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Reverse shoulder arthroplasty for massive irreparable rotator cuff tears: a reliable treatment method

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ABSTRACT

Background: Massive irreparable rotator cuff tears (MIRCT) are challenging problems for both patients and surgeons. Reverse total shoulder arthroplasty (RTSA) is a treatment option for patients with MIRCTs. However, previous reports have shown inconsistent results, varying patient satisfaction, and higher complication rates.

Methods: This is a retrospective multi-institutional study (22 institutions, 24 surgeons) of 203 patients (average age, 71 years) who underwent RTSA for MIRCT without glenohumeral arthritis with a mean follow-up of 50 months. Patients were divided into 4 groups based on preoperative shoulder active forward elevation (aFE) (<60°, <90°, ≥90°, >120°). Clinical outcomes were assessed using multiple patient-reported outcome measures (PROs), postoperative range of motion (ROM), patient satisfaction, and complication rate. Radiographic outcomes assessment included evaluation of postoperative scapular notching and humeral radiolucent lines.

Results: Patients in each group had significant ($P \leq 0.02$) improvements in PROs and ROM postoperatively. Patient satisfaction was highest in the group with >120° preoperative aFE (44/44, 100%). Scapular notching and humeral radiolucency were noted in 6% and 7% of patients, respectively. There were only 3 complications that required 2 revision surgeries. Overall, the complication rate (1.6%) and reoperation rate (1.1%) were considerably lower than previously reported.

Conclusion: RTSA is a reliable treatment for MIRCTs without glenohumeral arthritis that results in significant improvements in PROs and shoulder ROM. Compared to previous studies, we report a substantially higher satisfaction rates in all patients, especially in those with better preoperative ROM (aFE >120°), and a lower overall complication rate.

Level of evidence: Level IV; Therapeutic Study

Massive irreparable rotator cuff tears (MIRCT) are challenging problems for both patients and surgeons. MIRCTs can be a source of significant pain and compromised function. Although multiple treatment methods have been proposed, there is no specific treatment option that is appropriate for all patients. Nonarthroplasty options include débridement,[12] partial rotator cuff repair,[3] tuberoplasty,[15] tendon transfer,[7] superior capsular reconstruction,[13] and subacromial balloon

Approval for this study was obtained from the NYU IRB (study number i05-144_MOD41).

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placement.[2,4,18] Reverse total shoulder arthroplasty (RTSA) is another treatment option for patients with MIRCTs, however, this treatment option is not without controversy.[2,10,23] Previous reports of RTSA for treatment of MIRCTs have generally been small cohorts with inconsistent results, varying patient satisfaction, and higher complication rates.[1,6,10,14,24]

In this study, we report a large cohort of patients with MIRCTS without arthritis who were treated with RTSA. Our hypothesis is that patients with MIRCTs treated with RTSA can achieve successful outcomes with low complication rates and that outcomes are not predicted by preoperative active range of motion (ROM).

Materials and methods

The data in this study was obtained by querying an institutional review board (IRB) approved multi-institutional database (22 institutions and 24 surgeons). A consecutively series of patients were retrospectively identified by searching for those who underwent RTSA for the diagnosis of MIRCT without glenohumeral arthritis. Between 2009 and 2018, a total of 203 RTSA were performed in 203 patients. The preoperative diagnosis was established by the treating surgeon based on clinical evaluation (persistent pain, limited shoulder ROM, and rotator cuff weakness) and imaging studies. Standard radiographs were reviewed preoperatively, and the Hamada classification was used to evaluate for rotator cuff dysfunction and signs of glenohumeral arthritis.[9] The indications for RTSA included shoulder pain and/or unacceptable shoulder function including shoulder ROM limitations and weakness in patients that had failed nonoperative treatment. All patients were Hamada grade 1, 2, or 3 (no signs of glenohumeral arthritic changes).

Additionally, all patients had a functional deltoid muscle on preoperative physical examination. Alternative treatments (superior capsule reconstruction, tendon transfer, partial rotator cuff repair, rotator cuff débridement) were also discussed preoperatively and each patient elected to proceed with RTSA. Patients were followed for a minimum of 2 years (average follow-up: 50 months, range: 24-129 months). Patients in whom the clinical and/or radiological findings did not support the diagnosis of MIRCT without glenohumeral arthritis or those with follow-up of less than 2 years were excluded from the cohort, thus leaving 188 patients available for study analysis.

Surgical technique and postoperative protocol

The specific details of the surgical technique used in each individual case were based upon surgeon preference. However, a standard deltopectoral approach was used in all cases. The implants used in this study consisted of a medialized glenoid and lateralized humeral design with a 145° neck-shaft angle, and an onlay humeral component (Equinoxe, Exactech Inc., Gainesville, FL, USA) (Fig. 1). Noncemented humeral stems were used in 91% (172/188) of cases. The 38-mm glenosphere was used in the majority of cases (62%, 105/170), followed by 42 mm (34%, 58/170), 46 mm (3%, 5/170), and 36 mm (1%, 2/170). Subscapularis repair was performed in 47% (82/173) of patients. The repair technique was based upon surgeon preference. The postoperative protocol was not standardized and was determined by the treating surgeon.

Clinical evaluation

Patients were divided into 4 groups based upon their preoperative range of active shoulder elevation (aFE) ROM. Patients were initially divided into 2 main groups: pseudoparalytic shoulders (aFE $<90°$) and non-pseudoparalytic shoulders (aFE $\geq 90°$). Patients were then further divided into 2 subgroups: those with critical limitation in preoperative aFE (aFE $<60°$) and those with minor limitation (aFE $>120°$). Clinical assessment

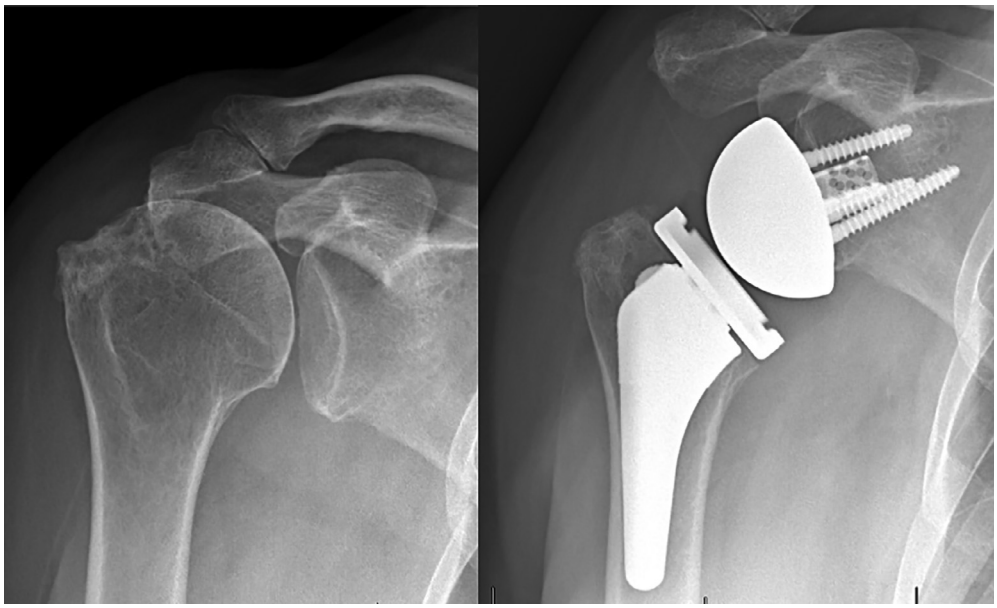

Figure 1 – Case of RTSA for Hamada grade 2 changes.

was performed preoperatively and postoperatively in all patients to evaluate differences in functional outcomes.

Clinical outcome analysis

The primary outcome measure of this study was postoperative function as determined by multiple patient reported outcome scores (PROs). Secondary outcomes were postoperative ROM, patient satisfaction, sleep disturbance, and postoperative complications.

Independent observers who did not participate in the patient's surgery assessed the patient's function and pain severity in a standardized manner during the preoperative and postoperative follow-up visits. Patient function and pain were assessed by the following PROs: Shoulder Pain and Disability Index (SPADI),[16] University of California – Los Angeles (UCLA) score,[20] American Shoulder and Elbow Surgeons (ASES) score,[12] Constant Score (CS),[11] Simple Shoulder Test (SST),[8] and Visual Analog Score (VAS) for pain.[5]

Active ROM including forward elevation, abduction, external rotation, and internal rotation, was assessed and documented in all patients preoperatively and at postoperative follow-up visits. Shoulder internal rotation was measured by vertebral segments and converted to the following score for statistical evaluation: 0° = 0, hip = 1, buttock = 2, sacrum = 3, L5-L4 = 4, L3-L1 = 5, T12-T8 = 6, T7 or higher = 7.[22] Complications and need for revision surgery were also recorded postoperatively.

In their last follow-up visit, patients were asked to subjectively grade their satisfaction with their treatment on a zero to 4-point scale as was previously reported by Mulieri et al:[14] "unsatisfactory," "satisfactory," "good," "excellent." Patients were also asked to grade their difficulties in sleeping on a three-point scale: "every night," "occasional disturbance," "undisturbed sleep."

Radiographic evaluation

The most recent available postoperative radiographs were compared to those that were performed immediately after surgery to evaluate for radiographic signs of radiolucent lines (RLL) around the humeral stem and scapular notching on the anterior-posterior view. Humeral RLL were classified according to the radiolucent line width (<2 or ≥2 mm) and the number of zones involved around the prosthesis as described by Throckmorton et al.[21] Scapular notching was classified according to the Sirveaux classification system.[19]

Statistical analysis

Descriptive statistics, including mean, range, and standard deviation, were presented for continuous variables, and frequencies were tabulated for categorical variables. Comparisons of preoperative and postoperative shoulder ROM and PROs were performed using a standard 2-tailed t-test for continuous variables. Unpaired t-test was used to evaluate differences in continuous variables (Δ) between the groups. The Chi-square test was used for comparisons between categorical variables. A *P* value of less than .05 was considered significant. All statistical analysis was performed using IBM SPSS software (SPSS version 26; IBM, Armonk, NY, USA).

Results

Study cohort

The study cohort consisted of 112 (59.6%) females and 76 (40.4%) males. The average age at the time of surgery was 71 years (range, 52-93). The mean body mass index was 28.53 kg/m^2 (range, 18.3-52.7), and in 130 (60.9%) cases, the dominant arm was operated on. There were no differences in demographic data (age, gender) between the pseudoparalytic and non-pseudoparalytic groups (Table I).

The RTSA was the primary procedure in 118 (62.7%) patients; 70 (37.3%) patients underwent at least one previous surgery prior to the RTSA as follows: 68 of the 70 patients (97%) underwent a previous rotator cuff repair. In f52 patients, a single surgery was performed, and 16 patients had undergone 2 or more rotator cuff repairs. In addition, 1 patient (1/70, 1.5%) underwent a labral repair, and another patient (1/70, 1.5%) had a humeral shaft fracture that was treated with an intramedullary nail prior to the RTSA (Table II).

Clinical outcomes

Patient-reported outcome scores

A significant improvement in all PROMs was noted postoperatively in all 4 groups ($P < .01$; Table III). Moreover, analysis of changes (Δ) in outcome scores (preoperative vs. postoperative) between the pseudoparalytic (aFE <90°) and non-

Table I – Demographic data.

	Value ± SD	N/ Total number of patients	Percent
Age at surgery (yr)	71.5 ± 8.22	188/188	100
Pseudoparalysis	71.9	113/188	60.1
Non-pseudoparalysis	70.1	75/188	39.9
Follow-up (mo)	49.15 ± 25.97	188/188	100
BMI (range)	28.53 (18.3-52.7)	188/188	100
Gender	Male	76/188	40.4
	Female	122/188	59.6
Pseudoparalysis	Male	42/113	37.1
	Female	71/113	62.9
Non-pseudoparalysis	Male	30/75	40
	Female	45/75	60
Arm dominance	Right	181/188	96.3
	Left	5/188	2.7
	Bilateral	2/188	1
Surgery performed on dominant arm	Dominant	130/188	60.9
	Non dominant	58/188	30.1
Revision surgeries	No	186/188	98.90
	Yes	2/188	1.10

SD, standard deviation; *N*, number of patients; *BMI*, body mass index (kg/m^2).

Table II – Distribution of surgeries–primary vs. previous surgery prior to RTSA.

Surgery type	N /total number of patients (%)
Primary RTSA	118/188 (62.7)
Surgeries performed prior to RTSA	70/188 (37.3)
Rotator cuff repair	68/70 (97)
Single repair	52
More than 1 repair	16
Open labral repair	1 /70 (1.5)
Intramedullary nail (following humeral shaft fracture)	1/70 (1.5)

RTSA, reverse total shoulder arthroplasty.

pseudoparalytic (aFE ≥ 90°) groups revealed a significantly greater improvement in SPADI score (-62.23 vs. −49.18, $P < .01$), UCLA score (+17.25 vs. +13.47, $P < .01$), CS (+38.02 vs. +20.57, $P < .01$), and the SST score (+6.29 vs. +4.82, $P < .01$) in the pseudoparalytic (aFE <90°) group. In addition, significantly greater improvements in the CS score (+39.87 vs. +16.09, $P < .01$) and in the SST score (+5.89 vs. +4.17, $P < .01$) were noted in the "<60°" group compared to the ">120°" group. However, although the pseudoparalytic group had greater improvements (Δ) in PROs, the non-pseudoparalytic group showed overall improved postoperative function scores in each one of the PROs (SPADI; 20.48 vs. 26.81, UCLA; 30.46 vs. 28.97, ASES; 84.25 vs.79.36, CS; 70.65 vs. 64.26, SST; 10.16 vs. 9.03) indicating better postoperative function in the non-pseudoparalytic group.

Pain symptoms represented by VAS scores significantly improved postoperatively in each one of the 4 groups ("<60°" group: from 7.51 to 2.45, "<90°" group: from 7.98 to 2.83, "≥90°" group: from 8.51 to 2.94, and in the ">120°" group: from 8.40 to 2.23; $P < .01$). Interestingly, although there were no significant differences in change (Δ) of VAS scores between the groups ("<90°" vs. "≥90°" [$P = .66$], and "<60°" vs. >" 120°" [$P = .29$]), greater improvement in pain levels ((Δ) VAS scores) was noted in the non-pseudoparalytic (aFE ≥90°) group and especially in the aFE >120° group who had the greatest change/improvement in VAS score (Δ= [−6.17]).

ROM

To evaluate differences in ROM between the groups ("<90°" vs. "≥90°" and "<60°" vs. ">120°"), statistical analysis was performed in 2 steps (Table IV). In the first step, the change between preoperative and postoperative ROM (Δ) was calculated for each of the 4 groups.

Significant improvements ($P < .01$) in all categories of ROM (abduction, forward elevation, external, and internal rotation) were noted in the pseudoparalytic group (aFE <90°). Similarly, significant improvements in forward elevation ($P = .02$) and external rotation ($P < .01$) were noted in the non-pseudoparalytic group. However, in the same group of patients (aFE ≥90°), there were nonsignificant improvements in abduction (104.66° vs. 124.62°, $P = .53$) and in internal rotation score (3.91 vs. 4.59, $P = .07$). Interestingly, a nonsignificant decrease of (−5.45°) in forward elevation was also noted postoperatively in the ">120°" group (148.38° vs. 142.93°, $P = .21$).

In the second step of the analysis, the changes (Δ) in ROM (from preoperative to postoperative) between the groups were analyzed. Significantly greater improvements in abduction (+65.23° vs. +18.77°, $P < .01$) and forward elevation (76.95° vs. 12.48°, $P < .01$) were noted in the pseudoparalytic group ("<90°") compared to the non-pseudoparalytic group ("≥90°"). Similarly, significantly greater improvements in abduction (+72.32° vs. +6.47°, $P < .01$), forward elevation (+90.88° vs. −5.45°) and external rotation (+18.36° vs. +8.29) were noted in the "<60°" group compared to the ">120°" group. However, despite the relatively smaller changes (Δ) in ROM compared to the other groups, patients in the ">120°" group had a greater ROM postoperatively in all planes (abduction =131.22°, forward elevation = 142.93°, external rotation 37.93°, Internal rotation score = 4.78/L1-L5).

Patient satisfaction

In all 4 groups, the majority of patients reported "Excellent" or "Good" satisfaction with their treatment. The non-pseudoparalytic group reported higher satisfaction rates compared to the pseudoparalytic group, however, this result was not statistically significant (91.4% vs. 84.4%, $P = .06$). The highest percentage of satisfied patients was noted in the ">120°" group (44/44, 100%), and the lowest percentage of satisfied patients was noted in the "<60°" group (42/51, 82.5%). The difference in satisfaction rates between these 2 groups was statistically significant ($P = .01$; Table V).

Postoperative nighttime symptoms

The majority of patients in all groups reported high rates of "undisturbed sleep" postoperatively, ranging between 70.6% of the patients in the "<60°" group to 83% in the ">120°" group. There were no statistically significant differences between the pseudoparalytic group and the non-pseudoparalytic group ($P = .48$) or between the "<60°" and the ">120°" groups ($P = .62$).

Primary procedure vs. prior surgery

Clinical outcomes were assessed between patients who underwent RTSA as a primary procedure (n = 118) and those who had at least one prior surgery (n = 70). Improvements in ROM and PROs were noted postoperatively in both groups of patients. However, those who underwent RTSA as the primary surgery had significantly greater improvement in all planes of ROM and in both the Constant and SST scores. Moreover, the majority of patients (70% or more) in both groups stated they were very satisfied with their treatment and had an "undisturbed sleep."

Complications and reoperations. Three postoperative complications occurred in 3 patients. One patient complained of numerous episodes of shoulder subluxations with spontaneous relocations that began 5 years after the RTSA. The patient underwent revision surgery, during which conversion to a constrained polyethylene liner was performed. Another patient was diagnosed with aseptic loosening of a noncemented humeral stem 5

Table III – Patients reported outcome scores.

PROs	Group preoperative aFE (°)	Preoperative N	Preoperative Score	Preoperative SD	Postoperative N	Postoperative Score	Postoperative SD	Change (Δ)	*P* value	*P* value of (Δ) between the groups
SPADI	< 90°	66	88.39	21.53	94	26.81	28.95	−62.23	< .01	< .01
	≥ 90°	80	68.73	30.19	92	20.48	23.70	−49.18	< .01	
	Total	146			186					
	< 60°	35	87.49	20.57	50	28.70	32.11	−58.79	< .01	.57
	>120°	45	63.84	29.80	45	16.16	20.55	−47.69	< .01	
	Total	80			95					
UCLA	< 90°	82	11.46	4.19	76	28.97	6.93	+17.25	< .01	< .01
	≥ 90°	92	16.50	3.80	79	30.46	5.16	+13.47	< .01	
	Total	174			155					
	< 60°	44	10.64	4.23	41	28.00	7.99	+17.36	< .01	.54
	>120°	45	17.80	4.09	41	31.10	4.87	+13.30	< .01	
	Total	89			82					
ASES	< 90°	85	35.41	18.07	92	79.36	21.06	+45.70	< .01	.19
	≥ 90°	93	43.01	17.35	93	84.25	18.15	+41.30	< .01	
	Total	178			185					
	< 60°	47	35.85	18.38	50	77.66	23.20	+41.81	< .01	.55
	>120°	46	45.54	17.32	46	87.04	16.03	+41.50	< .01	
	Total	93			96					
Cobnstant	< 90	72	27.11	12.21	62	64.26	17.37	+38.02	< .01	< .01
	≥ 90	82	49.74	13.71	68	70.65	14.33	+20.57	< .01	
	Total	154			130					
	< 60°	40	23.23	11.05	33	63.09	19.60	+39.87	< .01	< .01
	>120°	41	56.54	11.56	35	72.63	13.02	+16.09	< .01	
	Total	81			68					
SST	< 90°	84	3.12	2.57	91	9.03	3.28	+6.29	< .01	< .01
	≥ 90°	89	5.35	3.59	92	10.16	2.41	+4.82	< .01	
	Total	173			183					
	< 60°	46	2.85	2.26	50	8.74	3.39	+5.89	< .01	< .01
	>120°	45	6.18	3.33	46	10.35	2.44	+4.17	< .01	
	Total	166			175					
VAS (pain at rest)	< 90°	88	7.98	2.44	95	2.83	3.24	−5.32	< .01	.66
	≥ 90°	93	8.51	1.65	94	2.94	3.19	−5.56	< .01	
	Total	181			189					
	< 60°	49	7.51	2.72	51	2.45	3.11	−5.06	< .01	.29
	>120°	47	8.40	1.64	47	2.23	2.66	−6.17	< .01	
	Total	96			98					

PROs, patient-reported outcome scores; *aFE (°)*, active forward elevation (degrees); *N*, number of patients; *SD*, standard deviation; *SPADI*, shoulder pain and disability index; *UCLA*, University of California Los Angeles; *ASES*, American Shoulder and Elbow Surgeons; *SST*, simple shoulder test; *VAS*, visual analog Scale.

years after the initial surgery. Revision surgery was required in this patient. Both patients reported improved function following the revision procedures. A third patient was diagnosed with a scapular stress fracture 2 years after the shoulder replacement and was treated nonoperatively with immobilization with resolution of symptoms.

Radiographic outcomes

Radiolucent lines surrounding the humeral component were noted in 7% (10/138) of the RTSA performed (mean follow-up of 59.4 months). RLL of 2 mm or greater were noted in 90% (9/10) of these patients, and RLL less than 2 mm were noted only in one case (1/10, 10%). Scapular notching was noted in 6% (9/147) of cases (mean follow-up of 44.6 months). Seven cases

Table IV – Active shoulder range of motion.

Motion	Group preoperative aFE (°)	Preoperative N	Preoperative ROM°	Preoperative SD	Postoperative N	Postoperative ROM°	Postoperative SD	Change (Δ)	P value	P value (Δ) between the groups
Abduction	< 90°	91	46.29	24.14	72	112.73	37.82	+65.23	< .01	< .01
	≥ 90°	75	104.66	36.38	75	124.62	29.49	+18.76	.53	
	Total	166			147					
	< 60°	52	33.23	20.08	42	105.55	39.26	+72.32	< .01	< .01
	>120°	47	124.74	35.21	41	131.22	28.04	+6.47	.51	
	Total	99			83					
Forward elevation	< 90°	91	50.64	22.61	77	128.06	35.14	+76.95	< .01	< .01
	≥ 90°	75	125.10	26.87	75	138.80	28.09	+12.48	.02	
	Total	166			152					
	< 60°	52	32.88	13.84	42	123.76	38.54	+90.88	<.01	< .01
	>120°	47	148.38	14.84	41	142.93	25.40	−5.45	.21	
	Total	99			83					
External rotation	< 90°	91	19.33	21.61	77	34.22	20.05	+16.86	< .01	.26
	≥ 90°	75	25.54	23.25	75	34.06	23.84	+12.84	< .01	
	Total	166			152					
	< 60°	52	16.40	23.42	42	34.76	20.12	+18.36	<.01	.01
	>120°	47	29.64	24.59	41	37.93	15.29	+8.29	.01	
	Total	99			83					
Internal rotation score	< 90	91	3.43	2.15	75	4.64	1.71	+1.22	< .01	.88
	≥ 90	75	3.91	1.97	75	4.59	1.70	+0.54	.07	
	Total	166			150					
	< 60°	50	3.10	2.11	40	4.35	1.81	+1.25	< .01	.12
	>120°	47	4.51	1.62	41	4.78	1.78	+0.27	.39	
	Total	97			81					

aFE (°), active forward elevation (degrees); *N*, number of patients; *ROM (°)*, range of motion (degrees); *SD*, standard deviation.

were type 1 and 2 cases were type 2 according to the Sirveaux classification. In 5 patients, a 38-mm glenosphere was used, in 2, a 42 mm was used, and in 2 patients, the data regarding the glenosphere size was not available.

There was only 1 patient who required revision surgery for aseptic loosening. In that specific case, RLL were noted in 5 different zones around the humeral stem (a total of 15 mm), and the revision surgery was performed 55.5 months after the index surgery. No complications were noted at last follow-up visit.

Discussion

In this study, we utilized a multi-institution database to identify a large cohort of patients with MIRCTS without glenohumeral arthritis who underwent RTSA. Our study shows that excellent results can be achieved with respect to ROM and functional outcomes and differs from previous studies that have documented mixed results with lower patient satisfaction and higher complication rates.[1,6,10,14,24]

Our results document postoperative ROM improvements similar to the results of Mulieri et al[14] and better than those reported in other studies.[1,6,24] Our mean postoperative aFE was 133.85°, aAbd was 119.13°, aER was 36.9, and aIR between L5-L1. All ROM values were significantly improved postoperatively compared to preoperative values ($P < .01$). The variation in postoperative ROM values reported in the literature can possibly be explained by difference in prosthesis design. The previous studies with postoperative aFE <120° and aER <15° all utilized a Grammont-style prosthesis with both glenoid and humeral medialization.[1,6,24] Results from our cohort and the previous study with reported aFE >130 and aER >35 utilized a prosthesis with lateralization through the humerus and/or glenoid.[14] These design differences may be responsible, in part, for the differences in postoperative ROM.

The final postoperative PRs reported in our study are comparable to values reported in the current literature. Our postoperative CS for the entire cohort was 67.89, improved from 39.43 preoperatively (Δ 28.49). Others have reported postoperative CS to be between 55.8 and 74.0 (Δ 30.4-40.0).[1,6,24] Additionally, the average postoperative ASES score in our cohort was 82.30 which was improved from 39.28 preoperatively (Δ 43.02). The average postoperative ASES score in this study is higher in comparison to the results reported by Mulieri et al[14] who noted a postoperative ASES score of 75.4 (Δ 42.1). The

Table V – Patient satisfaction, return to sport, nighttime symptoms.

	Group preoperative aFE (°)	N (postoperative)	Unsatisfactory	Satisfactory	Good	Excellent	P value
Satisfaction	< 90°	91	9 (9.4%)	5 (5.2%)	12 (12.5%)	69 (71.9%)	.06
	≥ 90°	94	1 (1.1%)	7 (7.4%)	18 (19.1%)	68 (72.3%)	
	Total	185					
	<60°	51	6 (11.7%)	3 (5.8%)	3 (5.8%)	39 (76.7%)	
	>120°	44	0 (0%)	0 (0%)	9 (20.5%)	35 (79.5%)	.01
	Total	95					
			Every night	Occasional disturbance	Undisturbed sleep		
Nighttime symptoms (sleep)	< 90°	90	8 (8.5%)	18 (19.14%)	68 (72.36%)		.48
	≥ 90°	94	4 (4.2%)	17 (18.15%)	73 (77.65%)		
	Total	184					
	<60°	51	5 (9.8%)	10 (19.6%)	36 (70.6%)		
	>120°	47	2 (4.3%)	6 (12.7%)	39 (83.0%)		.62
	Total	98					

aFE, active forward elevation; *N*, number of patients.

mean postoperative SST score was 9.66 in our cohort which was improved from 4.26 preoperatively (Δ 5.4). Our results for SST were better than what has been reported (postoperative 6.5, Δ 4.0).[14] We also reported an average postoperative VAS of 2.85 which was improved from 8.27 (Δ 5.42). Our results showed a diminished mean postoperative VAS, but an overall greater improvement from preoperative baseline compared to the results reported by Mulieri et al (1.9, Δ 4.4).[14] The similarity of our PROs and those reported in the literature is not surprising. Even though previous studies reported higher complication rates compared to our findings, still, functional improvement was obtained after these complications were addressed.

Our cohort had only 3 complications postoperatively (1.6%), including 1 patient with recurrent instability, 1 patient with a scapular stress fracture, and 1 patient with aseptic humeral loosening. Two of the patients required revision surgery (1.1%). This complication rate is much lower than that currently reported in the literature (12%-50%).[1,6,14,24] We cannot say with certainty why the complication rate is lower in our study compared with other studies currently published. We report an average follow-up of 50 months with a minimum of 24 months. Since 2 of the 3 complications in this study occurred 5 years postoperatively, it is possible that the complication rate could increase with longer-term follow-up.

Hartzler et al[10] specifically evaluated patient risk factors for a poor functional improvement after RTSA for irreparable RTCs. They found that patient age <60, preoperative neurologic dysfunction, and a high preoperative SST score were all independent factors associated with a poor functional improvement. In our cohort, we did not find that younger age was associated with poor functional improvement. Patient's aged <60 years had a trend of lower change (Δ) from preoperative to postoperative with regards to function and ROM. However, this finding can be explained by higher baseline function noted in that group of patients prior to surgery. Patient's aged <60 years showed excellent function postoperatively in regard to ROM and PROs. There were no significant differences in PROs compared to patients that were >60 years of age, except that VAS was higher postoperatively in patients <60 years. This can be explained by a higher average baseline VAS score in patients <60 years. We also found no significant differences in satisfaction rate between the 2 age groups.

Unlike previous studies, we did not find improved preoperative ROM to negatively impact patient satisfaction. In fact, we found that patients with >120° of aFE preoperatively were the most satisfied group with all patients reporting that their shoulder was "Excellent" or "Good." However, patients with aFE >120 did lose approximately 5° of aFE on average postoperatively (148° vs. 143°). Although we cannot definitively state reason for this finding, this change was not statistically significant and the values of aAbd, aER, and aIR all improved postoperatively. Moreover, a loss of 5° of aFE is below the minimally important clinical difference previously reported in the literature and did not seem to negatively affect postoperative PROs and patient satisfaction.[17]

When looking specifically at patients with preoperative pseudoparalysis (aFE <90°) compared to patients without pseudoparalysis, the final patient outcomes favored the non-pseudoparalytic group. In patients with aFE >90° the average postoperative range of motion was globally better, and PROs were better with the exception of VAS. The pseudoparalytic group had greater improvement in ROM and PROs from preoperative to postoperative (Δ) due to a lower starting baseline, but final outcomes were comparatively lower. Satisfaction rates were similar between the 2 groups. As previously mentioned, these findings are different than what was previously reported in the literature.[1] In our cohort preoperative aFE >90° did not negatively affect patient outcomes or satisfaction. We believe the differences between the outcomes noted in our study and those reported in the literature can likely be

explained by larger cohort size, different implant design, and refined surgical technique utilized in the current study.

Our study is not without limitations. First, this is a retrospective, nonrandomized study which introduced the possibility of selection bias. Second, the study has only short- to medium-term follow-up, and it will be important to track long-term outcomes in the future especially since 2 of our complications presented 5 years after the initial surgery. Third, we report results from multiple centers and multiple surgeons which while it introduces variability, it also provides for more generalizable conclusions. And fourth, all cases in our cohort used the same RTSA implant design, and the results may not be generalizable to different prosthesis designs.

Conclusion

RTSA is a reliable treatment for MIRCTs without glenohumeral arthritis. We report significant improvements in PROs, ROM, and patient satisfaction and a lower complication rate than previously reported. In addition, we noted that higher preoperative aFE resulted in a high patient satisfaction rate and was not associated with poorer outcomes as has been previously reported. Longer-term follow-up and prospective studies are needed to confirm our results.

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