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REVIEW ARTICLE

Long-term results of reverse total shoulder arthroplasty for rotator cuff dysfunction: a systematic review of longitudinal outcomes

Lukas Ernstbrunner, MD*, Octavian Andronic, MD, Florian Grubhofer, MD, Roland S. Camenzind, MD, Karl Wieser, MD, Christian Gerber, MD

Department of Orthopaedics, Balgrist University Hospital, University of Zürich, Zürich, Switzerland

Background: The aim of this systematic review was to evaluate the longitudinal evolution of midterm to long-term results of reverse total shoulder arthroplasty (RTSA) for patients with massive irreparable rotator cuff tears (miRCT).

Methods: Databases were scanned for studies of RTSA for miRCT. Studies with a minimum Level IV of evidence were considered eligible. Studies were included if they reported a minimum of 5 years of follow-up and excluded if they reported RTSA combined with tendon transfers or as revision arthroplasty. Data were grouped based on results after 5 to 7 years, 7 to 10 years, and 10 to 20 years of follow-up.

Results: Eight studies with a total of 365 shoulders were included. After a mean follow-up of 9.5 years (range, 5-20 years), the preoperative absolute and relative Constant scores were significantly improved from 24 to 59 points ($P = .004$) and from 33% to 74% ($P = .009$). The preoperative Subjective Shoulder Value improved from 23% to 72% ($P = .049$). Active anterior elevation and abduction also improved significantly ($P = .004$ and $P = .014$, respectively), but active external rotation remained unchanged ($P = .855$). None of the clinical scores or active ranges of motion significantly deteriorated up to 20 years after the operation ($P > .05$). After 10 years, 42% of the RTSAs showed grade III or IV inferior scapular notching.

Conclusion: Pooled long-term results of RTSA for miRCT show significant improvement of overhead function and of objective and subjective outcome scores up to 20 years after surgery. Shoulder function and outcome scores also showed no significant deterioration between 5 and 20 years of follow-up. Longer follow-up will be needed to determine ultimate longevity.

Level of evidence: Level IV; Systematic Review

Keywords: Reverse total shoulder arthroplasty; rotator cuff tear; massive; irreparable; long-term; shoulder function

In patients with a dysfunctional shoulder resulting from a massive irreparable rotator cuff tears (miRCT), performing daily activities becomes an issue. A massive rotator cuff tear is defined as a complete detachment of at least 2 tendons.[18,20] In the chronic setting, cuff tears come along with muscular and tendinous retraction,[30,41,42] atrophy, and fatty infiltration of the muscles, leading to irreparability.[16,22] Rotator

*Reprint requests: Lukas Ernstbrunner, MD, Department of Orthopaedics, Balgrist University Hospital, University of Zürich, Forchstrasse 340, 8008 Zürich, Switzerland.

E-mail address: lukas.ernstbrunner@balgrist.ch (L. Ernstbrunner).

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cuff tears that are considered irreparable can only exceptionally lead to structural healing. These tears are often characterized by chronic pseudoparalysis, an acromiohumeral distance of <7 mm on an anteroposterior radiograph in the case of posterosuperior tears, or fatty infiltration of the supraspinatus and infraspinatus muscles greater than stage 2 according to the Goutallier classification[22] or its modification on magnetic resonance imaging.[16]

A reliable treatment option for patients with an irreparable rotator cuff with, or even without, glenohumeral osteoarthritis is reverse total shoulder arthroplasty (RTSA).[10,11,17,39] On one hand, RTSA provides pain relief and improves shoulder function and thus quality of life.[1,3,4,25,26,31] On the other hand, various disadvantages have been reported after RTSA.[12] Apart from radiographic signs of scapular notching,[10,17,36] radiolucency,[11] and humeral stem subsidence,[34] certain midterm to long-term studies appear to document functional deterioration between 5 and 10 years postoperatively.[13,24] In contrast, more recent studies reported stable functional long-term results of patients monitored every 2 to 5 years.[10,17]

Whether long-term outcome of RTSA for miRCT deteriorates after a certain period remains controversial. This systematic review evaluated the reported longitudinal midterm and long-term clinical and radiographic results of RTSA in patients with miRCT, with or without cuff tear arthropathy (CTA).

Materials and methods

Search strategy and criteria

A systematic computer-based search was conducted of the CENTRAL (Cochrane Central Register of Controlled Trials), PubMed, and Embase databases. Combinations of the following key words were used: "reverse total shoulder arthroplasty," "reverse total shoulder prosthesis," "reverse shoulder arthroplasty," and "reverse shoulder prosthesis" with the terms, "rotator cuff," "rotator cuff tear," "massive rotator cuff tear," "irreparable rotator cuff tear," "cuff tear arthropathy," and "cuff arthropathy." First, a blinded and independent process of selection based on title and abstract was made by 2 authors (O.A., L.E.). Second, a thorough analysis of eligible studies was performed by evaluating full texts. Any excluded study together with the reason of exclusion was noted.

Studies reporting midterm to long-term clinical or radiologic outcomes of RTSA for the treatment of rotator cuff dysfunction were selected based on predefined eligibility criteria.

Inclusion criteria were (1) human studies in English or German language; (2) minimum Level IV case series studies using Oxford Centre for Evidence-Based Medicine 2011 Levels of Evidence[32,40]; (3) RTSA for the treatment of miRCT or CTA; (4) a minimum of 5 years of follow-up; and (5) clinical or radiologic outcome reports.

Exclusion criteria were (1) review articles; (2) language not in English or German; (3) RTSA in combination with tendon transfers; (4) RTSA as revision surgery for previous arthroplasty; (5) RTSA in the treatment of other pathologies, including fractures, fracture sequelae, neoplasia, rheumatoid arthritis, Charcot arthropathy; or (6) follow-up of less than 5 years.

Data collection

Data collection was performed for clinical scores including the absolute Constant score (aCS) and sex- and age-matched relative Constant score (rCS),[5] and the Subjective Shoulder Value (SSV).[21] The following range of motion (ROM) values were included: active anterior elevation (AAE), active abduction, and active external rotation with the elbow at the side. Radiologic results were evaluated by the grade of inferior scapular notching according to the classification of Sirveaux et al.[36]

Two types of survivorship rates were extracted from Kaplan-Meier curves: one for the period free of reoperation and one for the time until failure (implant removal or conversion to hemiarthroplasty). Results from selected studies were subsequently grouped according to the duration of follow-up into 5 to 7 years, 7 to 10 years, and 10 to 20 years of follow-up.

Statistical analysis

Statistical analyses were performed using SPSS Statistics 24.0 software (IBM, Armonk, NY, USA). Preoperative and postoperative clinical scores and ROM were compared using the Mann-Whitney *U* test. Analyses of the longitudinal postoperative results was performed using the Kruskal-Wallis test. According to all of included studies, the α level was set at 0.05, and all *P* values were 2-tailed.

Results

Search results

Using combinations of the selected searching terms, we initially identified 4512 studies. After duplicates were removed, 1222 studies were included for title and abstract review, and 30 studies were identified for further full-text processing. During this stage, 8 studies[2,6,8-10,13,17,23] were found to meet the inclusion criteria and were included for the systematic review (Fig. 1).

All studies were retrospective case series with a Level IV of evidence. The study by Cuff et al[8] was an update of a previous report.[6] Both were subsequently included in the longitudinal analysis of ROM. There were 365 shoulders investigated, with a mean follow-up of 9.5 years (range, 5-20 years). The patient pool in 7 of 8 studies was divided into patients with miRCT and those with CTA.[2,6,8-10,17,23] From these, 133 (61%) were shoulders with CTA and 84 (39%) with miRCT (Table I). Subgroup analyses, however, was not feasible because only the study by Bacle et al[2] reported the functional outcome separately.

Clinical scores

Six studies used the same scoring systems (aCS, rCS, and SSV) and were included in this analysis. The studies of Cuff et al[6,8] used the American Shoulder and Elbow Surgeons scoring system and were excluded.

As such, 286 shoulders were evaluated using clinical scores. The aCS increased from an average of 24 points to an average

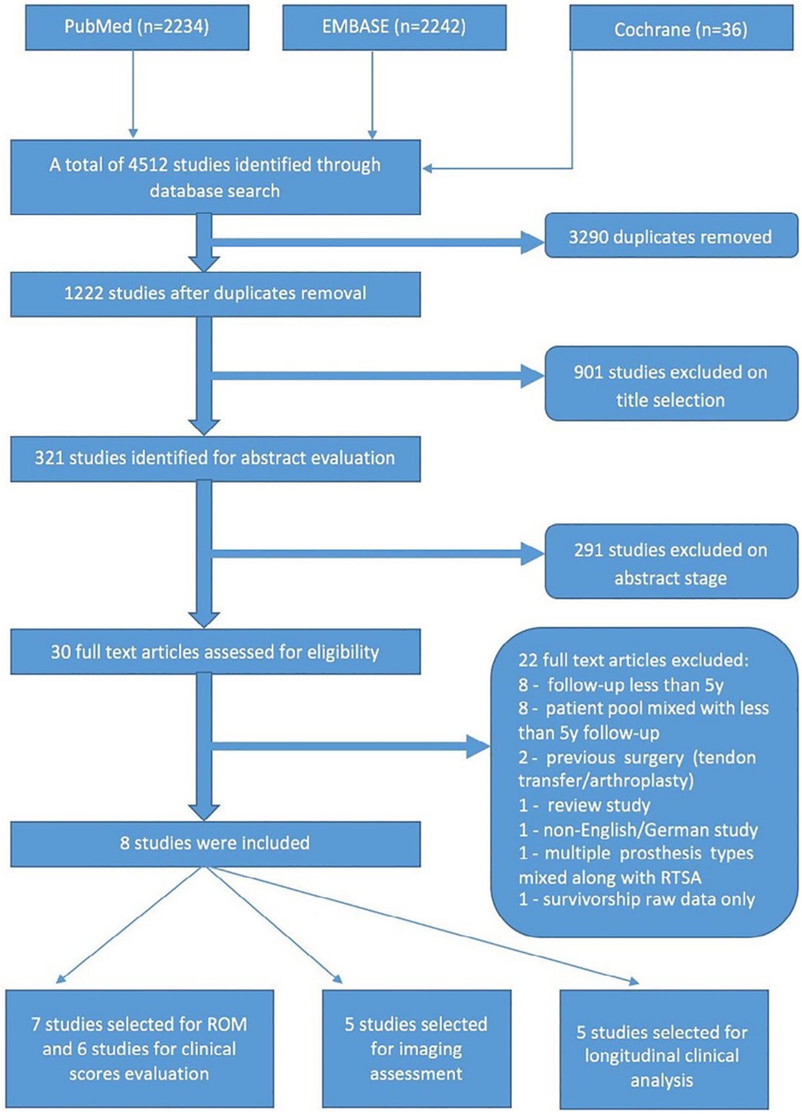

Figure 1 Flowchart of the systematic search. *RTSA*, reverse total shoulder arthroplasty; *ROM*, range of motion.

Table I Studies reporting midterm to long-term outcome of reverse total shoulder arthroplasty for rotator cuff dysfunction

Study	No.	Follow-up	Etiology	
		Mean (range), yrs	CTA, No. (%)	miRCT, No. (%)
Bacle et a,[2] (2017)	47	12.5 (10-20)	27 (57)	20 (43)
Ernstbrunner et al[10] (2017)	23	11.7 (8-19)	14 (61)	9 (39)
Ek et al[9] (2013)	40	7.75 (5-14.3)	19 (48)	21 (52)
Gruber et al[23] (2016)	28	5,7 (5.3-6.1)	28 (100)	0
Cuff et al[6] (2012)	57	5.2 (5-6.6)	34 (60)	23 (40)
Cuff et al[8] (2017)*	32	11 (10-12.3)	19 (59)	13 (41)
Favard et al[13] (2011)	148	7.5 (5-17)	Not available	
Gerber et al[17] (2018)	22	16.1 (15-19)	11 (50)	11 (50)
Total and averages	365	9.49 (5-20)	133 (61)	84 (39)

CTA, cuff tear arthropathy; *miRCT*, massive irreparable rotator cuff tear.
No. is the sample size (number of performed RTSA).
* This study is an update of Cuff [6] (2012) and was excluded from total and averages calculation.

Table II Preoperative and postoperative clinical scores at the latest follow-up

Study	No.	SSV, %		Absolute CS, points		Relative CS, %	
		Pre	Post	Pre	Post	Pre	Post
Bacle[2] (2017)	47	—	—	23 ± 13	59 ± 13	—	—
Ernstbrunner[10] (2017)	21	20 ± 13	71 ± 27	24 ± 9	59 ± 19	29 ± 11	69 ± 21
Ek[9] (2013)	26	23 ± 16	66 ± 28	27 ± 13	57 ± 20	34 ± 16	74 ± 24
Gruber[23] (2016)	28	—	—	—	—	38 (12-69)	70 (44-94)
Favard[13] (2011)	148	—	—	24 ± 10	62 ± 17	33 ± 14	85 ± 24
Gerber[17] (2018)	16	27 ± 18	78 ± 26	23 ± 11	58 ± 19	30 ± 13	73 ± 23
Total and averages	286	23	72	24	59	33	74

SSV, Subjective Shoulder Value; CS, Constant score.
No. is the number of shoulders available at follow-up.
Data are presented as mean ± standard deviation or as mean (range).

of 59 points ($P = .004$). The rCS also improved from 33% to a mean of 74% ($P = .009$). The SSV improved from a mean of 23% to a mean of 72% ($P = .049$; Table II).

ROM assessment

Preoperative and postoperative values for AAE, active abduction, and active external rotation were collected from all of the studies included in this review.[2,6,8-10,13,17,23] A total of 318 shoulders were clinically evaluated and showed a significant improvement regarding AAE (from 66° to 127°, $P = .004$) and active abduction (from 63° to 113°; $P = .014$). External rotation remained statistically unchanged at 19° preoperatively and 24° at the final follow-up ($P = .855$; Table III).

Scapular notching

Radiographic findings were reported in 5 of 8 studies.[9,10,13,17,23] From 257 RTSAs available at 5 to 7 years, 63 (25%) were diagnosed with grade III or IV. At 7 to 10 years of follow-up, 43 of 110 RTSAs (39%) showed grade III or IV notching. At a follow-up of 10 or more years, 29 of 60 RTSAs (48%) had a diagnosis of grade III or IV of inferior scapular notching (Table IV).

Longitudinal functional analysis

There were 5 studies[8-10,13,17] that reported clinical outcome based on the duration of follow-up in a longitudinal fashion.

For the longitudinal analysis of clinical outcome scores, 4 studies were included.[9,10,13,17] There were 204 RTSAs available at 5 to 7 years of follow-up, 104 RTSAs available at 7 to 10 years, and 74 RTSAs available at a follow-up of 10 or more years (Table V). No significant deterioration was found over time for the clinical outcome scores aCS ($P = .151$), rCS ($P = .982$), and SSV ($P = .232$).

All 5 studies were included in the longitudinal analysis of ROM, with 261 RTSAs at 5 to 7 years, 104 RTSAs at 7 to 10 years, and 106 RTSAs at 10 or more years of follow-up.[8-10,13,17] The findings demonstrated that AAE ($P = .869$), abduction ($P = .844$), and active external rotation ($P = .722$) remained statistically unchanged between 5 and more than 10 years of follow-up (Table VI).

Survivorship analysis

The survivorship analysis included 7 studies.[2,8-10,13,17,23] Three studies[9,10,17] reported 2 types of survivorship rates, one for the period free of reoperation for any complication and one for

Table III Preoperative and postoperative range of motion at the latest follow-up

Study	No.*	Active anterior elevation		Abduction		External rotation	
		Pre, °	Post, °	Pre,°	Post,°	Pre,°	Post,°
Bacle[2] (2017)	47	—	131 ± 26	—	—	—	—
Ernstbrunner[10] (2017)	21	64 ± 32	117 ± 34	58 ± 30	111 ± 47	28 ± 26	26 ± 19
Ek[9] (2013)	26	72 ± 38	119 ± 34	67 ± 37	112 ± 39	27 ± 27	26 ± 20
Gruber[23] (2016)	28	—	139 (70-180)	—	135 (50-170)	—	17 (−20 to 40)
Cuff[8] (2017)	32	68 (15-152)	136 (10-180)	67 (19-159)	123 (0-180)	16 (−40 to 78)	48 (−30 to 90)
Favard[13] (2011)	148	70 ± 34	129 ± 33	—	—	5 ± 18	11 ± 19
Gerber[17] (2018)	16	53 ± 32	101 ± 27	55 ± 28	86 ± 20	20 ± 26	18 ± 21
Total and averages	318	66	127	63	113	19	24

Data are presented as mean ± standard deviation or as mean (range).
* The number of shoulders available at follow-up.

Table IV Degree of inferior scapular notching at different stages of the follow-up

Study	5-7 yrs, No. (%)				7-10 yrs, No. (%)				≥10 yrs			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
Ernstbrunner[10] (2017)	11 (65)	2 (12)	2 (12)	1 (6)	12 (63)	3 (16)	2 (11)	1 (5)	7 (41)	4 (24)	3 (18)	2 (12)
Ek[9] (2013)	6 (21)	4 (14)	6 (21)	1 (4)	0	2 (22)	4 (44)	1 (11)	—	—	—	—
Gruber[23] (2016)	7 (64); I + II		0	0	—	—	—	—	—	—	—	—
Favard[13] (2011)	—	—	52 (35); III + IV		29 (43); I + II		32 (47); III + IV		16 (40) I + II		20 (50); III+IV	
Gerber[17] (2018)	2 (15)	5 (38)	1 (8)	0	2 (14)	4 (29)	3 (21)	0	2 (17)	2 (17)	4 (33)	0
Total and averages	I + II 37 (17)		III + IV 63 (29)		I + II 52 (47)		III + IV 43 (39)		I + II 31 (45)		III+IV 29 (48)	

Data are presented as the number of shoulders evaluated or as percentage according to the grade of inferior scapular notching, I to IV.

the time until failure. According to these studies, the survivorship after RTSA implantation until reoperation for any reason is 85% at 5 years, 74% at 10 years, and 70% at 15 years. When viewing the revision rates involving prosthesis removal or conversion to hemiarthroplasty, the average survivorship is 94% at 5 years, 90% at 10 years, and 85% at 15 years after surgery (Table VII).

Discussion

The main finding of this systematic review is that the pooled results of RTSA for miRCT, with or without glenohumeral arthropathy, show significant improvement of overhead shoulder function and of clinical outcome scores at the time of long-term follow-up. Moreover, the analysis of pooled longitudinal long-term outcome observed neither significant deterioration of subjective and objective outcome scores nor active ROM at least to the longest follow-up hitherto reported (20 years).

The pooled analysis of long-term clinical outcome scores of the approximately 300 shoulders showed substantial improvement in CSs and subjective outcome at the final follow-up. Favard et al[13] and Guery et al[24] reported a certain break of shoulder function after 6 to 8 years. These results, however, should be interpreted in light of the fact that the authors did not conduct a longitudinal analysis of the same cohort but analyzed different cohorts at different time points. In contrast, Ernstbrunner et al,[10] Ek et al,[9] and Gerber et al[17] studied the clinical outcome of RTSA for miRCT in a longitudinal fashion of the same patients. No deterioration of objective or subjective outcome over time was observed, neither after 5 nor after more than 10 years of follow-up. Our pooled longitudinal analysis of approximately 200 shoulders showed no significant deterioration of CSs or SSV.

Active overhead ROM was reported to improve reliably after RTSA for a dysfunctional shoulder.[2,3,6,8-10,13,23,36,39] These pooled long-term results are consistent, with active anterior flexion and abduction above 110° and a mean improvement of more than 50°. Also, longitudinal overhead function showed no statistical deterioration. According to the results of Gerber et al,[17] active abduction seems to drop drastically after 8 to 12 years. They attributed this finding to deltoid muscle weakness related to advanced age and to nonphysiological muscle fiber recruitment associated to the biomechanical changes associated with the RTSA, including distalization and medialization of the center of rotation. Based on the relatively small cohort of the included patients, more long-term studies are needed for further clarification.

Regarding external rotation, only the studies of Cuff et al[6,8] reported significant postoperative improvement after 5 and 10 years. In contrast to the other studies included for analysis,[2,9,10,13,17] the RTSA design implanted incorporated a lateral center of rotation.[7] Another factor to consider is the preoperative morphologic appearance of the teres minor muscle.[29,37] Although some authors reported active external rotation after RTSA is correlated with the state of the teres minor muscle,[36] Ernstbrunner et al,[10] albeit in a small cohort of patients, could not confirm this finding. Other studies advocated for a concomitant latissimus dorsi transfer, which was associated with reliable improvement of active external rotation.[10,19]

Still, rotator cuff dysfunction is believed to be the best indication for RTSA.[3,4,9,10,13-15,17,24,27,33,38,39] Approximately 40% the patients included in this review had a miRCT with glenohumeral arthropathy. Because the provided results were not separately analyzed for patients with miRCT, with or without CTA, we were not able to draw back a conclusion on the influence of CTA on outcome. Guery et al[24] showed that with the end points explantation of the prosthesis, glenoid loosening, and a CS of <30, RTSA survivorship favors CTA compared with other etiologies. In accordance, Ernstbrunner et al[10] and Gerber et al[17] showed that the presence of CTA was not associated with any postoperative clinical result, including the SSV. Also, Bacle et al[2] reported that patients with CTA were among the highest CSs compared with other etiologies at the time of the long-term follow-up. Notwithstanding, further studies with more statistical power analyzing the influence of preoperative glenohumeral arthropathy on long-term outcome are necessary.

Although not a subject of the present study, the reported complication rates in certain included studies should be noted. Favard et al[13] reported a complication rate of 18%, with infection and glenoid complications most commonly observed.

Table V Longitudinal analysis of clinical scores

Study	5-7 yrs				7-10 yrs				≥10 yrs			
	No.	aCS (pts)	rCS (%)	SSV (%)	No.	aCS (pts)	rCS (%)	SSV (%)	No.	aCS (pts)	rCS (%)	SSV (%)
Ek[9] (2013)	26	55 ± 19	70 ± 25	62 ± 26	18	62 ± 18	72 ± 20	73 ± 24	—	—	—	—
Ernstbrunner[10] (2017)	17	61 ± 16	70 ± 17	68 ± 23	69	59.96	82.13	—	17	57 ± 20	67 ± 23	66 ± 28
Favard[13] (2011)	148	61.53	85.24	—	9	60 ± 10	72 ± 11	69 ± 24	41	56.76	78	—
Gerber[17] (2018)	13	61 ± 18	73 ± 22	67 ± 27	18	62 ± 18	72 ± 20	73 ± 24	16	58 ± 19	73 ± 23	78 ± 25
Total and averages	204	60	75	66	104	60	76	72	74	57	73	72

aCS, active Constant score; *rCS*, relative Constant score; *SSV*, Subjective Shoulder Value.
Data are presented as mean ± standard deviation.

Table VI Longitudinal analysis of range of motion

Study	5-7 yrs				7-10 yrs				≥10 yrs			
	No.	AAE, °	Abd, °	ER, °	No.	AAE, °	Abd, °	ER, °	No.	AAE, °	Abd, °	ER, °
Ek[9] (2013)	26	106 ± 43	98 ± 42	23 ± 26	8	122 ± 22	118 ± 30	13 ± 27	—	—	—	—
Ernstbrunner[10] (2017)	17	124 ± 34	114 ± 38	27 ± 25	18	119 ± 33	118 ± 46	26 ± 28	17	115 ± 37	111 ± 49	24 ± 22
Favard[13] (2011)	148	128.59	—	10.6	69	124.92	—	9.06	41	124.12	—	6.89
Gerber[17] (2018)	13	118 ± 33	112 ± 35	26 ± 30	9	117 ± 25	110 ± 26	28 ± 15	16	108 ± 30	90 ± 22	19 ± 21
Cuff[6,8] (2012, 2017)	57	148 (50-180)	136 (50-180)	52 (−60 to 100)	—	—	—	—	32	136 (10-180)	123 (0-180)	48 (−30 to 90)
Total and averages	261	129	119	32	104	121	115	19	106	124	112	29

AAE, active anterior elevation; *Abd*, abduction; *ER*, external rotation.
Data are presented as mean ± standard deviation or as mean (range).

Table VII Survivorship analysis

Study	Survivorship (%) until					
	Reoperation for any complication			Failure*		
	5 yrs	10 yrs	15 yrs	5 yrs	10 yrs	15 yrs
Bacle[2] (2017)	—	—	—	96	93	86
Ernstbrunner[10] (2017)	—	73	70	90	87	84
Ek[9] (2013)	88	76	—	98	88	82
Gruber[23] (2016)	—	—	—	92	—	—
Cuff [8] (2017)	—	—	—	94	91	—
Favard[13] (2011)	—	—	—	95	89	79
Gerber[17] (2018)	82	74	—	96	92	92
Total and averages	85	74	70	94	90	85

* A failure was considered when the implant was removed or replaced by hemiarthroplasty.

The studies of Ek et al[9] and Ernstbrunner et al[10] showed in a specific cohort of patients aged younger than 65 and 60 years of age, respectively, where revisions of the RTSA were performed, that the complication rates can even be as high as 38% and 39%, respectively. However, they also showed that in cases where RTSA preservation was possible, the magnitude of improvement[10] of both the CSs and of the SSV[9] were similar between patients with and without complications at the long-term follow-up.

This is in accordance with the most recent study of Gerber et al,[17] who showed in an analysis of the 15-year result of a first-generation implant that if complications can be treated with retention of the implant, outcome does not appear to be compromised. The relatively high complication rate is also opposed by a pooled survival rate of the implant of more than 85% in the first 15 years. Furthermore, the high complication rate may be lowered with current techniques and experience.

Our pooled analysis shows that after a follow-up of more than 10 years, almost half of the patients showed grade III or IV inferior scapular notching. The influence of inferior scapular notching on clinical and radiographic outcome remains controversial.[3,13,28,35,36]

There have been suggestions that inferior scapular notching is associated with poorer outcomes. More recent studies[10,17] demonstrated, however, that it is not the ultimate shoulder function but instead the poor preoperative shoulder function that might be associated with advanced scapular notching.

To our knowledge, this is the first systematic review reporting longitudinal midterm and long-term results after RTSA in patients with miRCT with or without CTA. We believe the findings of the current study are important for both physicians' knowledge and also for the patients' expectations.

However, our study has several limitations that need to be considered. In the clinical score analysis, we did not include the studies from Cuff et al[6,8] because they used a different scoring system (American Shoulder and Elbow Surgeons). There was also no possibility of reporting the outcome separately for patients with miRCT with or without CTA, because only Bacle et al[2] did so. There is a possibility of patient pool intersection in studies performed at the same institution.[9,10,17] Finally, we do not know the ultimate longevity of RTSA for miRCT, which should be analyzed in future studies.

Conclusions

Pooled long-term results of RTSA for miRCT show significant improvement of overhead function and of objective and subjective outcome scores up to 20 years after surgery. Pooled longitudinal shoulder function and outcome scores also showed no significant deterioration between 5 and 20 years of follow-up. Longer follow-up will be needed to determine ultimate longevity. Advanced inferior scapular notching is common in the long term but is not associated with glenoid component loosening and with uncertain relevance for the clinical outcome.

The current study reflects the outcomes after RTSA only for patients with miRCT or CTA, or both; thus, the results cannot be extrapolated to patients excluded from this study.

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