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REVIEW ARTICLES

Complications and implant survivorship following primary reverse total shoulder arthroplasty in patients younger than 65 years: a systematic review

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Background: Concerns exist regarding the complication rates and implant survivorship of reverse total shoulder arthroplasty (RTSA) in younger patients.

Methods: A systematic review of the literature regarding the existing evidence on RTSA in patients younger than 65 years was performed using the CENTRAL (Cochrane Central Register of Controlled Trials), PubMed, and Embase databases on June 9, 2019. Articles published between 1995 and 2019 with combinations of the following keywords were identified: "reverse shoulder arthroplasty" and "65," "60," and/or "55." Complications, reoperations, and revisions were recorded. Reoperation-free survival and implant survival rates were grouped at 2, 5, and 10 years. Range of motion and clinical outcomes, along with postoperative radiographic results, were recorded.

Results: Data from 7 studies with a total of 286 shoulders were obtained for quantitative analysis. The mean patient age was 58.4 years (mean age range, 48.9-60.4 years), and the mean follow-up period was 4.7 years (mean follow-up range, 3.0-7.8 years). The overall rate of complications was 18.6%; reoperations, 14.4%; and revisions, 11.2%. The reoperation-free survival rate was 97% at 2 years, 88%-90% at 5 years, and 76% at 10 years. The implant survival rate was 99% at 2 years, 91%-98% at 5 years, and 88% at 10 years. Active abduction, forward elevation, and external rotation significantly improved from preoperatively to postoperatively. All clinical outcome measures significantly improved from preoperatively to postoperatively, with no decline seen over time. The overall rate of infrascapular notching was 22.7% at final follow-up.

Conclusion: RTSA is safe and effective in patients younger than 65 years. Complication, reoperation, and revision rates were similar to those seen in older patient cohorts, without an increase in revisions owing to aseptic loosening. Clinical outcome scores showed significant and lasting improvements.

Level of evidence: Level IV; Systematic Review

Keywords: Reverse total shoulder arthroplasty; young patients; complication; reoperation; revision; implant survival

Reverse total shoulder arthroplasty (RTSA) has classically been used to restore function and decrease pain in elderly patients with cuff tear arthropathy.[5-7,40] Recently, its indications have expanded to include massive rotator cuff

No institutional review board approval was required for this systematic review.

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tears, proximal humeral fractures or fracture sequelae, inflammatory arthritis, and revision arthroplasty.[10,16,28,37,49] Although short- to mid-term clinical outcomes of RTSA in elderly patients have been excellent, concerns remain over long-term implant survivorship as well as the high complication rates reported in some series.[4,22,46,49] In addition, several studies have demonstrated clinical deterioration after 8-10 years without radiographic evidence of prosthetic failure.[15,22] Surgeons and consensus groups have thus historically recommended restricting the use of RTSA to older patients.[24]

The management of the young patient with pathology meeting the indications for RTSA poses a challenge to the treating surgeon, and this dilemma is becoming increasingly prevalent. It is expected that the demand for primary arthroplasty in patients younger than 55 years will increase 333% by 2030.[36] Although joint-sparing options such as physical therapy, corticosteroid injection, arthroscopic débridement, rotator cuff repair, tendon transfer, and superior capsular reconstruction exist, these may not durably improve shoulder pain and function.[14,20] In recent years, as surgical technique and implant design have improved, RTSA has been adopted in younger patients and multiple clinical outcome studies have been published with short- to mid-term follow-up.[2,12-14,25,29,32,35,42,43]

In light of the high functional demands of this patient demographic, it is important to critically evaluate the clinical outcomes and longevity of RTSA in younger patients. Similarly to previous work performed by Roberson et al[38] in total shoulder arthroplasty, the main purpose of this study was to systematically review the existing literature to assess overall complication rates and implant survival across different time points following RTSA in patients younger than 65 years. In addition, clinical outcomes, range of motion (ROM), and radiographic findings are reported.

Materials and methods

This study was a systematic review of the literature regarding the existing evidence on RTSA in patients younger than 65 years. It was conducted in accordance with the 2009 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) statement.[31] The study was performed using the CENTRAL (Cochrane Central Register of Controlled Trials), PubMed, and Embase databases on June 9, 2019. Articles published between 1995 and 2019 with combinations of the following keywords were identified: ''reverse shoulder arthroplasty'' and ''65,'' ''60,'' and/or ''55.'' Two authors (B.T.G. and J.D.S.) independently selected articles based on title, then abstract, and finally, full-text review, and the results were compared at each stage of the selection process. Any disagreements were resolved by communication with a third author (B.T.S.).

We selected studies that reported clinical outcomes and implant survival after RTSA in patients who were younger than 65 years at the time of surgery. The inclusion criteria were (1) human studies in the English language, (2) minimum level IV case-series studies using Oxford Centre for Evidence-Based Medicine 2011 levels of evidence,[34,51] (3) primary RTSA, (4) minimum 2-year follow-up of entire patient cohort, and (5) clinical outcome scores. The exclusion criteria were (1) non–English-language human studies, (2) follow-up of less than 2 years, (3) no full text available, (4) no clinical outcomes reported, and (5) prior arthroplasty.

Data collection

Complications, reoperations, and revisions were recorded. Reoperation-free survival and implant survival rates were grouped at 2, 5, and 10 years. The following ROM values were included: active forward elevation, active abduction, and active external rotation with the arm at the side. Data on internal rotation were not available for collection. Data for the following clinical outcome scores were collected: American Shoulder and Elbow Surgeons (ASES) score, Simple Shoulder Test (SST) score, absolute Constant score (aCS), relative Constant score (rCS), Subjective Shoulder Value (SSV), University of California at Los Angeles (UCLA) shoulder score, and visual analog scale score for pain. Radiographic results included scapular notching according to the classification of Sirveaux et al,[46] glenoid lucency, and glenoid and humeral loosening.

Statistical analyses

Statistical analyses were performed using SPSS Statistics software (version 24.0; IBM, Armonk, NY, USA). Preoperative and postoperative clinical scores and ROM were compared using the Mann-Whitney *U* test. According to all of the included studies, the α level was set at .05, and all *P* values were 2-tailed.

Results

Study selection

We identified 9 studies after application of the inclusion and exclusion criteria: 3 level III and 6 level IV studies (Fig. 1).[2,12-14,23,29,32,35,42] Because of patient overlap in the studies by Ernstbrunner et al[13] and Ek et al,[12] the smaller study by Ernstbrunner et al was excluded. Thus, the final list included 8 studies for evaluation. Matthews et al[29] compared patients younger than 65 years with an older demographic, whereas Black et al[2] compared primary RTSA patients younger than 65 years with revision arthroplasty patients within the same age group. Muh et al[32] compared patients with primary RTSA and no prior surgery vs. patients with a history of surgery. The remaining studies reported data on patient cohorts younger than 65 years.[12-14,35,42] Because Hartzler et al[23] provided only qualitative data in a logistic regression analysis between young age and functional outcome, only 7 studies provided quantitative data for analysis. The

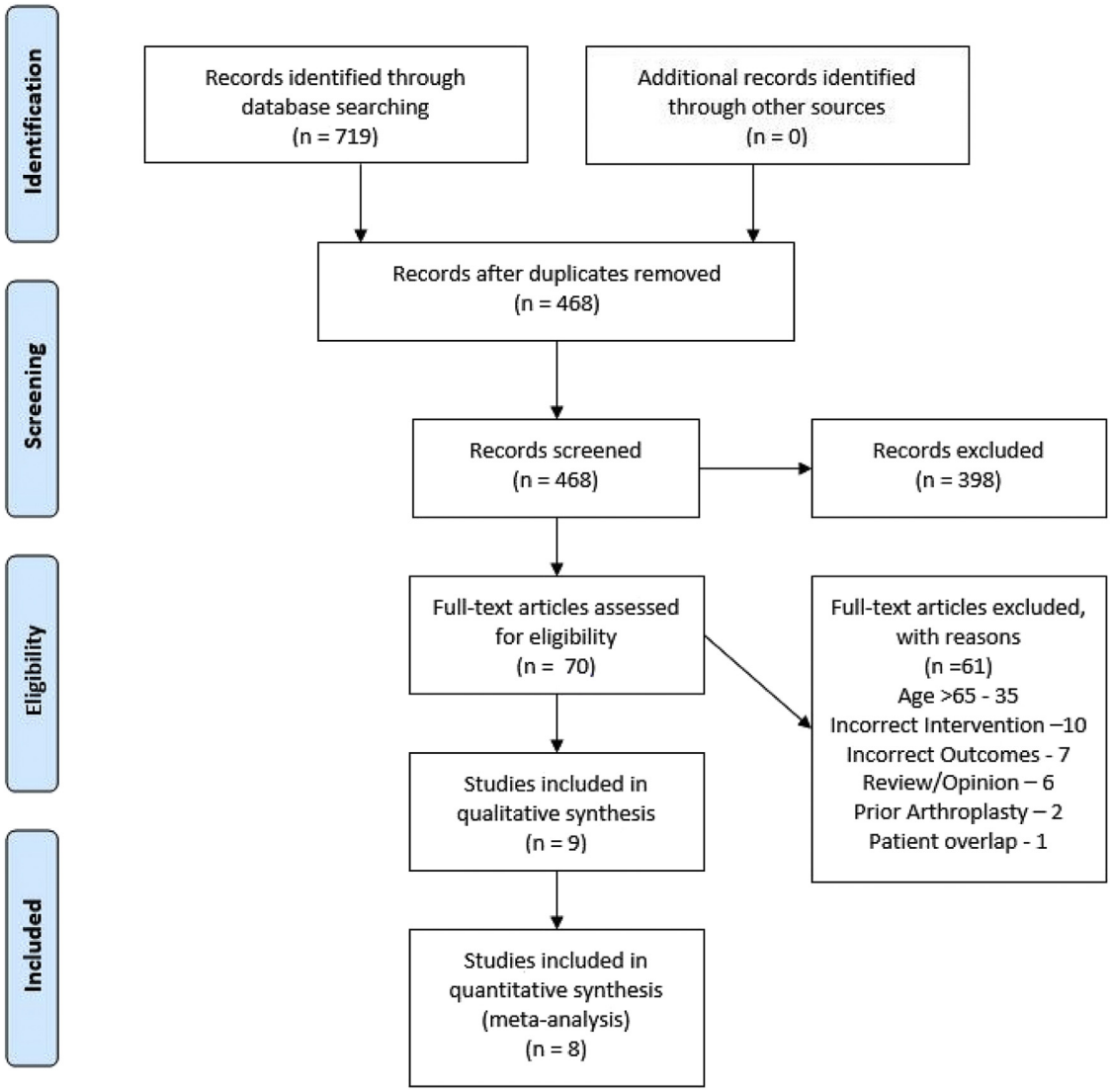

Figure 1 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) flowchart of study selection criteria.

earliest study was published in 2009, and the most recent study was published in 2019 (Table I).[14,29]

Demographic data

The included studies examined a total of 286 shoulders. There were a total of 96 men and 120 women, with 2 studies not reporting sex.[14,32] The average patient age was 58.4 years (range, 48.9-60.4 years). The mean follow-up period was 4.7 years (range, 3.0-7.8 years) postoperatively. The mean percentage of patients who underwent prior surgery, as reported by 3 studies, was 54%.[12,29,42] Two studies also reported the percentage of cases undergoing surgery on the dominant arm, which averaged 68.8%.[12,29] The indications for surgery in all studies included in the quantitative analysis are shown in Table II.

Complications, reoperations, and revisions

Of the 8 studies included in this review, 5 reported complications, reoperations, and revisions.[2,12,29,35,42] There were 40 postoperative complications reported among 215 shoulders (18.6%). Only 2 intraoperative complications were reported: 1 greater tuberosity fracture and 1 glenoid fracture. In the same group of patients, there were 31 reoperations and 24 revisions. Thus, the overall reoperation rate was 14.4%, and the overall revision rate was 11.2%. A detailed breakdown of complications is shown in Table III. The most frequent postoperative complications were instability, which occurred in 10 of 215 cases (4.7%) and led to revision in 9 of 10 cases, and infection, which also occurred in 10 cases (4.7%) and necessitated revision in all cases. Overall, the top 3 reasons for reoperation and revision were infection, instability, and fracture. Of note, the study by Ek et al[12] had the longest

Table I Individual study details and patient demographic characteristics

Study	Year	Journal	Level of evidence	Shoulders, n	Follow-up, yr	Mean age, yr	Sex
Black et al[2]	2014	*JSES*	III	33	4.6	59.3	24 F/9 M
Ek et al[12]	2013	*JSES*	IV	40	7.8	60.0	17 F/24 M
Matthews et al[29]	2019	*J Hand Surg Am*	III	43	4.0	60.4	26 F/17 M
Otto et al[35]	2017	*JSES*	IV	32	5.0	48.9	13 F/19 M
Samuelsen et al[42]	2017	*JSES*	IV	67	3.0	60.0	40 F/27 M
Favard et al[14]	2009	*OTSR*	IV	49	5.1	58.8	—
Muh et al[32]	2013	*JBJS*	IV	22	—	—	—
Total	—	—	—	286	4.7	58.4	120 F/96 M

JSES, Journal of Shoulder and Elbow Surgery; F, female; *M,* male; *OTSR, Orthopaedics & Traumatology: Surgery & Research; JBJS, Journal of Bone and Joint Surgery.*

follow-up rate and reported the highest complication, reoperation, and revision rates.

Survivorship

Data on implant survival were reported 2 of 8 studies. Samuelsen et al[42] reported a reoperation-free survival rate of 97% at 2 years and 90% at 5 years, whereas Ek et al[12] reported a rate of 88% at 5 years and 76% at 10 years. The implant survival rate as reported by Samuelsen et al was 99% at 2 years and 91% at 5 years, whereas Ek et al reported a rate of 98% at 5 years and 88% at 10 years (Table IV, Fig. 2). Additional analysis of reoperation-free survival data from 3 studies found an 84.4%-100% rate at 4-4.9 years. Similarly, the implant survival rate was 87.5%-100% at 4-4.9 years.

Range of motion

Four studies measured active abduction[12,29,35,42] and active forward elevation.[12,29,32,35] Active forward elevation improved from 70° to 123° ($P = .0001$), and active abduction improved from 62° to 118° ($P = .0003$). The patient cohort without any prior surgery in the study performed by Muh et al[32] demonstrated the highest average increase in forward elevation. Five studies reported preoperative and postoperative values for external rotation, with only 3 reporting statistically significant improvements.[12,29,32,35,42] Active external rotation significantly improved from 18.0° to 30° ($P = .03$).

Clinical outcomes

The ASES score was the most commonly reported outcome measure. Five studies reported postoperative ASES scores, with 3 reporting preoperative and postoperative values. The ASES score significantly improved from 31.3 to 68.3 ($P = .0003$). Four studies reported the SST, which significantly improved from 2.0 to 6.7 ($P = .03$).[2,29,35,42] Three studies reported preoperative and postoperative values for the Constant score, with 2 reporting the aCS and all 3 reporting the rCS. The aCS improved from 24.8 to 58.5 ($P = .003$), and the rCS improved from 33.5 to 71.9 ($P = .003$).[12,29,32] Two studies reported the postoperative SSV, which improved from 21.2 to 70.5 ($P = .01$).[12,29] One study reported improvement in the UCLA score from 12.6 to 27.[29] The visual analog scale score for pain was reported in 2 studies, which improved from 7.3 to 2.2 ($P = .006$).[2,32] In the only study to report patient satisfaction, Samuelsen et al[42] found that 90% of patients were satisfied via a binary

Table II Summary of indications for reverse total shoulder arthroplasty

Authors	Total cases, n	CTA, n	MRCT, n	GHA, n	FX or FS, n	RA, n	Miscellaneous, n
Black et al[2]	33	—	33 (all PS)	—	—	—	—
Ek et al[12]	40	19*	21	—	—	—	—
Matthews et al[29]	43	23	2	11	4	3	—
Otto et al[35]	32	10	—	4	5	2	Failure of RC surgery in 11
Samuelsen et al[42]	67	51	—	15	—	—	Osteonecrosis in 1
Favard et al[14]	49	—	—	—	—	—	—
Muh et al[32]	22	8	9 (all PS)	—	1 (MRCT)	1 (MRCT)	Post-traumatic arthritis in 3
Total, n (%)†	286	111 (38.8)	65 (22.7)	30 (10.5)	10 (3.5)	6 (2.1)	15 (5.2)

CTA, cuff tear arthropathy; *MRCT,* massive rotator cuff tear; *GHA,* glenohumeral arthritis; *FX,* fracture; *FS,* fracture sequelae; *RA,* rheumatoid arthritis; *PS,* pseudoparalysis; *RC,* rotator cuff.

* Grade 4 or 5 according to Hamada-Walch system.[23,49]

† Percentage of all cases.

Table III Incidences of complications, reoperations, and revisions

	No. of complications (% of all cases)	No. of reoperations (% of all cases)	No. of revisions (% of all cases)
Instability	10 (4.7)	9 (4.2)	9 (4.2)
Infection	10 (4.7)	10 (4.7)	10 (4.7)
Fracture*	7 (3.3)	3 (1.4)	1 (0.5)
Glenoid failure	4 (1.9)	4 (1.9)	3 (1.4)
Other†	5 (2.3)	3 (1.4)	—
Neurologic‡	3 (1.4)	1 (0.5)	—
Polyethylene wear	1 (0.5)	1 (0.5)	1 (0.5)
Total	40 (18.6)§	31 (14.4)§	24 (11.2)§

* Scapular spine fracture in 4, acromial fracture in 2, and traumatic humeral fracture in 1.
† Hematoma in 2, deltoid rupture in 1, soft-tissue impingement in 1, and symptomatic hardware in 1.
‡ Radial nerve palsy in 1, brachial plexus palsy in 1, and unknown in 1.
§ Percentage of all 215 cases.

scale. The study by Matthews et al[29] was the only study to report the return-to-sports rate; it found that 67% of patients returned without limitation or with slight difficulty.

Radiographic outcomes

Data on inferior scapular notching were available for 176 shoulders across 4 studies, with an overall rate of 22.7%.[12,29,35,42] In all studies, scapular notching was classified according to the previously established classification system proposed by Sirveaux et al.[46] Grade 2 notching or higher was found in 12.5% of patients. A breakdown of scapular notching stratified by implant type was not available. Samuelsen et al[42] found an increased risk of notching in patients with cuff tear arthropathy. Ek et al[12] found significantly lower Constant scores in patients with any grade of notching. The study by Samuelsen et al was the only study to report glenoid lucency; it found a rate of 3%. The rate of humeral lucency was 0%. In 3 studies, the rate of radiographic glenoid and humeral loosening was 0%.[12,29,35]

Discussion

The literature is clear that RTSA improves clinical outcomes and decreases pain in appropriately selected patients.[17,22,33,46,49,50] However, concerns remain over reports of high complication rates and declining implant survivorship over time, which have tempered the enthusiasm for expanding this procedure to younger populations.[7,15,22] The aim of this study was to conduct a systematic review of RTSA in patients younger than 65 years, with a focus on complications and implant survival, as well as to assess clinical and radiographic outcomes.

In this systematic review, the overall rate of complications was 18.6%; reoperations, 14.4%; and revisions, 11.2%. The reported rates reflect all postoperative complications as reported by the included studies. These rates compare favorably with the 24% complication rate found by Zumstein et al[52] in a 2011 meta-analysis of RTSA in all age groups. The higher rate of complications seen by Zumstein et al may be a result of their broad inclusion criteria, which included revision RTSA in 27.6% of cases. Instability and infection were the 2 most common and morbid complications seen in our study.

The rate of instability of 4.7% in this study was similar to but slightly higher than the 4.1% rate reported by Zumstein et al.[52] Among the patients with postoperative instability, 9 of 10 cases went on to revision. Rates of instability in the literature range from as low as 1.5% up to 31%,[8,9,18,47,52] and the most common associated factors include prosthesis design, surgical approach, elevated body mass index, male sex, and subscapularis deficiency. Although the precise causes of instability could not be determined from the available articles, the overall rate of instability certainly does not preclude the use of RTSA in patients younger than 65 years.

The postoperative infection rate found in this study was also 4.7%. All 10 patients with a diagnosis of a postoperative infection went on to revision. This infection rate falls within the range established in the literature relating to older patients of 1%-15%.[5,17,22,28,46,47,49]

Table IV Reoperation-free and implant survival rates in all studies

	Reoperation-free survival, %			Implant survival (revision free), %		
	2 yr	5 yr	10 yr	2 yr	5 yr	10 yr
Ek et al[12]	—	88	76	—	98	88
Samuelsen et al[42]	97	90	—	99	91	—
Black et al[2]	87.9 at mean follow-up of 4.5 yr			94.0 at mean follow-up of 4.5 yr		
Matthews et al[29]	100 at mean follow-up of 4.0 yr			100 at mean follow-up of 4.0 yr		
Otto et al[35]	84.4 at mean follow-up of 4.9 yr			87.5 at mean follow-up of 4.9 yr		

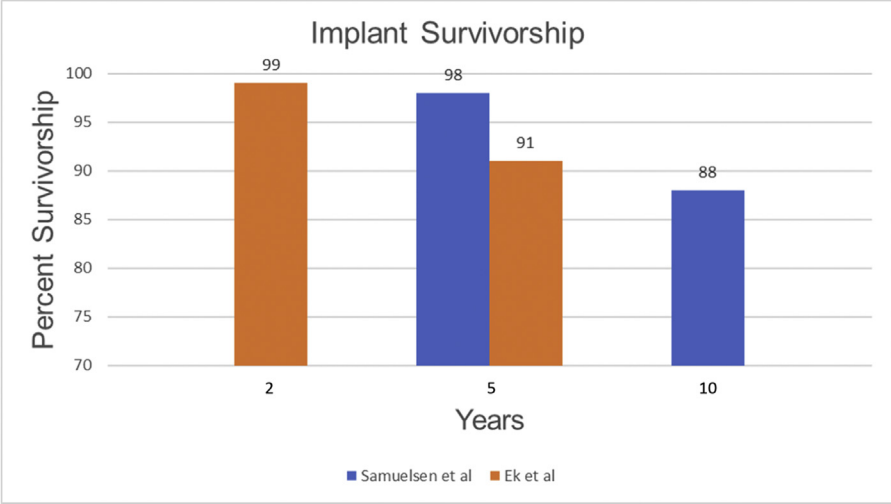

Figure 2 Implant survivorship for 2, 5, and 10 years as reported by 2 studies.

Although the infection rates are variable across published studies, the risk to younger patients as found in this study seems to be similar to that experienced by older populations.

Implant survival is of paramount importance when considering RTSA in younger patients. Whether revision becomes necessary secondary to instability, infection, or some other cause, the literature has demonstrated higher complication rates and lower patient satisfaction with revision compared with primary RTSA.[41,44] This effect is magnified when a patient requires revision RTSA at a young age. In a large patient cohort, Wagner et al[48] found that older age was associated with lower reoperation and revision rates after RTSA. However, the results of our study refute this finding, with rates similar to those in studies conducted in older patient populations. The implant survivorship rates in our study ranged from 91% to 98% at 5 years, and on the basis of a limited group of patients in 1 study, the rate was 88% at 10 years. This finding is comparable to the results of studies with mean ages older than 65 years, with reported implant survival rates of 92%-96% at 5 years, 89%-93% at 10 years, and 79%-92% at 15 years.[1,11,15,19,21] Bacle et al[1] reported implant survival rates of 96% at 5 years and 93% at 10 years, with survival declining to 86% at 15 years, in a cohort of 64 patients (mean age, 83 years) with rotator cuff dysfunction. Gerber et al,[19] in a series of 22 patients treated for an irreparable rotator cuff, reported survivorship rates of 96% at 5 years, 92% at 10 years, and 92% at 15 years in a relatively younger patient cohort (mean age, 68 years).

The findings of our study partially debunk the notion that younger patients will have higher failure rates as a result of aseptic loosening owing to their increased activity level. The most common causes of revision in this study (instability and infection) are the same as those observed in older patients. Aseptic loosening or glenoid failure requiring revision was observed in only 1.4% of patients in our cohort, which is similar to a 0.90% pooled prevalence in primary RTSA patients of all ages recently published in a meta-analysis by Rojas et al.[39] Further longitudinal studies are needed to determine whether implant survival in younger patients will continue to mirror that in older patients or whether there will be a point of divergence. The downward trend in implant survival is certainly concerning and warrants careful consideration when contemplating RTSA in young patients.

Our analysis showed that infrascapular notching occurred at a rate of 22.7%. The study by Ek et al[12] had the longest follow-up and reported the highest rate of scapular notching, with 56% at final follow-up. Three additional studies reported an increase in the scapular notching rate over time, which is consistent with prior reports.[13,27,32] The Grammont-style prosthesis has been associated with high rates of notching owing to its medialization of the center of rotation and was used in over half of cases in this study. The clinical significance of infrascapular notching and its impact on glenoid loosening and functional outcomes is still unclear despite many reports in the literature.[3,15,26,30,45,46] Ek et al reported a significantly lower rCS in patients with any grade of notching vs. those who did not have notching (65.6% vs. 85.6%). It is possible that scapular notching might have more of an effect on function in younger and higher-demand patient populations, but this relationship and its impact on glenoid loosening require additional inquiry.

Clinical outcome scores universally improved in the included studies, although the outcome scores used varied and thus analysis of outcome scores stratified by diagnosis

was not possible. It is important to note that in the studies that reported outcome scores over time, no deterioration in rCS and SSV was observed after 5 and 10 years. This finding is in line with the results reported by Gerber et al[19] in an older patient population.[12,13] The study by Matthews et al[29] is the only study in the literature to compare clinical outcomes after primary RTSA between younger (≤65 years) and older (≥70 years) populations; it showed similar improvements in functional scores, although younger patients had lower postoperative functional scores for all outcome measures assessed(Constant, ASES, UCLA, SST, 12-Item Short Form Health Survey, and Shoulder Pain and Disability Index 130). It is likely that the lower postoperative outcome scores found by Matthews et al are a result of younger patients' higher expectations of function, thereby emphasizing the importance of a surgeon's role in setting patient expectations prior to surgery.

To our knowledge, this is the first systematic review analyzing the performance of primary RTSA in a younger patient population. The analysis showed that complication rates, survivorship, and functional improvement are similar to those reported in the literature in elderly populations. Thus, the findings reported in this review suggest RTSA is a reasonable treatment option for younger patients with limited treatment alternatives. However, because of the longer life expectancy and higher functional demands of younger patients, additional studies with further follow-up of 10 years or greater are needed to further establish long-term survivorship. Nonetheless, the findings reported in this study may serve as a guide for clinical decision making and managing patient expectations regarding survivorship and complications following RTSA prior to 65 years of age.

This study has several limitations that must be mentioned. There were no level I studies that fit the inclusion criteria. Moreover, in the clinical outcome calculation, a meta-analysis could not be performed because of the varied reporting scales of included studies. Stratification of complications, revisions, and reoperations by implant used and by indication was not possible because studies did not report these data. No study included in this review published 15-year data, which precludes any comparisons to prior studies at this time point. Future studies should include survivorship rates in old and young patients to enhance our knowledge about the longevity of RTSA.

Conclusion

RTSA is safe and effective in patients younger than 65 years. Complication, reoperation, and revision rates were similar to those seen in older patient cohorts, without an increase in revisions owing to aseptic loosening. Clinical outcome scores showed significant and lasting improvements.

Disclaimer

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