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Reverse total shoulder arthroplasty for patients with preserved active elevation and moderate-to-severe pain: a matched cohort study



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Background: Patients undergoing reverse total shoulder arthroplasty (RTSA) predictably report reduced pain and improved function postoperatively. However, it is not known if patients with differing preoperative active motion achieve the same benefit after surgery. The purpose of the present study is to evaluate patient-reported outcomes (PROs), range of motion (ROM), and satisfaction after RTSA in patients with moderate-to-severe pain with preserved active preoperative ROM compared with matched controls with restricted preoperative active ROM.

Methods: A multicenter shoulder arthroplasty registry was utilized to identify patients with at least two-year clinical follow-up after RTSA with a 135° implant. The study cohort with preserved motion included patients with greater than one standard deviation above the overall mean for preoperative forward elevation (FE) (140°) as well as a preoperative visual analog pain scale (VAS) ≥ 5.0 . The control cohort with more restricted motion had preoperative FE of less than 140° and also with preoperative VAS ≥ 5.0 . The control patients were matched 2:1 to study patients by age (± 2 years), sex, and preoperative VAS (± 1.5). Outcomes measured were as follows: PROs, ROM, strength, and strength and satisfaction.

Results: Twenty-seven patients were identified that comprised the preserved preoperative FE study cohort; 54 patients were included in the restricted elevation cohort as controls. The groups were similar at baseline for demographics, surgical diagnoses, and most PROs, other than the Constant-Murley, which was higher in the preserved motion cohort. At two years postoperatively, both cohorts demonstrated similar PROs, strength, and ROM (other than internal rotation with the arm abducted 90 degrees) and had a similar number of patients who rated the RTSA as meeting or exceeding their expectations. The change in ROM from preoperatively was significantly different with the restricted cohort, achieving a larger increase in forward flexion ($51 \pm 26^\circ$ vs. $-13 \pm 35^\circ$, $P < .001$).

Conclusion: Patients indicated for RTSA with preserved preoperative FE and moderate pain achieve similar final ROM, pain reduction, increases, and strength compared with patients who undergo RTSA with restricted preoperative FE. Despite losing on average 13 degrees of FE from preoperatively by two years postoperatively, patients with preserved preoperative FE are comparably satisfied with their outcome.

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Over the past few decades in the United States, there has been an increased acceptance and utilization of reverse total shoulder arthroplasty (RTSA). Utilizing a national database, Best et al¹

This work was performed at the University of Virginia, Charlottesville, VA, USA. Southern Oregon Institutional Review Board approved this study (IRB #16-014).

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demonstrated that from 2012 to 2017, the population-adjusted incidence of primary RTSA increased from 7.1 surgeries per 100,000 persons to 19.3 surgeries per 100,000 persons. This increase is due, in part, to myriad indications for the procedure, improvements in instrumentation and implants, and more widespread training of this procedure by industry and in fellowship programs. In addition to irreparable rotator cuff tears,¹¹ RTSA is currently indicated for rotator cuff arthropathy,¹⁶ for advanced

glenoid deformity with an intact rotator cuff,⁶ and for complex proximal humerus fractures.¹²

However, as the indications for the procedure expand, it is imperative that surgeons understand who benefits from the surgery. This knowledge allows for improved patient selection and preoperative counseling about expectations. Rauck et al¹⁰ demonstrated that patients with improvements in pain and outcome scores are more likely to be satisfied with a RTSA, so it is important that surgeons are able to better predict who will accomplish these goals and thus be satisfied with their outcome.

Certain patients who undergo a RTSA are pseudoparetic/pseudoparalytic or simply have restricted active motion due to rotator cuff dysfunction. Other patients may compensate and have preserved active motion, but both subsets of patients can still have a significant degree of pain. It is not currently known how many patients with preserved active preoperative motion benefit from RTSA compared with patients with restricted preoperative motion and how their postoperative motion compares.

The purpose of the present study is to evaluate patient-reported outcomes (PROs), range of motion (ROM), strength, and satisfaction after RTSA in patients with moderate-to-severe pain with preserved active preoperative elevation compared with matched controls with restricted active elevation. We hypothesized that both cohorts will have similar outcomes at two years, but the restricted motion cohort will experience larger improvements.

Materials and methods

Database and study patients

A prospectively maintained, multicenter database of patients undergoing RTSA was queried to retrospectively identify patients for the present study. Institutional Review Board approval was obtained. The inclusion criteria were as follows: (1) RTSA, (2) preoperative VAS 5.0 or higher, and (3) preoperative and minimum two-year postoperative PROs and ROM measurements. The exclusion criteria were as follows: (1) proximal humerus fractures, (2) revision arthroplasty, and (3) workers' compensation.

Two cohorts were then created: (1) preserved preoperative forward elevation (FE), which was established to be preoperative FE a minimum of one standard deviation greater than the mean for the entire data set ($>140^\circ$ FE), and (2) restricted preoperative FE, which was established to be $<140^\circ$ FE. The preserved cohort was a sample of opportunity; all patients who met the inclusion and exclusion criteria that fit that group were included. Once the preserved cohort was established, patients with restricted elevation were matched 2:1 based on the preoperative visual analog pain scale (VAS) ± 1.5 points, sex, and age ± 2 years. 2:1 matching was the maximum matching iterations that could be performed and result in a complete matching cycle.

Baseline data

The registry database was then utilized to record baseline data including age, sex, body mass index, arm dominance, diabetes mellitus, and tobacco use. The indication for the procedure (cuff tear arthropathy, glenohumeral arthritis, failed rotator cuff repair, or irreparable tear) was also evaluated for all patients. This information was compared between the two groups to identify any preoperative differences.

In addition, baseline PRO data were queried: VAS pain score, Western Ontario Osteoarthritis of the Shoulder index score, Veterans RAND 12 mental score, American Shoulder and Elbow Surgeons (ASES) score, and Constant-Murley score. ROM measurements included active FE, active external rotation (ER) in

adduction (ER0) and in 90 degrees of abduction (ER90), and active internal rotation (IR) measured by achieved spinal level and at 90 degrees of abduction (IR90).

Surgical technique

Fourteen surgeons contribute to this database with slight variations in technique. Utilizing a deltopectoral approach, the biceps tendon was either tenodesed or tenotomized. The subscapularis was managed as per the surgeon's preference (peel or tenotomy) followed by a 135° humeral head cut using either a free-hand technique or intramedullary or extramedullary guide. After appropriate glenoid exposure was obtained, the glenoid was prepared using sequential reaming steps as per the manufacturer's recommended technique, and then, a baseplate was implanted (Universal Baseplate or Modular Glenoid System; Arthrex, Inc., Naples, FL, USA). After press-fitting the 135° inlay stemmed humeral component (Univers Revers or Apex Revers System, Arthrex Inc.), the final sizes of the humeral polyethylene liner and glenosphere were decided on based on the surgeon's assessment of construct stability. The subscapularis was managed based on the surgeon's preference, tendon mobility, and tissue quality.

Outcomes

For all patients in both cohorts, two-year postoperative outcomes were collected including VAS pain score, ASES score, Western Ontario Osteoarthritis of the Shoulder index score, single assessment numeric evaluation, Constant-Murley score, Veterans RAND 12 Mental score, shoulder ROM, and shoulder strength. At two years after surgery, each patient also completed a survey investigating whether the outcome exceeded his/her expectations, met his/her expectations, or did not meet his/her expectations in these 3 categories, (1) pain level, (2) strength and motion, and (3) sports (when applicable) as well as activities of daily living.

Statistical analysis

Comparisons of continuous variables (mean age, body mass index, PROs, ROM) were performed using Student's T tests. Comparisons of categorical variables (sex, dominant arm, tobacco use, diabetes mellitus, diagnosis, satisfaction) were performed using chi-squared tests. All statistical analyses were performed using SPSS, version 27 (IBM, Armonk, NY, USA). $P < .05$ was considered significant for all comparisons.

Results

Baseline data

Fifty-four patients in the restricted elevation control cohort were matched to 27 patients in the preserved elevation study cohort. Including an average age of 68.0 ± 7.3 years and 68.1 ± 7.3 years ($P = .954$) all baseline demographics and distribution of surgical diagnoses were statistically similar (Table I).

Preoperative PROs were all statistically similar except for the Constant-Murley score which was lower in the restricted motion cohort (29.9 ± 10.2 vs. 40.7 ± 10.8 , $P < .001$). Strength testing demonstrated no baseline difference between the cohorts (Table II).

Regarding preoperative active motion, the cohort with restricted elevation had significantly worse FE ($87 \pm 26^\circ$ vs. $148 \pm 8^\circ$, $P < .001$), ER with the arm at the side ($24 \pm 18^\circ$ vs. $33 \pm 19^\circ$, $P = .041$), and ER with the arm abducted to 90 degrees ($19 \pm 23^\circ$ vs. $33 \pm 31^\circ$, $P = .025$). IR was similar between groups (Table II).

Table I
Demographic comparison of RSA patients with and without good preop forward elevation.

Patient characteristics	Preserved FE (n = 27)		Matched with restricted FE (n = 54)		P value
Demographics					
Age: years (mean, s.d.)	68.0	7.3	68.1	7.3	.954
Sex: female (n, %)	14	51.9%	28	51.9%	1.000
BMI: kg/m ² (mean, s.d.)	29.8	7.3	30.4	6.5	.708
Dominant arm: yes (n, %)	17	63.0%	32	59.3%	.748
Tobacco use: yes (n, %)	2	7.4%	4	7.4%	1.000
Diabetes mellitus: yes (n, %)	2	7.4%	5	9.3%	.780
Surgical diagnosis					
Cuff tear arthropathy (n, %)	14	51.9%	24	44.4%	.529
Glenohumeral arthritis (n, %)	6	22.2%	17	31.5%	.384
Failed cuff repair/irreparable cuff (n, %)	5	18.5%	9	16.7%	.835
Other (n, %)	2	7.4%	4	7.4%	1.000
Surgical/implant					
Glenosphere diameter					
33 mm (n, %)	1	3.7%	4	7.4%	.514
36 mm (n, %)	14	51.9%	26	48.1%	.753
39 mm (n, %)	4	14.8%	10	18.5%	.678
42 mm (n, %)	8	29.6%	14	25.9%	.724
Glenoid lateralization					
0 mm (n, %)	2	7.4%	7	13.0%	.453
2 mm (n, %)	1	3.7%	0	0.0%	.155
4 mm (n, %)	17	63.0%	31	57.4%	.631
6 mm (n, %)	4	14.8%	10	18.5%	.678
8 mm (n, %)	3	11.1%	6	11.1%	
Other surgical					
Subscapularis repair (n, %)	13	48.1%	22	40.7%	.526
CT-based preoperative planning (n, %)	5	18.5%	8	14.8%	.669

FE, forward elevation; BMI, body mass index; CT, computed tomography; RSA, reverse shoulder arthroplasty.

Table II
Comparison of baseline PROs and ROM.

Baseline PROs	Preserved FE (n = 27)		Restricted FE (n = 54)		P value
	Mean	Std. Dev.	Mean	Std. Dev.	
VAS pain	7.5	1.3	7.3	1.4	.537
ASES	32.9	9.3	30.1	11.6	.279
WOOS	30.7	10.5	29.6	15.9	.746
SANE	36.6	24.2	27.4	22.5	.095
Constant-Murley	40.7	10.8	29.9	10.1	<.001
VR-12 Mental	47.4	10.9	47.2	13.1	.946
Baseline ROM	Mean	Std. Dev.	Mean	Std. Dev.	P value
Active FF (degrees)	148	8	87	26	<.001
Active ER at side (degrees)	33	19	24	18	.041
Active ER at 90 (degrees)	33	31	19	23	.025
Active IR (spinal level)	L4	4	L5	2	.136
Active IR at 90 (degrees)	27	30	19	21	.167
Baseline strength	Mean	Std. Dev.	Mean	Std. Dev.	P value
Constant-Murley	5.3	4.0	4.5	3.9	.391
ER in neutral	5.7	3.6	6.5	3.5	.340
Belly press	7.9	5.6	8.2	4.9	.805

FE, forward elevation; Std. Dev., standard deviation; PROs, patient-reported outcomes; ROM, range of motion; VAS, visual analog pain scale; WOOS, Western Ontario Osteoarthritis of the Shoulder; ASES, American Shoulder and Elbow Surgeons; VR-12, Veterans RAND 12; IR, internal rotation; ER, external rotation; SANE, single assessment numeric evaluation; FF, forward flexion.

Clinical outcomes

At two years after surgery, all PROs were similar between groups. In addition, all ROM parameters and strength measurements were not significantly different (Table III).

Between the two cohorts, significant differences were noted when comparing the changes from preoperative to two-year postoperative Constant-Murley and ROM measurements. The Constant-Murley score exhibited a greater significant increase in the restricted elevation cohort (35.6 ± 14.9 vs. 22.0 ± 19.6, P < .001). In addition, the restricted elevation cohort demonstrated

significantly greater improvement in FE (51 ± 26° vs. -13 ± 35°, P < .001), ER0 (45 ± 29° vs. 20 ± 43°, P = .003), and IR90 (22 ± 25° vs. 3 ± 34°, P = .006). The changes in the other ROM measurements and strength were similar (Table IV).

Patient satisfaction

When comparing the percentage of patients who rated their outcome as met or exceeded expectations in all 4 categories, there was no significant difference between the two cohorts (Table V).

Table III
Comparison of two-year outcomes.

Final PROs, ROM, and strength					
2-year PROs	Preserved FE (n = 27)		Restricted FE (n = 54)		P value
	Mean	Std. Dev.	Mean	Std. Dev.	
VAS pain	1.5	2.0	0.9	1.9	.192
ASES	80.5	17.1	85.1	15.2	.222
WOOS	82.3	17.8	87.2	17.2	.236
SANE	75.7	18.2	77.8	23.9	.689
Constant-Murley	63.6	13.6	65.1	13.0	.631
VR-12 Mental	52.3	9.1	54.0	7.5	.374
2-year ROM	Mean	Std. Dev.	Mean	Std. Dev.	P value
Active FF (degrees)	136	36	138	18	.739
Active ER at Side (degrees)	52	27	45	22	.215
Active ER at 90 (degrees)	53	29	63	20	.073
Active IR (spinal level)	13	3	14	3	.161
Active IR at 90 (degrees)	30	15	40	18	.015
2-year strength	Mean	Std. Dev.	Mean	Std. Dev.	P value
Constant-Murley	8.4	4.9	8.9	4.4	.644
ER in neutral	8.8	3.9	9.8	4.6	.336
Belly press	9.6	4.0	10.1	4.7	.637

FE, forward elevation; Std. Dev., standard deviation; PROs, patient-reported outcomes; ROM, range of motion; VAS, visual analog pain scale; WOOS, Western Ontario Osteoarthritis of the Shoulder; ASES, American Shoulder and Elbow Surgeons; VR-12, Veterans RAND 12; IR, internal rotation; ER, external rotation; SANE, single assessment numeric evaluation; FF, forward flexion.

Table IV
Comparison of change from preoperative to after operation.

Change in PROs, ROM, and strength from preoperative					
Change in PROs	Preserved FE (n = 27)		Restricted FE (n = 54)		P value
	Mean	Std. Dev.	Mean	Std. Dev.	
VAS pain	-6.0	2.1	-6.4	2.0	.407
ASES	47.6	16.4	55.1	18.4	.077
WOOS	51.7	20.7	57.5	24.9	.300
SANE	39.1	34.0	50.4	32.6	.151
Constant-Murley	22.0	19.6	35.6	14.9	<.001
VR-12 Mental	4.9	9.8	6.8	14.7	.546
Change in ROM	Mean	Std. Dev.	Mean	Std. Dev.	P value
Active FF (degrees)	-13	35	51	26	<.001
Active ER at side (degrees)	19	26	21	21	.710
Active ER at 90 (degrees)	20	43	45	29	.003
Active IR (spinal levels, n)	1	4	1	4	1.000
Active IR at 90 (degrees)	3	34	22	25	.006
Change in strength	Mean	Std. Dev.	Mean	Std. Dev.	P value
Constant-Murley	3.1	5.2	4.3	5.5	.349
ER in neutral	3.1	4.6	3.3	4.9	.860
Belly press	1.6	6.0	2.0	6.0	.778

FE, forward elevation; Std. Dev., standard deviation; PROs, patient-reported outcomes; ROM, range of motion; VAS, visual analog pain scale; WOOS, Western Ontario Osteoarthritis of the Shoulder; ASES, American Shoulder and Elbow Surgeons; VR-12, Veterans RAND 12; IR, internal rotation; ER, external rotation; SANE, single assessment numeric evaluation; FF, forward flexion.

Table V
Comparison of satisfaction/expectations.

Satisfaction measures	Preserved FE (n = 27)		Restricted FE (n = 54)		P value
	n (met/exceeded)	% (met/exceeded)	n (met/exceeded)	% (met/exceeded)	
Pain level	26	96.3%	53	98.1%	.613
Motion and strength	23	85.2%	48	88.9%	.633
ADLs	23	85.2%	51	94.4%	.162
Sport (n applicable)	14 (18)	77.8%	30 (33)	90.9%	.193

FE, forward elevation; ADLs, activities of daily living.

Discussion

The present study demonstrates that despite significantly worse active shoulder ROM before RTSA, this cohort of patients with moderate-to-severe pain has similar ROM measurements and PROs at 2 years postoperatively when compared with a cohort of comparable patients who have preserved preoperative motion. In addition, both cohorts experience similar high levels of postoperative satisfaction and low pain scores.

For patients with moderate-to-high levels of pain, pain reduction is an important goal of an RTSA, and this study showed that, regardless of preoperative motion, a significant reduction in pain is achievable postoperatively. Consistent with this study, pain control has been shown in multiple previous studies to be predictable after RTSA. Utilizing a short stemmed platform, Dukan et al² reduced the VAS score from 6.8 preoperatively to 0.4 at an average of 38.8 months of follow-up. For patients with irreparable rotator cuff tears and no glenohumeral arthritis, Mulieri et al⁷ demonstrated that, with a minimum of two-year follow-up, the VAS score decreased from 6.3 preoperatively to 1.9. These numbers are in line with the patients in the present study, mirror the results of a systematic review by Petrillo et al,⁹ and exceed the VAS minimal clinically important difference (MCID) threshold of 1.4 for shoulder arthroplasty as established by Tashjian et al.¹⁴

In addition to pain control, a successful shoulder surgery should include an improvement in or maintenance of preoperative ROM. The restricted motion cohort obtained a mean improvement of $51 \pm 26^\circ$ in FE and $45 \pm 29^\circ$ in ER at two years after surgery, and the preserved motion cohort actually lost a mean of $13 \pm 35^\circ$ in FE while improving measurements in all other areas tested. When the FE measurements are examined more closely, 14 patients (52%) in the preserved motion cohort actually lost some degree of FE, but this had no effect on their final PROs or satisfaction with the surgery. Based on the systematic review by Oosterwijk et al,⁸ the mean FE achieved postoperatively in both cohorts would allow patients to do all activities of daily living with the exception of reaching up to a high shelf.

The amount of improvement in motion in the restricted motion cohort is similar to the amount that Dukan et al² found in their study. In their 76 patients, the FE improved from 89° to 131° ($P < .001$), and the external rotation improved from 25° to 36° ($P < .001$); similarly, the cohort in the present study improved from 87° to 138° and from 24° to 45° , respectively. Mulieri et al⁷ achieved a similar improvement in FE from 53° to 134° ($P < .0001$) in 60 shoulders at a minimum of two years of follow-up.

At two years after surgery, both cohorts showed a significant improvement in PROs, and previous literature has also demonstrated this same finding. A total of 96% and 89% of patients in the restricted and preserved cohorts met the ASES MCID of 20.9. By comparing the Constant and ASES scores in patients after an RTSA, Dukan et al² demonstrated an increase in the Constant score from 44.2 to 87.9 ($P < .001$) and ASES score from 36.2 to 84.3 ($P < .001$). A systematic review by Petrillo et al⁹ included seven publications and showed a statistically significant improvement in all clinical scores after RTSA. Ernstbrunner et al³ performed a level IV systematic review to evaluate the long-term outcomes after RTSA which included 8 studies with 365 shoulders. The mean follow-up for all shoulders was 9.5 years (range 5 to 20 years), and significant increases were seen with Constant and Subjective Shoulder Value scores when compared with preoperative values. When these patients were categorized based on the duration of follow-up, outcome scores showed no significant deterioration between 5 and 20 years, suggesting that the early improvements appear to be durable.

Risk factors for a poor functional improvement after RTSA was evaluated by Hartzler et al⁴ by retrospectively reviewing patients

with massive rotator cuff tears and a minimum of two years of follow-up. Based on Simple Shoulder Test scoring, they found that young age, high preoperative function, and neurologic dysfunction were associated with poor functional improvement. Based on preoperative diagnosis, Kennedy et al⁵ noted that patients undergoing a revision of a TSA to an RTSA had the lowest PROs and outcomes.

A hard to quantify but important and easy to understand outcome for patients is how the surgery outcome measures up against expectations. A previous study by Vajapey et al¹⁵ found that preoperative opioid use and workers' compensation status were risk factors for poor postoperative satisfaction. To help predict who will be satisfied after RTSA, Rauck et al¹⁰ assessed 161 patients two years after surgery. They noted that higher satisfaction is associated with an improvement in pain and outcome scores, and this is consistent with the findings in the present study. Lower postoperative satisfaction was associated with higher preoperative shoulder function, worse physical health, and worse mental health. When comparing our two cohorts, there was no significant difference in postoperative expectations being met when stratified by preoperative FE. However, preoperative PROs for both cohorts were similar (other than the Constant-Murley score which heavily weighs ROM in the score), which indicates that motion may not play a large role in patients' function when their pain is moderate or severe.

There are several limitations of the present study which deserve mentioning. First, this is a retrospective study and is subject to the typical biases of retrospective research. In addition, this is small sample size (81 patients in total) with short-term follow-up. However, Simovitch et al¹³ demonstrated that most improvements after a shoulder arthroplasty are appreciated by 6 months with a smaller amount of incremental improvement up to two years, so this follow-up is sufficient to capture this recovery. The ROM and PROs in the two cohorts mirror those seen in previous studies, so including more patients in this study is unlikely to change in conclusion. Furthermore, based on the work by Ernstbrunner et al,³ we do not expect these results to change with longer follow-up. Because this is a database study with 14 contributing surgeons without identical rehabilitation protocols, there is some variability regarding surgical technique and recovery which introduces some inconsistencies but may make the results more generalizable. This study did include multiple indications for the RTSA, and although these were statistically spread equally between the cohorts, some were only present in small numbers.

Conclusion

Patients indicated for RTSA with preserved preoperative FE and moderate pain achieve similar final ROM, pain reduction, increases, and strength compared with patients who undergo RTSA with restricted preoperative FE. Despite losing on average 13 degrees of FE from before operation by two years postoperatively, patients with preserved preoperative FE are comparably satisfied with their outcome. Surgeons should counsel their patients who have preserved active FE preoperatively that they may have a decline in their active elevation compared with their preoperative level, but will likely see an improvement in all other measures of function and pain relief.

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Conflicts of interest: Dr. Werner is a consultant for Arthrex and receives research support from Biomet and Flexion Therapeutics. Drs. Lederman, Gobezie, and Denard are consultants for and receive

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