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Revision reverse total shoulder arthroplasty in patients 65 years old and younger: outcome comparison with older patients



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Background: Reverse total shoulder arthroplasty (RTSA) is a procedure growing in prevalence among younger populations. Consequently, its use in revision arthroplasty is growing in this demographic. However, studies examining the functional outcomes of revision RTSA in younger populations compared with older populations are lacking. The primary purpose of this study is to evaluate the functional outcomes of revision RTSA in patients 65 years old and younger compared with older patients who underwent revision RTSA. We hypothesized that younger patients would have similar outcomes to older patients and both groups would demonstrate improvement in outcomes.

Methods: A retrospective review was conducted on a prospectively collected research database at a single tertiary referral center of all patients who underwent RTSA between 2007 and 2018. Patients 65 years old or younger who underwent a revision RTSA and had minimum 2-year follow-up were evaluated. A control group of patients ≥ 70 years old who underwent revision RTSA were also evaluated. Demographics, surgical factors, active range of motion (ROM), and patient-reported outcomes (PROMs) were compared. The ROM parameters measured were forward elevation, abduction, external rotation, and level of internal rotation. The PROMs collected included American Shoulder and Elbow Surgeons score, Simple Shoulder Test score, University of California–Los Angeles score, Constant score, normalized Constant, and Shoulder Pain and Disability Index 130. The differences in outcomes were compared against the minimal clinically important difference and substantial clinical benefit reported for primary reverse shoulder arthroplasty.

Results: A total of 81 patients undergoing revision RTSA were evaluated at a mean follow-up of 4.5 years with 42 patients in the study group and 39 patients in the control group. Both groups demonstrated similar demographics and rates of prior surgeries. Preoperative outcome scores were lower in the study group (≤ 65 years old) than those in the older control group with American Shoulder and Elbow Surgeons score, Simple Shoulder Test score, and Shoulder Pain and Disability Index 130 remaining worse postoperatively. Both groups experienced statistically significant improvements in ROM from before operation to after operation, with slightly higher improvements in overhead motion in the younger cohort. Both the study group and the control group demonstrated statistically significant improvements in all PROMs with improvement above the substantial clinical benefit for the Constant and Simple Shoulder Test scores. Despite lower functional outcomes reported in the study group postoperatively, the improvement from before operation to after operation in all PROMs was similar between groups.

Conclusion: Revision RTSA is a viable option for patients ≤ 65 years old with a poorly functioning shoulder arthroplasty. ROM and outcome improvements are similar compared with older patients undergoing revision RTSA, but the preoperative and postoperative functional outcomes are worse in the younger patients.

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Reverse total shoulder arthroplasty (RTSA) was originally designed to treat patients with severe rotator cuff deficiency.^{10,11} Many studies have reported good clinical outcomes,^{5,6,20,27,32,35,43,50} leading to an expansion of RTSA indications. In addition to severe rotator cuff deficiency, RTSA is now

used for fractures, instability arthropathy, shoulder girdle tumors, and revision arthroplasty.¹⁵ Historically, RTSA was reserved for older patients because of concerns regarding prosthesis longevity and the possibility of declining function over time.^{19,23} Despite this, younger patients are vulnerable to shoulder pathology that warrants RTSA, and as implant designs improve and complications decrease, RTSA has been extended to a younger population. Younger patients tend to have higher expectations after RTSA.³⁴ A number of studies have examined RTSA outcomes in younger populations (<65 years old)^{16,17,30,34,36,37,40,44,45} and suggest that RTSA in this demographic does yield functional improvement.

The demand for shoulder arthroplasty among younger adults is increasing and is projected to grow for years to come. Padegimas et al.⁴¹ showed that demand for primary shoulder arthroplasties in the younger generation is predicted to increase by 333% from 2011 to 2030. As the number of RTSAs increase, so will the number of complications and revisions.^{12,24} The reported revision rates for RTSA range from 10.1% to 13.4%,^{18,56} and in the younger population, the rate of revision was found to be higher than that of older, less active patients.^{7,19,49} Many studies have shown that revision RTSA has favorable clinical results,^{7,9,19,29,33,38,42} but few have specifically investigated revision RTSA outcomes in patients younger than 65 years old, and none to our knowledge have compared this demographic to an older cohort of patients.

The purpose of this study is to present clinical outcomes of a series of patients ≤ 65 years old who underwent revision RTSA and compare their outcomes with a control group of patients ≥ 70 years old. We hypothesize that the functional outcomes after revision RTSA will be comparable with older patients.

Methods and materials

A retrospective review was conducted on a prospectively collected research database at a tertiary referral center (University of Florida) of all patients who underwent RTSA between 10/1/2007 and 12/31/2018 that participated in the database. The inclusion criteria for the study cohort were patients 65 years old or younger at the time they underwent revision RTSA surgery and had a minimum follow-up of 2 years. Control patients were identified as patients who underwent revision RTSA, were 70 years or older at the time of surgery, and had a 2-year minimum follow-up. The exclusion criteria were revision for infection, any history of prior infection, fracture or tumor of the operated shoulder, and less than 2 years of follow-up.

All cases were managed with the deltopectoral approach and the same postoperative rehabilitation and weight-bearing precaution protocols.

Demographic and surgical data were collected including age, gender, medical comorbidities, type of the implant being revised, estimated blood loss, bone graft use, and whether the humeral stem was retained. Radiographic imaging was performed preoperatively and postoperatively on all patients using standardized anterior-posterior, axillary lateral, and scapular lateral views. Postoperative radiographs were evaluated for radiolucent lines, component loosening, and scapular notching. Scapular notching was classified as per the system introduced by Sirveaux et al.⁵⁰

Patients were followed at postoperative intervals of 2 weeks, 6 weeks, 3 months, 6 months, and annually thereafter. Functional scores were calculated at postoperative visits and included American Shoulder and Elbow Surgeons (ASES) score,³ Simple Shoulder Test-12 (SST-12),³ University of California–Los Angeles shoulder rating scale,² Constant shoulder score,¹³ normalized Constant shoulder score,²⁸ and the Shoulder Pain and Disability Index 130 (SPADI 130). Range of motion (ROM) measurements were obtained in a standardized manner using a goniometer by a research

coordinator (A.M.S.). These included active motion in forward elevation, abduction, external rotation at 0° abduction, and internal rotation to the anatomical level (vertebral level that the thumb could reach). In addition, strength of external rotation and abduction was measured. All complications relating to the surgery were reviewed.

The unpaired t-test assuming equal variance was used to compare continuous variables including the ROM parameters and outcome scores between groups. Patients undergoing another revision procedure after the index procedure were included in the demographic and complication comparisons, but not for the ROM and outcome comparisons. A Fisher exact test for dichotomous variables was used to compare demographic data between groups. Statistical significance was set at $P < .05$. In addition to statistical significance, the minimal clinically important difference (MCID) was also examined, as described by Simovitch et al for reverse shoulder arthroplasty (RSA).⁴⁷ This is a measurement that evaluates the threshold for clinical improvement that the patients can identify as an improvement. MCID values for RSA used in this study were ASES score, 10.3; Constant score, -0.3; University of California–Los Angeles score, 7.0; SST score, 1.4; SPADI score, 20.0; active shoulder abduction, -1.9; active forward flexion, -2.9; and active shoulder external rotation, -5.3. The substantial clinical benefit (SCB), another parameter described by Simovitch et al,⁴⁸ evaluates the threshold of a patient's perception of a substantial clinical improvement, as evaluation based on statistical significance alone can be limited in evaluating clinical improvements.³¹ The MCID and SCB values for RSA used in this study are referenced in [Table III](#).

Results

A total of 215 revision shoulder arthroplasties were performed in the study time period in 197 patients ([Fig. 1](#)). Forty-two study patients (18 men and 24 women) were identified in the younger study group with an average age of 57.9 years (range, 38–64 years) and an average follow-up of 4.7 years (range, 2–11 years; median, 4 years). The two-year follow-up rate for both study and control groups was 65% for patients meeting the inclusion criteria ([Fig. 1](#)). Twenty-six procedures (62%) were performed on the dominant arm. In the study group, 5 implants were revised to RTSA from resurfacing arthroplasty, 15 from hemiarthroplasty, 16 from TSA, and 6 from RTSA. Five patients (12%) in the study group had more than one arthroplasty before revision to RTSA.

The control group consisted of 39 patients, 15 men and 24 women, with an average age of 75.8 years (range, 70–85 years) and average follow-up of 4.5 years (range, 2–10 years; median, 4 years). Similar to the study group, 28 procedures (72%) were performed on the dominant arm. One of the controls had more than one arthroplasty before revision to RTSA (3%). Demographics and prior procedures were similar between groups (see [Table I](#)). Smokers comprised 14% of study patients and 13% of controls. Only 1 patient in the control group had chronic kidney disease not requiring dialysis, and none had severe liver disease. More patients in the control group did require glenoid bone grafting (28% vs. 7%, $P = .02$). There were no statistically significant differences between study patients and controls in blood loss or the number of retained humeral stems, but there was a higher prevalence of hypertension in the control group (72% vs. 48%, $P = .04$). There were no significant differences among other comorbidities.

Range of motion

Preoperative ROM was statistically similar between groups with all values being slightly lower in the younger patients ([Table II](#)). Final postoperative ROM remained similar in the study and control

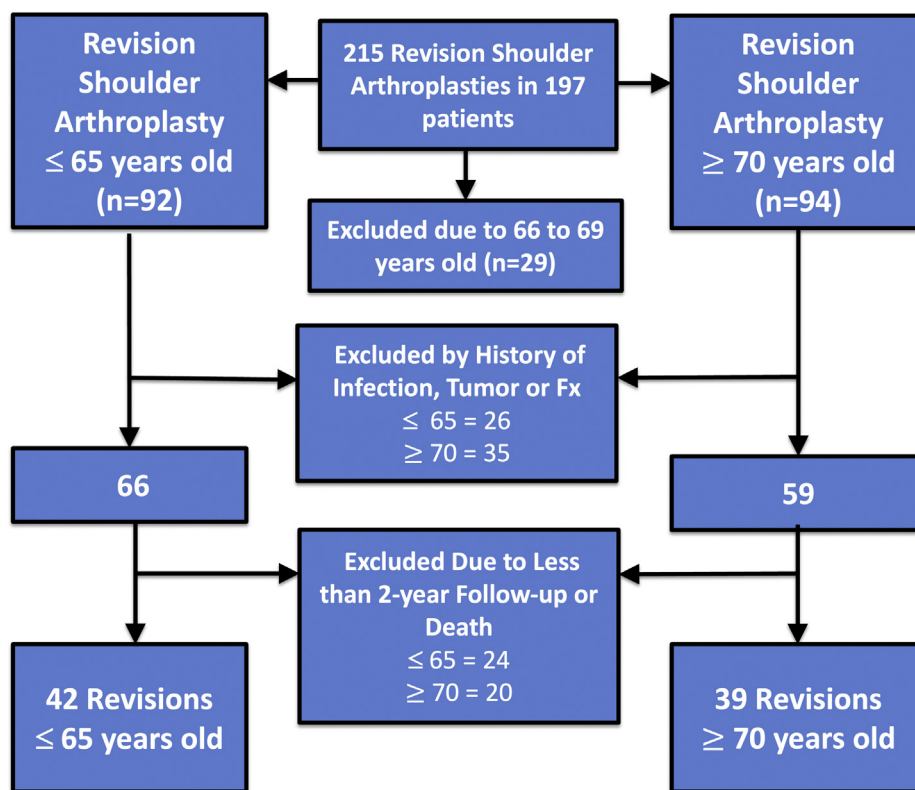


Figure 1 Flowchart of patient data collection. Patients who underwent revision RTSA from 10/1/2007 to 12/31/2018 were initially included, and patients were then excluded based on the criteria described in the figure. RTSA, reverse total shoulder arthroplasty.

Table I
Demographic and surgical data.

Demographic and surgical data	≤65 yr old	≥70 yr old	P value
Number of shoulders	42	39	
Mean follow-up (yr)	4.7	4.5	.643
Males/females	18/24	15/24	.821
Average age	57.9	75.8	<.001*
Right/left-handed	38/4	32/7	.339
Dominant side surgery	26	28	.480
Revision from:			
Resurfacing	5	2	.434
Hemiarthroplasty	15	10	.234
TSA	16	19	.375
RTSA	6	8	.561
Preoperative diagnosis			
Periprosthetic fracture	2	2	1.00
Hardware loosening (glenoid/humeral)	3/4	13/6	.369
Dislocations or instability	10	8	.793
RTC failure (prior hemi or TSA)	17	14	.819
Unexplained pain	9	7	.784
>1 arthroplasty before rTSA	5	1	.203
History of fracture on the operative side	8	10	.595
Diabetes (%)	12%	13%	1.00
Heart disease (%)	12%	15%	.751
Hypertension (%)	48%	72%	.041*
Blood loss (mL)	442	393	.210
Bone graft used	3	11	.018*
Stem retained	13	16	.365

TSA, anatomic total shoulder arthroplasty; RTSA, reverse total shoulder arthroplasty; RTC, rotator cuff; rTSA, revision reverse total shoulder arthroplasty.
*denotes statistical significance at $\alpha < 0.05$.

groups (Table II). Both the study group (patients ≤65 years old) and the control group (patients ≥70 years old) showed improvements in all postoperative ROM scores except external rotation compared

with preoperative values; however, external rotation improvement exceeded the MCID (Table III). The average active forward elevation in the study group improved from 62° to 108° ($P < .05$) and from 70° to 107° ($P < .05$) in the control group. The average active abduction improved from 57° to 99° ($P < .05$) in study patients and from 69° to 99° ($P < .05$) in control patients. Both of these improvements exceeded the SCB. Elevation strength improved from 5.6 to 9.6 in patients ≤65 years old and from 6.3 to 7.4 in patients ≥70 years old, neither of which was statistically significant. Improvements in ROM were statistically similar between the groups with the mean improvements in forward flexion and abduction being slightly higher for the younger patients.

Functional outcome scores

All preoperative outcome measures were significantly worse in the younger patient cohort (Table II). Final postoperative outcome scores remained worse in the younger patient population with the ASES score, SST, and SPADI-130 reaching significance (Table II).

Both cohorts of patients reported significant improvements in outcome scores from before operation to after operation in all outcome measures evaluated, with all improvements exceeding the MCID (Table III). The Constant score improved from 28 to 47 ($P < .05$) in patients ≤65 years old who underwent revision RTSA and from 36 to 51 ($P < .05$) in patients ≥70 years old who underwent revision RTSA. ASES scores increased from 32 to 55 ($P < .05$) in the younger cohort and from 45 to 71 ($P < .05$) in the older cohort. The magnitude of change in outcome scores from before operation to after operation was similar between the 2 groups, despite slightly better ROM improvement in the younger patient cohort (Table III).

Table II
Preoperative and postoperative active ROM and outcome scores.

Outcome	Preoperative		P value	Postoperative		P value
	≤65 yr old	≥70 yr old		≤65 yr old	≥70 yr old	
Forward elevation	62°	70°	.284	108°	107°	.894
Abduction	57°	69°	.105	99°	99°	.964
External rotation	21°	26°	.366	24°	25°	.828
Internal rotation score	3.7	4.0	.733	4.3	5.5	.176
ASES	32.2	45.4	.003*	55.1	70.5	.008*
SST	3.0	4.8	.005*	6.5	8.3	.025*
UCLA	11.9	15.1	.013*	21.7	23.8	.298
Constant	27.7	35.6	.015*	46.8	51.1	.355
Normalized Constant	31.3	42.3	.026*	53.3	61.0	.136
SPADI-130	92.8	80.0	.026*	62.4	39.8	.002*
ER strength (pounds)	7.4	6.8	.681	9.3	7.6	.328
Elevation strength (pounds)	5.6	6.3	.620	9.6	7.4	.182

ASES, American Shoulder and Elbow Surgeons; SST, Simple Shoulder Test; UCLA, University of California—Los Angeles; SPADI-130, Shoulder Pain and Disability Index 130; ER, external rotation.
*denotes statistical significance at $\alpha < 0.05$.

Table III
Changes in clinical outcomes, MCID and SCB.

Outcome	Change from preop to postop			MCID	SCB
	≤65 yr old	≥70 yr old	P value		
Forward elevation	46°	36°	.099	−2.9°	22.3°
Abduction	42°	30°	.090	−1.9°	19.6°
External rotation	3°	−1°	.301	−5.3°	3.6°
Internal rotation score	0.6	1.6	.541		
ASES	22.9	25.2	.968	10.3	25.9
SST	3.4	3.5	.826	1.4	3.2
UCLA	9.8	8.7	.532	7.0	10.4
Constant	19.2	15.5	.227	−0.3	13.6
Normalized Constant	22.0	18.6	.276		
SPADI-130	−30.4	−40.1	.369		
ER strength (pounds)	2.0	0.8	.189		
Elevation strength (pounds)	4.0	1.1	.097		

MCID, minimal clinically important difference; SCB, substantial clinical benefit; ASES, American Shoulder and Elbow Surgeons; SST, Simple Shoulder Test; UCLA, University of California—Los Angeles; SPADI-130, Shoulder Pain and Disability Index 130; ER, external rotation.

Complications

There was no statistically significant difference in complication rates between patients ≤65 years old who underwent revision RTSA and patients ≥70 years old who underwent revision RTSA (see Table IV). Complications occurred in 24% of study patients and 23% of control patients. Three patients in the younger group (7%) underwent revision surgery, with no patients over 70 years old undergoing re-revision surgery. Four patients (10%) in the study group had instability with 3 requiring closed reduction, whereas no instability occurred in the control group. Periprosthetic fractures were sustained by 10% of patients in both groups all treated non-operatively. Scapular notching was seen more commonly in the older patients (26% vs. 5%, $P = .013$).

Discussion

With the growing number of revision shoulder arthroplasty procedures performed, studies evaluating outcomes in different populations are necessary to improve appropriate patient counseling. Specifically, this study evaluated the outcome differences between younger and older patients undergoing revision to reverse shoulder arthroplasty. When performed in patients ≤65 years old, revision to RTSA resulted in lower postoperative overhead ROM and outcome scores than in patients ≥70 years, but improvements in

ROM and outcome scores were similar. These results suggest that younger patients have higher expectations for revision RTSA than older patients given their lower functional outcome scores despite similar ROM, but do obtain significant benefit in overhead ROM and outcome scores after revision RTSA.

Multiple studies have reported on the outcomes of young patients undergoing primary RTSA generally with good outcomes.^{7,16,17,30,34,36,37,40,44,45} One recent systematic review which included 6 articles and 245 patients showed significant midterm functional outcome improvements in patients ≤65 years old who underwent RTSA, but reported a high complication rate of 13%.⁵² In addition, Muh et al³⁷ noted a relatively low satisfaction rate of 81% in young patients who underwent RTSA for multiple indications including failed arthroplasty despite improved functional outcomes. Friedman et al²² analyzed a large database of 660 patients who underwent primary RTSA and found that for every 1-year increase in patient age, there was a 0.19-point increase in the ASES score in spite of a 0.39-degree decrease in forward flexion, suggesting that younger patients expect higher function and have less satisfaction than older patients who underwent primary RTSA.

Since the onset of its use in revision arthroplasty, multiple studies have proven RTSA to be a reliable option with overall good outcomes.^{1,4,14,21,25,26,29,33,38,39,42,46,51,53,54} Postoperative final outcome scores have been reported as decent for revision to RTSA for a variety of indications, including Constant scores between 49.3 and 60.6,^{25,26} ASES scores between 56.3 and 71.3,^{4,21,25,26,33,39,42,46,51,53,54} and SST scores between 4.0 and 7.6,^{21,38,42,53,54} which are similar to our study.

Although the efficacy of RTSA for revision arthroplasty has been demonstrated, there is only one study to our knowledge that specifically investigates the outcomes of revision to RTSA in younger patients. Black et al⁷ investigated the outcomes and complications experienced by patients ≤65 years old undergoing revision RTSA. Their study compared a cohort of 32 patients with a mean age of 59 years undergoing revision RTSA with an age-matched control group of 33 patients undergoing primary RTSA. Black et al⁷ showed that the visual analog scale for pain, the ASES score, and the SST were similar preoperatively and postoperatively in young patients who underwent primary and revision RTSA with significant improvements in both groups, but the subjective shoulder value was better postoperatively for the patients who underwent primary RTSA (76% vs. 60%, respectively, $P = .05$). This suggests that although significant improvements are possible with revision RTSA in young patients, they appear to perceive their function as moderately less compared with similarly aged patients with primary RTSA.

Table IV
Complications.

Complications	≤65 yr old	≥70 yr old	P value
Revision surgery	3 (7%)	0	.242
Infection	0	0	1.00
Periprosthetic fracture	4 (10%)	4 (10%)	1.00
Instability	4 (10%)	0	.117
	-		
	3 closed reduction		
	-		
	1 subluxation		
Glenoid loosening	2 (5%)	4 (10%)	.421
Humeral loosening	2 (5%)	1 (3%)	1.00
Total patients with any complication besides notching	10 (24%)	9 (23%)	1.00
Scapular notching	2 (5%)	10 (26%)	.013*

*denotes statistical significance at $\alpha < 0.05$.

Our study suggests that younger patients undergoing revision to RTSA have higher expectations of function from the surgery than older patients given that the improvement in overhead ROM was slightly better for the younger patients in our study, but the post-operative outcomes in the young cohort were worse (despite a similar change from before operation to after operation). One similarly designed study which compared the results of younger and older patients undergoing primary RTSA showed a similar trend as our study.³⁴ Matthews et al³⁴ examined primary RTSA outcomes in a group of patients ≤65 years old compared with a control group of patients ≥70 years old. In their cohort of 86 patients (matched by sex and preoperative diagnosis), they found worse preoperative and postoperative functional outcomes in the patients ≤65 years old who underwent RTSA than in patients ≥70 years old who underwent RTSA. However, improvement from before operation to after operation was comparable between groups. We believe that the explanation for this phenomenon lies in the difference of perception of outcomes between the older and younger patients. It is believed that younger patients who undergo RTSA have higher activity levels and expectations than older patients who receive the same procedure. Another similar study comparing young patients who underwent primary RTSA with an older patient cohort reported similar functional outcome scores and satisfaction between the groups with only postoperative ROM being better in the younger patients which may be suggestive of their higher expectations (similar functional scores despite better ROM),³⁰ which is similar to the findings in our study on revision RTSA. Walters et al⁵⁵ performed a study examining the activity levels of patients <65 years old who underwent RTSA and those who are >65 years old and found that there were no significant differences in reported postoperative activity levels between the groups. In addition, younger patients self-regulated their activities to minimize pain. This leads us to believe that the reason for lower postoperative outcome scores in younger patients is due to higher expectations and a worse perception of function in that demographic.

Although revision to RTSA has shown promising results, complications remain common. The complication rate of revision to RTSA reported in the literature ranges from 8.7% to 35.7%,^{4,8,25,26,33,38,39,42,46,51,54} and the reoperation rate reported ranges from 7.7% to 23.8%,^{1,21,25,26,33,38,39,42,46,51,53} which are both similar to our study. However, these studies did not specifically examine younger patients. Some studies have shown that younger patients have higher revision rates in primary RTSA than older patients.^{7,19,49} Therefore, it is important for surgeons to weigh the

potential benefits of the procedure with its complications when discussing revision RTSA.

There are a number of limitations associated with this study. First, the study was retrospective in nature and is subject to the limitations associated with this study type. In addition, the relatively short mean follow-up time of around 4.5 years may not be enough time for late complications to occur. Further long-term follow-up is needed to understand the complications that can occur over the long term. The type of arthroplasty before the revision to reverse shoulder arthroplasty was not matched between cases and controls because of lack of sufficient matched controls based on the previous implant or indication for revision which can introduce some bias. Finally, the relatively small sample size is a limitation, and larger studies are needed to truly understand the outcomes of younger patients undergoing revision RTSA.

Conclusion

Our findings show that patients ≤65 years old who undergo revision RTSA experience improved functional outcomes compared with before operation, but their final postoperative outcomes are inferior compared with that of an older cohort of patients (≥70 years old), despite a similar rate of outcome improvement. Revision RTSA is a reliable procedure to reduce pain and restore function in young patients with failed prior shoulder arthroplasty, but more long-term studies are needed to fully elucidate how patients fare after the procedure.

Disclaimers:

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Conflicts of interest: Dr. Thomas W. Wright receives royalties and has a consultancy agreement with Exactech, Inc. Dr. Bradley S. Schoch receives royalties and has a consultancy agreement with Exactech, Inc. Dr. Joseph J. King is a paid consultant with Exactech, Inc. The University of Florida Department of Orthopaedics and Rehabilitation receives research support from Exactech, Inc. The remaining authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

References

- Alentorn-Geli E, Clark NJ, Assenmacher AT, Samuelsen BT, Sánchez-Sotelo J, Cofield RH, et al. What are the complications, Survival, and outcomes after revision to reverse shoulder arthroplasty in patients older than 80 Years? *Clin Orthop Relat Res* 2017;475:2744–51. <https://doi.org/10.1007/s11999-017-5406-6>.
- Amstutz HC, Sew Hoy AL, Clarke IC. UCLA anatomic total shoulder arthroplasty. *Clin Orthop Relat Res* 1981;7:20.
- Angst F, Schwyzer HK, Aeschlimann A, Simmen BR, Goldhahn J. Measures of adult shoulder function: Disabilities of the Arm, shoulder, and Hand Questionnaire (DASH) and its short version (QuickDASH), shoulder pain and Disability index (SPADI), American Shoulder and Elbow Surgeons (ASES) Society standardized shoulder assessment form, Constant (Murley) score (CS), Simple shoulder test (SST), Oxford shoulder score (OSS), shoulder Disability Questionnaire (SDQ), and Western Ontario shoulder instability index (WOSI). *Arthritis Care Res (Hoboken)* 2011;63:S174–88. <https://doi.org/10.1002/acr.20630>.
- Austin L, Zmistowski B, Chang ES, Williams GR. Is reverse shoulder arthroplasty a reasonable alternative for revision arthroplasty? *Clin Orthop Relat Res* 2011;469:2531–7. <https://doi.org/10.1007/s11999-010-1685-x>.
- Baulot E, Chabernaud D, Grammont PM. [Results of Grammont's inverted prosthesis in omarthritis associated with major cuff destruction. Apropos of 16 cases]. *Acta Orthop Belg* 1995;61:112–9.
- Baulot E, Garron E, Grammont PM. [Grammont prosthesis in humeral head osteonecrosis. Indications—results]. *Acta Orthop Belg* 1999;65:109–15.
- Black EM, Roberts SM, Siegel E, Yannopoulos P, Higgins LD, Warner JJ. Reverse shoulder arthroplasty as salvage for failed prior arthroplasty in patients 65 years of age or younger. *J Shoulder Elbow Surg* 2014;23:1036–42. <https://doi.org/10.1016/j.jse.2014.02.019>.
- Boileau P. Complications and revision of reverse total shoulder arthroplasty. *Orthop Traumatol Surg Res* 2016;102:S33–43. <https://doi.org/10.1016/j.otsr.2015.06.031>.
- Boileau P, Gonzalez JF, Chuinard C, Bicknell R, Walch G. Reverse total shoulder arthroplasty after failed rotator cuff surgery. *J Shoulder Elbow Surg* 2009;18:600–6. <https://doi.org/10.1016/j.jse.2009.03.011>.
- Boileau P, Watkinson D, Hatzidakis AM, Hovorka I, Neer Award 2005: the Grammont reverse shoulder prosthesis: results in cuff tear arthritis, fracture sequelae, and revision arthroplasty. *J Shoulder Elbow Surg* 2006;15:527–40. <https://doi.org/10.1016/j.jse.2006.01.003>.
- Boileau P, Watkinson DJ, Hatzidakis AM, Balg F. Grammont reverse prosthesis: design, rationale, and biomechanics. *J Shoulder Elbow Surg* 2005;14:1475–61S. <https://doi.org/10.1016/j.jse.2004.10.006>.
- Chalmers PN, Boileau P, Romeo AA, Tashjian RZ. Revision reverse shoulder arthroplasty. *J Am Acad Orthop Surg* 2019;27:426–36. <https://doi.org/10.5435/JAAOS-D-17-00535>.
- Constant CR, Murley AH. A clinical method of functional assessment of the shoulder. *Clin Orthop Relat Res* 1987;160–4.
- Dines JS, Fealy S, Strauss EJ, Allen A, Craig EV, Warren RF, et al. Outcomes analysis of revision total shoulder replacement. *J Bone Joint Surg Am* 2006;88:1494–500. <https://doi.org/10.2106/JBJS.D.02946>.
- Drake GN, O'Connor DP, Edwards TB. Indications for reverse total shoulder arthroplasty in rotator cuff disease. *Clin Orthop Relat Res* 2010;468:1526–33. <https://doi.org/10.1007/s11999-009-1188-9>.
- Ek ET, Neukom L, Catanzaro S, Gerber C. Reverse total shoulder arthroplasty for massive irreparable rotator cuff tears in patients younger than 65 years old: results after five to fifteen years. *J Shoulder Elbow Surg* 2013;22:1199–208. <https://doi.org/10.1016/j.jse.2012.11.016>.
- Ernstbrunner L, Suter A, Catanzaro S, Rahm S, Gerber C. Reverse total shoulder arthroplasty for massive, irreparable rotator cuff tears before the age of 60 Years: long-term results. *J Bone Joint Surg Am* 2017;99:1721–9. <https://doi.org/10.2106/JBJS.17.00095>.
- Favard L. Revision of total shoulder arthroplasty. *Orthop Traumatol Surg Res* 2013;99:S12–21. <https://doi.org/10.1016/j.otsr.2012.11.010>.
- Favard L, Levigne C, Nerot C, Gerber C, De Wilde L, Mole D. Reverse prostheses in arthropathies with cuff tear: are survivorship and function maintained over time? *Clin Orthop Relat Res* 2011;469:2469–75. <https://doi.org/10.1007/s11999-011-1833-y>.
- Ferreira Neto AA, Malavolta EA, Assunção JH, Trindade EM, Gracitelli MEC. Reverse shoulder arthroplasty: clinical results and quality of life evaluation. *Rev Bras Ortop* 2017;52:298–302. <https://doi.org/10.1016/j.rboe.2017.04.007>.
- Franke KJ, Christmas KN, Downes KL, Mighell MA, Frankle MA. Does the etiology of a failed hemiarthroplasty affect outcomes when revised to a reverse shoulder arthroplasty? *J Shoulder Elbow Surg* 2020;29:S149–56. <https://doi.org/10.1016/j.jse.2019.08.019>.
- Friedman RJ, Cheung EV, Flurin PH, Wright T, Simovitch RW, Bolch C, et al. Are age and patient gender associated with different rates and magnitudes of clinical improvement after reverse shoulder arthroplasty? *Clin Orthop Relat Res* 2018;476:1264–73. <https://doi.org/10.1007/s11999-000000000000270>.
- Guery J, Favard L, Sirveaux F, Oudet D, Mole D, Walch G. Reverse total shoulder arthroplasty. Survivorship analysis of eighty replacements followed for five to ten years. *J Bone Joint Surg Am* 2006;88:1742–7. <https://doi.org/10.2106/JBJS.E.00851>.
- Habermeyer P, Magosch P. [Strategies in revision shoulder arthroplasty]. *Orthopade* 2013;42:542–51. <https://doi.org/10.1007/s00132-012-2025-5>.
- Holschen M, Franetzi B, Witt KA, Liem D, Steinbeck J. Conversions from anatomic shoulder replacements to reverse total shoulder arthroplasty: do the indications for initial surgery influence the clinical outcome after revision surgery? *Arch Orthop Trauma Surg* 2017;137:167–72. <https://doi.org/10.1007/s00402-016-2595-5>.
- Holschen M, Franetzi B, Witt KA, Liem D, Steinbeck J. Is reverse total shoulder arthroplasty a feasible treatment option for failed shoulder arthroplasty? A retrospective study of 44 cases with special regards to stemless and stemmed primary implants. *Musculoskelet Surg* 2017;101:173–80. <https://doi.org/10.1007/s12306-017-0467-y>.
- Kang JR, Dubiel MJ, Cofield RH, Steinmann SP, Elhassan BT, Morrey ME, et al. Primary reverse shoulder arthroplasty using contemporary implants is associated with very low reoperation rates. *J Shoulder Elbow Surg* 2019;28:S175–80. <https://doi.org/10.1016/j.jse.2019.01.026>.
- Katolik LI, Romeo AA, Cole BJ, Verma NN, Hayden JK, Bach BR. Normalization of the Constant score. *J Shoulder Elbow Surg* 2005;14:279–85. <https://doi.org/10.1016/j.jse.2004.10.009>.
- Kelly JD, Zhao JX, Hobgood ER, Norris TR. Clinical results of revision shoulder arthroplasty using the reverse prosthesis. *J Shoulder Elbow Surg* 2012;21:1516–25. <https://doi.org/10.1016/j.jse.2011.11.021>.
- Leathers MP, Ialenti MN, Feeley BT, Zhang AL, Ma CB. Do younger patients have better results after reverse total shoulder arthroplasty? *J Shoulder Elbow Surg* 2018;27:S24–8. <https://doi.org/10.1016/j.jse.2017.11.014>.
- Leopold SS, Porcher R. Editorial: the minimum clinically important difference—the Least We can do. *Clin Orthop Relat Res* 2017;475:929–32. <https://doi.org/10.1007/s11999-017-5253-5>.
- Leung B, Horodyski M, Struk AM, Wright TW. Functional outcome of hemiarthroplasty compared with reverse total shoulder arthroplasty in the treatment of rotator cuff tear arthropathy. *J Shoulder Elbow Surg* 2012;21:319–23. <https://doi.org/10.1016/j.jse.2011.05.023>.
- Levy JC, Virani N, Pupello D, Frankle M. Use of the reverse shoulder prosthesis for the treatment of failed hemiarthroplasty in patients with glenohumeral arthritis and rotator cuff deficiency. *J Bone Joint Surg Br* 2007;89:189–95. <https://doi.org/10.1302/0301-620X.89B2.18161>.
- Matthews CJ, Wright TW, Farmer KW, Struk AM, Vasilopoulos T, King JJ. Outcomes of primary reverse total shoulder arthroplasty in patients younger than 65 Years old. *J Hand Surg Am* 2019;44:104–11. <https://doi.org/10.1016/j.jhbsa.2018.11.008>.
- Mizuno N, Denard PJ, Raiss P, Walch G. Reverse total shoulder arthroplasty for primary glenohumeral osteoarthritis in patients with a biconcave glenoid. *J Bone Joint Surg Am* 2013;95:1297–304. <https://doi.org/10.2106/JBJS.L.00820>.
- Monir JG, Abeyewardene D, King JJ, Wright TW, Schoch BS. Reverse shoulder arthroplasty in patients younger than 65 years, minimum 5-year follow-up. *J Shoulder Elbow Surg* 2020;29:e215–21. <https://doi.org/10.1016/j.jse.2019.10.028>.
- Muh SJ, Streit JJ, Wanner JP, Lenarz CJ, Shishani Y, Rowland DY, et al. Early follow-up of reverse total shoulder arthroplasty in patients sixty years of age or younger. *J Bone Joint Surg Am* 2013;95:1877–83. <https://doi.org/10.2106/JBJS.L.10005>.
- Ortmaier R, Resch H, Matis N, Blocher M, Auffarth A, Mayer M, et al. Reverse shoulder arthroplasty in revision of failed shoulder arthroplasty—outcome and follow-up. *Int Orthop* 2013;37:67–75. <https://doi.org/10.1007/s00264-012-1742-z>.
- Otte RS, Naylor AJ, Blanchard KN, Cancienne JM, Chan W, Romeo AA, et al. Salvage reverse total shoulder arthroplasty for failed anatomic total shoulder arthroplasty: a cohort analysis. *J Shoulder Elbow Surg* 2020;29:S134–8. <https://doi.org/10.1016/j.jse.2020.04.013>.
- Otto RJ, Clark RE, Frankle MA. Reverse shoulder arthroplasty in patients younger than 55 years: 2- to 12-year follow-up. *J Shoulder Elbow Surg* 2017;26:792–7. <https://doi.org/10.1016/j.jse.2016.09.051>.
- Padegimas EM, Maltenfort M, Lazarus MD, Ramsey ML, Williams GR, Namdari S. Future patient demand for shoulder arthroplasty by younger patients: national projections. *Clin Orthop Relat Res* 2015;473:1860–7. <https://doi.org/10.1007/s11999-015-4231-z>.
- Patel DN, Young B, Onyekwelu I, Zuckerman JD, Kwon YW. Reverse total shoulder arthroplasty for failed shoulder arthroplasty. *J Shoulder Elbow Surg* 2012;21:1478–83. <https://doi.org/10.1016/j.jse.2011.11.004>.
- Rittmeister M, Kerschbaumer F. Grammont reverse total shoulder arthroplasty in patients with rheumatoid arthritis and nonreconstructible rotator cuff lesions. *J Shoulder Elbow Surg* 2001;10:17–22.
- Samuelsen BT, Wagner ER, Houdek MT, Elhassan BT, Sánchez-Sotelo J, Cofield R, et al. Primary reverse shoulder arthroplasty in patients aged 65 years or younger. *J Shoulder Elbow Surg* 2017;26:e13–7. <https://doi.org/10.1016/j.jse.2016.05.026>.
- Sershon RA, Van Thiel GS, Lin EC, McGill KC, Cole BJ, Verma NN, et al. Clinical outcomes of reverse total shoulder arthroplasty in patients aged younger than 60 years. *J Shoulder Elbow Surg* 2014;23:395–400. <https://doi.org/10.1016/j.jse.2013.07.047>.
- Shields E, Wiater JM. Patient outcomes after revision of anatomic total shoulder arthroplasty to reverse shoulder arthroplasty for rotator cuff failure or

- component loosening: a matched cohort study. *J Am Acad Orthop Surg* 2019;27:e193-8. <https://doi.org/10.5435/JAAOS-D-17-00350>.
47. Simovitch R, Flurin PH, Wright T, Zuckerman JD, Roche CP. Quantifying success after total shoulder arthroplasty: the minimal clinically important difference. *J Shoulder Elbow Surg* 2018;27:298-305. <https://doi.org/10.1016/j.jse.2017.09.013>.
 48. Simovitch R, Flurin PH, Wright T, Zuckerman JD, Roche CP. Quantifying success after total shoulder arthroplasty: the substantial clinical benefit. *J Shoulder Elbow Surg* 2018;27:903-11. <https://doi.org/10.1016/j.jse.2017.12.014>.
 49. Singh JA, Sperling JW, Cofield RH. Revision surgery following total shoulder arthroplasty: analysis of 2588 shoulders over three decades (1976 to 2008). *J Bone Joint Surg Br* 2011;93:1513-7. <https://doi.org/10.1302/0301-620X.93B11.26938>.
 50. Sirveaux F, Favard L, Oudet D, Huquet D, Walch G, Molé D. Grammont inverted total shoulder arthroplasty in the treatment of glenohumeral osteoarthritis with massive rupture of the cuff. Results of a multicentre study of 80 shoulders. *J Bone Joint Surg Br* 2004;86:388-95. <https://doi.org/10.1302/0301-620x.86b3.14024>.
 51. Tashjian RZ, Granger E, Broschinsky K, Kawakami J, Chalmers PN. Effect of complications on outcomes after revision reverse total shoulder arthroplasty. *JSES Int* 2020;4:662-8. <https://doi.org/10.1016/j.jseint.2020.03.016>.
 52. Vancolen SY, Elsayi R, Horner NS, Leroux T, Alolabi B, Khan M. Reverse total shoulder arthroplasty in the younger patient (≤ 65 years): a systematic review. *J Shoulder Elbow Surg* 2020;29:202-9. <https://doi.org/10.1016/j.jse.2019.06.018>.
 53. Wagner ER, Hevesi M, Houdek MT, Cofield RH, Sperling JW, Sanchez-Sotelo J. Can a reverse shoulder arthroplasty be used to revise a failed primary reverse shoulder arthroplasty?: revision reverse shoulder arthroplasty for failed reverse prosthesis. *Bone Joint J* 2018;100-B:1493-8. <https://doi.org/10.1302/0301-620X.100B11.BJJ-2018-0226.R2>.
 54. Walker M, Willis MP, Brooks JP, Pupello D, Mulieri PJ, Frankle MA. The use of the reverse shoulder arthroplasty for treatment of failed total shoulder arthroplasty. *J Shoulder Elbow Surg* 2012;21:514-22. <https://doi.org/10.1016/j.jse.2011.03.006>.
 55. Walters JD, Barkoh K, Smith RA, Azar FM, Throckmorton TW. Younger patients report similar activity levels to older patients after reverse total shoulder arthroplasty. *J Shoulder Elbow Surg* 2016;25:1418-24. <https://doi.org/10.1016/j.jse.2016.01.011>.
 56. Zumstein MA, Pinedo M, Old J, Boileau P. Problems, complications, reoperations, and revisions in reverse total shoulder arthroplasty: a systematic review. *J Shoulder Elbow Surg* 2011;20:146-57. <https://doi.org/10.1016/j.jse.2010.08.001>.