASES	83.4	17.2	85.2	17.5	.431
WOOS	86.3	17.0	87.0	18.9	.776
SANE	75.6	24.3	80.0	23.2	.156
VR-12 Mental	55.6	7.4	53.4	10.0	.062
2-y ROM					
Active FF (degrees)	136	25	137	28	.789
Active ER at side (degrees)	47	21	46	19	.554
Active ER at 90 (degrees)	61	28	62	26	.747
Active IR (spinal level)	L3	3	L4	3	.002
Active IR at 90 (degrees)	38	22	38	22	.965
2-y Belly Press Test					
Strength	8.9	5.5	9.9	5.6	.163

ASES, American Shoulder and Elbow Surgeons; *BMI*, body mass index; *ER*, external rotation; *FF*, forward flexion; *IR*, internal rotation; *PROs*, patient-reported outcomes; *ROM*, range of motion; *SANE*, Single Assessment Numeric Evaluation; *Std. Dev.*, standard deviation; *VAS*, visual analog scale; *VR-12*, Veterans RAND 12; *WOOS*, Western Ontario Osteoarthritis of the Shoulder.
This table captures the 2-year outcome data postoperatively, through patient-reported outcome data as well as range of motion. The 5 different 2-year patient-reported outcome metrics that were used include VAS pain, ASES, WOOS, Constant-Murley, and VR-12 Mental. The 5 different 2-year range of motion metrics included active forward flexion, active external rotation at side, active external rotation at 90°, active internal rotation (based on spinal level), and active internal rotation at 90° (based on degrees). Two-year belly press strength test results were also recorded.

Discussion

The results of this study demonstrate that although obesity is associated with statistically significant restrictions in multiple preoperative functional and clinical outcomes, post-RSA obese patients exhibit no significant difference from nonobese patients in outcomes apart from a worse active IR. At baseline, obese patients undergoing RSA have lower ASES, WOOS scores, ER90, IR spinal level, and belly press strength. Linear regression analyses were used to control for additional confounding variables and supported the above finding by demonstrating that increasing BMI negatively correlated with preoperative ER and correlated with worse preoperative IR by spinal level even after controlling for factors such as age, sex, tobacco use, and dominant arm.

Following RSA, however, obese patients made larger improvements compared to nonobese patients, specifically in VAS pain, ASES score, and ER90. The only parameter that remained statistically significant post-RSA between the 2 cohorts was IR by spinal level which was significantly worse in obese patients compared to nonobese patients. This supports our original hypothesis that obese patients would have less IR post-RSA but would perform similarly across PROs and the other ROM metrics when compared to the nonobese group. Linear regressions showed that increasing BMI

Table IV
Comparison of change from preop to postop (N = 245).

Change in PROs and ROM from preop	BMI <30 (n = 134)		BMI ≥30 (n = 111)		*P*
	Mean	Std. Dev.	Mean	Std. Dev.	
Change in PROs					
VAS pain	−4.4	3.0	−5.2	2.7	.041
ASES	41.4	22.7	48.6	22.6	.014
WOOS	48.5	23.2	53.8	23.6	.079
SANE	41.7	35.0	49.0	32.0	.088
VR-12 Mental	4.7	13.0	2.1	11.3	.101
Change in ROM					
Active FF (degrees)	44	34	48	42	.452
Active ER at side (degrees)	17	25	20	23	.333
Active ER at 90 (degrees)	33	34	43	34	.017
Active IR (spinal level)	1	4	1	3	.731
Active IR at 90 (degrees)	20	28	23	29	.354
Change in Belly Press Test					
Strength	3.7	7.3	6.8	6.6	.001

ASES, American Shoulder and Elbow Surgeons; *BMI*, body mass index; *ER*, external rotation; *FF*, forward flexion; *IR*, internal rotation; *PROs*, patient-reported outcomes; *ROM*, range of motion; *SANE*, Single Assessment Numeric Evaluation; *Std. Dev.*, standard deviation; *VAS*, visual analog scale; *VR-12*, Veterans RAND 12; *WOOS*, Western Ontario Osteoarthritis of the Shoulder.
This table captures the change between baseline and postoperative outcomes for both baseline patient-reported outcome data as well as baseline range of motion data. The 5 different baseline patient-reported outcome metrics that were used include VAS pain, ASES, WOOS, Constant-Murley, and VR-12 Mental. The 5 different baseline range of motion metrics included active forward flexion, active external rotation at side, active external rotation at 90°, active internal rotation (based on spinal level), and active internal rotation at 90° (based on degrees). The difference between 2-year and baseline belly press strength test data was also recorded.

was associated with worse postoperative IR by spinal level; however, several other factors also had significant associations with postoperative IR by spinal level such as gender, glenosphere diameter, and preoperative IR by spinal level. This suggests that although obesity may restrict some RSA candidates from achieving the same level of IR as a nonobese patient, there are other factors that predict postoperative IR other than just BMI. With regards to IR by spinal level specifically, both elbow flexion as well as ROM in joints other than just the shoulder may itself be confounding.

The importance of shoulder IR in performing activities of daily living and patient satisfaction has been well described, and therefore, reproducibly measuring the degree of IR and factors affecting IR continue to be studied.[13,24] Ludewig et al determined that shoulder IR is a complex motion and involves the glenohumeral, scapulothoracic, sternoclavicular, and acromioclavicular joints.[14] With IR involving all the “shoulder joints,” its impact post RSA merits continued discussion. Rohman et al identified risk factors for loss of postoperative IR and found patients with substantial IR preoperatively had a higher probability of losing IR when compared to patients with decreased preoperative IR. Interestingly, this study found patients with substantial IR had a higher BMI and had loss of IR postoperatively.[16] In 2 additional studies, Eichinger et al showed that increasing BMI was inversely correlated with IR score, and Rol et al demonstrated improved IR after RSA in patients with a lower BMI.[7,17] Conversely, Werner et al did not observe any correlation between BMI and IR (at 90° or by spinal level).[22] With regards to IR, our study is like this study as IR at 90° was not statistically different in BMI >30 patients. However, our finding was like Eichinger and Rol with a higher spinal level noted on IR (spinal level) in BMI <30 patients.

The effect of obesity on postoperative complications in shoulder arthroplasty has also been reviewed in the literature. Werner et al published a 2.8% dislocation rate and 5.1% revision rate in super-obese patients (BMI >50) compared to 1% and 2.8% in an unmatched cohort, respectively.[21] In another study by Gupta et al, he reported increased medical and surgical complications in post-RSA patients with BMI >35 and theorized the increased complications occurred directly from obesity including increased operative times, blood loss, and decreased cardiac reserve.[9] In contrast to these studies, Cogan reported that obesity may not be associated with mechanical complications (instability, fracture, and revision) when obese and nonobese patients were matched accounting for age, sex, Charlson Comorbidity Index, diabetes, and smoking.[6] In a recent article by Reid et al, the effects of obesity on both clinical and functional outcomes following shoulder arthroplasty, the authors determined that while significant motion loss and poorer outcomes were noted in obese patients compared to nonobese patients, the differences did not exceed the minimal clinically important difference or substantial clinical benefit criteria. Moreover, they concluded that a total shoulder arthroplasty procedure indicated in an obese patient should not be restricted solely based on BMI.[15] This study supports the findings noted by Cogan and Reid with poorer preoperative ROM and PROs noted preoperatively in obese patients, but no statistical differences were noted at 2-year follow-up when compared to nonobese patients.

In summary, while obesity may be a risk factor for intraoperative complications, the current clinical study demonstrates that patients with a BMI >30 achieve similar clinical and functional outcomes post-RSA across all metrics, except for IR by spinal level specifically. However linear regression analysis suggested that there are multiple factors apart from just BMI such as gender, glenosphere diameter, and preoperative IR which may also be contributory to the obese group having worse postoperative IR by spinal level. Moreover, this study suggests that an RSA procedure indicated in an obese patient should not be restricted solely based on BMI. There are multiple limitations to this study. The first being the retrospective nature of the study which is an obvious disadvantage, with inferior evidence to that of a prospective study. The second limitation would be the 2-year follow-up period. However, the patients are enrolled in a national registry so a longer follow-up is planned. Third, linear regression analysis suggested that although BMI is a significant factor in determining specific preoperative and postoperative outcomes for patients, these outcomes are multifactorial and several other patient characteristics also contribute. Humeral/glenoid retroversion, subscapularis management, glenoid lateralization, and compiling data from a registry with patients from 14 different surgeons are all additional variables that may confound the results, however controlling for these factors in statistical analysis is difficult without an exceedingly large sample size. Finally, there is potential for variability in IR measurements specifically depending on the staff. This limitation is augmented by the fact that the data are compiled from multicenter locations which can add to the variability of the measurements. In addition, IR by spinal level can be confounded by elbow flexion and ROM from joints other than just the shoulder. Despite variations in IR measurement, ROM was performed by trained staff in standardized fashion to minimize this.

Conclusion

The heightened complication risk associated with obesity in shoulder arthroplasty continues to remain a focus. As the number of RSA procedures continues to rise in increasing BMI patients, accurately reporting clinical and functional outcomes is essential to improve access and care in this patient population. This study found that although obese patients had restrictions in external and internal rotation as well as lower scores in certain PROs such as ASES and WOOS before RSA, postoperatively there is no major difference in PROs or ROM measurements between obese and nonobese patients apart from a worse active IR by spinal level in the obese group (L4 vs. L3, $P = .002$). However, linear regression analysis suggested that there are multiple factors apart from just BMI such as gender, glenosphere diameter, and preoperative IR which may also be contributory to the obese group having worse postoperative IR by spinal level.

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