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Reverse total shoulder arthroplasty clinical and patient-reported outcomes and complications stratified by preoperative diagnosis: a systematic review

June Kennedy, PT, DPT, OCS[a,*], Christopher S. Klifto, MD[b], Leila Ledbetter, MLIS[c], Garrett S. Bullock, PT, DPT[d]

[a]*Department of Physical and Occupational Therapy, Duke University Health Systems, Durham, NC, USA*
[b]*North Carolina Orthopedic Clinic, Durham, NC, USA*
[c]*Duke University Medical Center Library, Durham, NC, USA*
[d]*Nuffield Department of Orthopaedics, Rheumatology, and Musculoskeletal Sciences, University of Oxford, Oxford, UK*

Objective: This systematic review aimed to investigate differences in clinical outcomes, patient-reported outcomes (PROs), and complication types and rates among preoperative diagnoses following reverse total shoulder arthroplasty (RTSA): rotator cuff tear arthropathy, primary osteoarthritis, massive irreparable rotator cuff tear, proximal humeral fracture, rheumatoid arthritis (RA), and revision of anatomic arthroplasty (Rev).
Literature search: Three electronic databases were searched from inception to January 2020.
Study selection criteria: The inclusion criteria were (1) patients with a minimum age of 60 years who underwent RTSA for the stated preoperative diagnoses, (2) a minimum of 2 years' follow-up, and (3) preoperative and postoperative values for clinical outcomes and PROs.
Data synthesis: Risk of bias was determined by the Methodological Index for Non-randomized Studies tool and the modified Downs and Black tool. Weighted means for clinical outcomes and PROs were calculated for each preoperative diagnosis.
Results: A total of 53 studies were included, of which 36 (68%) were level IV retrospective case series. According to the Methodological Index for Non-randomized Studies tool, 33 studies (62%) showed a high risk of bias; the 3 randomized controlled trials showed a low risk of bias on the modified Downs and Black tool. RTSA improved clinical outcomes and PROs for all preoperative diagnoses. The Rev group had poorer final outcomes as noted by a lower American Shoulder and Elbow Surgeons score (69) and lower pain score (1.8) compared with the other preoperative diagnoses (78-82 and 0.4-1.4, respectively). The RA group showed the highest complication rate (28%), whereas the osteoarthritis group showed the lowest rate (1.4%).
Conclusion: Studies in the RTSA literature predominantly showed a high risk of bias. All preoperative diagnoses showed improvements; Rev patients showed the worse clinical outcomes and PROs, and RA patients showed higher complication rates. The preoperative diagnosis in RTSA patients can impact outcomes and complications.

Institutional review board approval was not required for this systematic review.

*Reprint requests: June Kennedy, PT, DPT, 3500 Heatherwood Ln, Durham, NC 27713, USA.
E-mail address: June.kennedy@duke.edu (J. Kennedy).

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Level of evidence: Level IV; Systematic Review

Keywords: Rehabilitation; cuff tear arthropathy; primary osteoarthritis; massive irreparable rotator cuff tear; proximal humeral fracture; rheumatoid arthritis; revision shoulder

Reverse total shoulder arthroplasty (RTSA) was approved for use in the treatment of rotator cuff tear arthropathy (CTA) in the United States in 2003.[73] The prosthetic implant design uses fixed-fulcrum mechanics that medialize the glenohumeral joint center of rotation such that the deltoid functions as both an elevator and compressor to the joint, thereby compensating for rotator cuff deficiency.[39] The prosthesis utility has expanded to include management of primary glenohumeral osteoarthritis (OA) with excessive glenoid erosion,[94] massive irreparable rotator cuff tear (MIRCT) without arthritis,[3] rheumatoid arthritis (RA),[95] proximal humeral fracture (PHFx),[7,30] revision of anatomic total shoulder arthroplasty (TSA),[87,89] and other complicated shoulder conditions such as tumors.[72] RTSA was reported to be the most common primary form of shoulder arthroplasty in one registry, increasing from 27% in 2005 to 52% in 2015, and the rise was attributed to its use for varied preoperative diagnoses.[13] Clinical outcomes and patient-reported outcomes (PROs) may vary following RTSA, dependent on the preoperative diagnosis, owing to differences in muscle function and preoperative functional mobility.

Postoperative RTSA differences, according to etiology, were previously investigated in 2007, with poorer outcomes reported for the group with revision of anatomic TSA compared with the CTA, MIRCT, and OA groups.[90] However, this study did not include an analysis of acute PHFx or RA preoperative diagnoses; furthermore, RTSA prosthetic design has evolved,[43] with numerous studies reporting results since this 2007 article. Inferior results for revision of anatomic TSA compared with CTA were also reported in 2013; however, comparison among other preoperative diagnoses was not analyzed in this study.[91] A more recent cohort study investigated the outcome of RTSA stratified by 7 preoperative diagnoses, which did not include revision of anatomic TSA; however, this article reflected the outcomes of 1 medical practice, which may not be generalizable.[45]

Knowledge about outcomes of RTSA for variable diagnoses can assist clinicians in setting appropriate patient goals and in helping patients develop realistic expectations for recovery. Expectation is closely linked to patient satisfaction.[67,68] Therefore, establishing differences in outcomes following RTSA for different preoperative diagnoses is impactful so that clinicians can help patients develop realistic goals for recovery. Younger patients may have different functional demands than elderly patients, which impact RTSA performance and longevity, thereby influencing expectations and outcomes after RTSA.[54] Therefore, the purpose of this systematic review was to investigate differences in clinical outcomes, PROs, and complication types and rates among preoperative diagnoses following RTSA: rotator CTA, primary OA, MIRCT, PHFx, RA, and revision of anatomic arthroplasty (Rev).

Methods

Study design

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines.[53] It was prospectively registered with PROSPERO (identification no. 166957).

Search strategy and eligibility

A literature search was conducted by professional medical librarians (L.L. and a nonauthor) in PubMed (new version), Embase, and Web of Science from the inception through January 20, 2020. Search keywords included "reverse" combined with "shoulder joint" combined with "arthroplasty, replacement" and were limited to studies performed in humans and published in the English language. The search strategy and outcome are summarized in Supplementary Table S1. Specific criteria for consideration in the literature search are outlined in the Population-Intervention-Comparison-Outcome-Time (PICOT) chart in Table I. The inclusion criteria were (1) patients aged $\geq$ 60 years who underwent RTSA with a preoperative diagnosis of CTA, OA, MIRCT, PHFx, RA, or Rev; (2) a minimum of 2 years' follow-up; and (3) preoperative and postoperative values for clinical outcome measures (shoulder range of motion [ROM]) and PRO measures (pain score; American Shoulder and Elbow Surgeons [ASES] score; Constant score; Disabilities of the Arm, Shoulder and Hand score; Single Assessment Numeric Evaluation score; or other measures). The exclusion criteria were (1) RTSA for preoperative diagnoses other than those stated; (2) studies that reported results for combined preoperative diagnoses; (3) RTSA that included an additional muscle transfer (eg, latissimus dorsi transfer); (4) studies with <20 patients; and (5) studies reporting on patients undergoing anatomic shoulder arthroplasty (including hemiarthroplasty or anatomic TSA).

Each preoperative diagnosis warranting RTSA was further delineated as follows:

- Rotator CTA: rotator cuff tear with concomitant arthritis of the glenohumeral joint confirmed by radiologic studies including radiographs, magnetic resonance imaging scans, and/or

Table I Elements for consideration in search strategy for systematic review

Population	Intervention	Comparison	Outcome	Time
Patients aged ≥ 60 yr undergoing RTSA	RTSA for the following: Rotator cuff tear arthropathy Primary osteoarthritis Massive irreparable rotator cuff tear Proximal humeral fracture Rheumatoid arthritis Revision of anatomic total shoulder arthroplasty	Preoperative to postoperative measures (delta values) for each diagnosis Final outcome variables as well as delta values compared across diagnoses	Clinical and patient-reported outcome measures including the following: Pain Active range of motion ASES score, Constant score, DASH score, SANE score, or other patient-reported outcome measures Complication rate and type	Minimum 2-yr follow-up

RTSA, reverse total shoulder arthroplasty; *ASES*, American Shoulder and Elbow Surgeons; *DASH*, Disabilities of the Arm, Shoulder and Hand; *SANE*, Single Assessment Numeric Evaluation.

computed tomography scans showing superior migration of the humeral head[45,90]
- Primary OA with an intact rotator cuff: OA of the glenohumeral joint with an intact rotator cuff as shown by no proximal migration of the humeral head on imaging studies[90]
- MIRCT without arthritis: radiographs showing elevation of the humeral head on the glenoid without evidence of cartilage erosion[3,45]
- Acute PHFx: fractures managed within 6 weeks of injury[7,45]
- RA: an established diagnosis of the condition with erosion of glenohumeral articular cartilage and/or rotator cuff deficiency[45,95]
- Revision of anatomic shoulder arthroplasty (Rev): revision of either a hemiarthroplasty or anatomic TSA[90]

Study selection

Two reviewers (J.K. and G.S.B.) used Covidence systematic review software (Veritas Health Innovation, Melbourne, VIC, Australia) to independently screen titles and abstracts that were identified in the literature search, and the same reviewers screened articles selected for full-text review. Disagreement at the title and abstract review stage, as well as at the full-text review stage, was resolved by a third party (C.S.K.) who was blinded to the 2 voters' selections. Following screening, a hand search was performed to identify articles that may have been missed in the preliminary literature search.

Quality assessment of included studies

Two reviewers independently determined the study design using the Oxford Centre for Evidence-based Medicine levels of evidence from I to V.[64] Two reviewers also independently scored the risk of bias for nonrandomized studies using the Methodological Index for Non-randomized Studies (MINORS) tool.[81] The modified Downs and Black tool was used to assess the risk of bias for randomized controlled studies.[23] Consensus on disagreements in scores was reached by discussion. The MINORS appraisal tool assigns a score of 0 (not reported), 1 (inadequately reported), or 2 (adequately reported) to 8 items for noncomparative studies, with an additional 4 items for comparative studies. The scores are categorized regarding the level of evidence in the following manner: 0-6, very low; 7-10, low; 11-16, moderate; and >16, strong.[46] The modified Downs and Black tool uses a checklist of 15 items for assessment of the quality of evidence. Studies scored 12-15 are regarded as high quality; 10 or 11, moderate quality; and ≤9, low quality.[23]

Data extraction

A custom data extraction sheet was developed using Microsoft Excel (Microsoft, Redmond, WA, USA), and extraction was shared among 3 of the investigators (40% by G.S.B., 40% by J.K., and 20% by C.S.K.). Twenty percent of the articles (11 of 53) were randomly selected for a second assessment of data extraction among the investigators to determine the agreeability of data extraction. Data extraction agreement was 75%. As a result, all data were hand checked for agreement and discrepancies were corrected by referring to the included studies.

Extracted data included study characteristics (lead author, year of publication, time to final endpoint for follow-up, and sample size) and patient information (sex, age, and preoperative diagnosis indicating RTSA procedure). Clinical outcomes for ROM including shoulder flexion, abduction, external rotation with the arm at the side (ER0), external rotation with the arm at 90° of abduction (ER90), and internal rotation were extracted from the studies. PROs extracted included pain level rated using the Numeric Pain Rating Scale (NPRS) ranging from 0-10; ASES score; total unadjusted Constant score; Disabilities of the Arm, Shoulder and Hand score; Single Assessment Numeric Evaluation score; and other PROs. These clinical outcomes and PROs were extracted from studies at the preoperative and final postoperative measurement points, and the delta values of preoperative to postoperative change were recorded. Only the final outcome measures were extracted for the PHFx group as PHFx is an

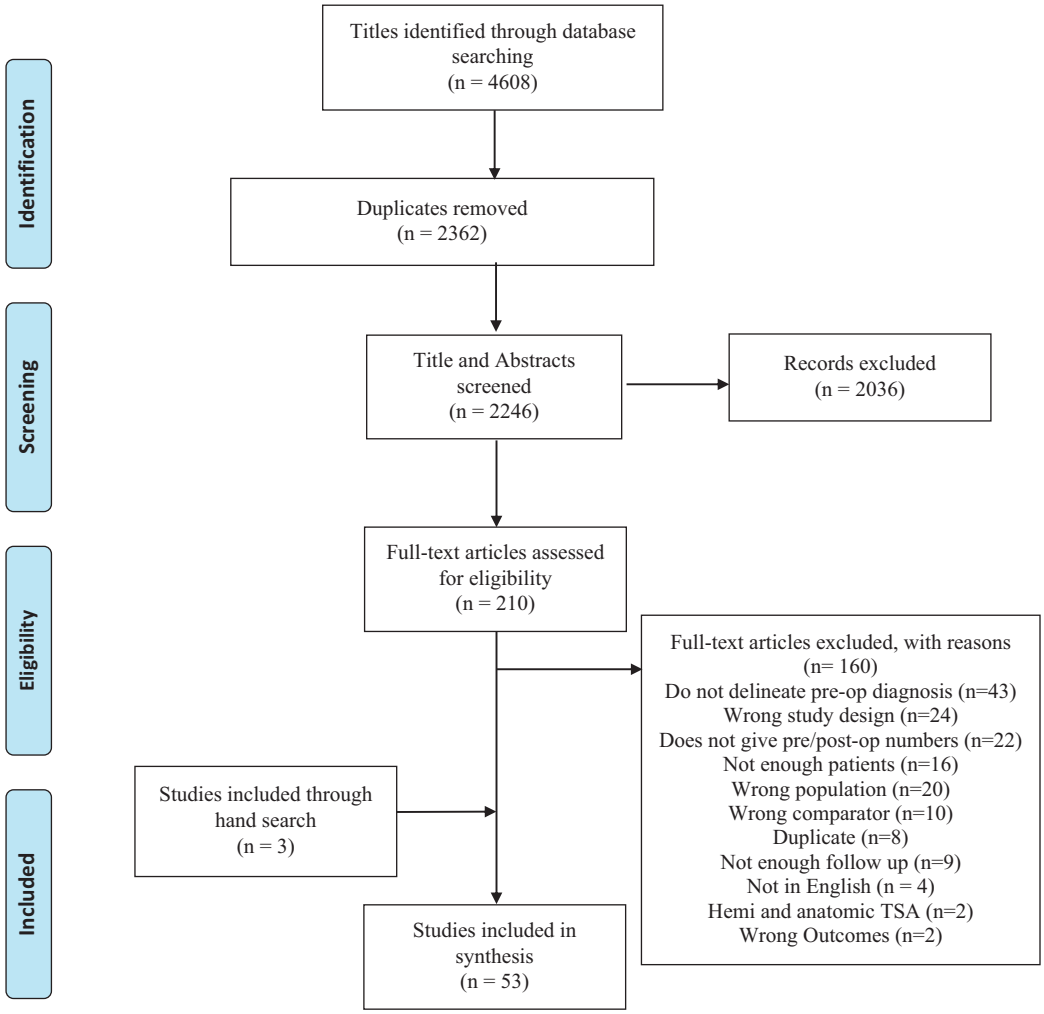

Figure 1 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) flowchart. *pre-op*, preoperative; *pre/post-op*, preoperative/postoperative; *Hemi*, hemiarthroplasty; *TSA*, total shoulder arthroplasty.

unanticipated injury; therefore, preoperative values are not commonly obtained. On completion of data extraction for all studies, the data were sorted by preoperative diagnosis for aggregation and comparison among groups. The number and type of reported complications were recorded and sorted by preoperative diagnosis.

Statistical analysis

Descriptive analysis was performed because of high variance and risk of bias and low quality of evidence for the majority of the studies. The weighted mean by study sample size was calculated for aggregated patient-specific data (age and time to follow-up), delta values, and final endpoint measures for all clinical and patient-reported variables for each preoperative diagnosis. The variance for the weighted means was recorded as the range from lowest to highest reported across studies for each diagnostic classification. Microsoft Excel was used to calculate the weighted means and ranges. The rates of total complications and each type of complication for each preoperative diagnosis were calculated as the number of complications reported (total and type, respectively) divided by the pooled sample size.

Results

The literature search identified 4608 articles among the 3 databases. After duplicate removal, as well as title, abstract, and full-text review, a total of 53 articles were included in this systematic review (Fig. 1).[1-3,6-10,16,18-21,22,24-27,30-34,36-38,41,44,45,48-52,55,57-61,65,66,71,74,75,77,79,80,82,83,86,87,89,90,93,95]

Quality of evidence

There were 36 level IV retrospective noncomparative case series,[1,2,6,9,18,19,22,24-26,30-32,34,36,37,41,44,48,49,51,52,55,57,59-61,71,74,79,80,82,87,89,93,95] 12 level III retrospective comparative

Table II Study and patient characteristics according to preoperative diagnosis

Study/patient characteristics	Cuff tear arthropathy	Primary osteoarthritis	Massive irreparable rotator cuff tear	Proximal humeral fracture	Rheumatoid arthritis	Revision
No. of studies	24	8	6	12	3	15
Total No. of patients	1524	376	470	856	52	435
Age, yr	74.2 (67-82.6)	71.8 (71-85)	72.4 (71-84)	77.5 (72-80)	71.3 (70.1-74.4)	68.9 (64-83)
Sex						
Male	529	82	141	62	7	122
Female	1206	117	211	344	30	243
Time to follow-up, mo	41.2 (22-150)	52.2 (36-150)	48 (24-150)	35.6 (24-59)	42.8 (36-50)	49.3 (24-150)

Age, sex, and time to follow-up represent the weighted mean values by sample size for all studies included in each preoperative diagnostic group; ranges are reported in parentheses. The numbers of male and female patients represent the numbers included at final follow-up.

studies,[3,7,8,16,20,21,27,45,50,76,83,86] 2 level II prognostic studies,[10,90] and 3 level I randomized controlled trials.[33,65,75]

The mean MINORS score for the 36 noncomparative case series was 8.91, which indicates an overall low quality of evidence. Of these studies 4 were very low quality[24,26,61,82,23] were low quality,[1,2,3,18,22,30,31,32,36,41,49,51,55,57,59,69,71,79,80,87,89,93,95] and 9 were moderate quality.[9,19,25,34,37,44,48,52,72] The mean MINORS score for the 14 comparative studies was 14.5, which indicates a moderate level of evidence. Of these studies 2 were low quality,[8,90] 8 were moderate quality,[3,7,10,16,21,27,50,86] and 4 were strong quality.[20,45,77,83] According to the modified Downs and Black tool, the mean score for the 3 randomized controlled trials was 12.3, which indicates a high level of evidence. Of these studies, 2 were high quality[65,75] and 1 was moderate quality[33] (Supplementary Table S2).

Preoperative diagnoses

There were a total of 24 CTA,[1,2,6,8,10,19,21,22,25,27,31,33,34,44,45,50,51,57,65,74,80,82,86,90] 8 OA,[6,18,24,45,48,52,83,90] 6 MIRCT,[3,6,34,45,55,90] 12 PHFx,[7-9,16,20,30,32,41,59,71,75,79] 3 RA,[37,44,95] and 15 Rev[6,8,19,26,34,36,44,49,60,61,77,87,89,90,92] preoperative diagnosis cohorts included in this review (Table II). Only 2 studies isolated outcomes for patients with MIRCT,[3,55] and only 3 studies did so for RA.[37,44,95]

The cohort with a preoperative diagnosis of Rev had the youngest patients, with a weighted mean of 69 years (range, 68-83 years), whereas the PHFx group had the oldest patients, with a weighted mean of 77.5 years (range, 72-80 years). The ages of the CTA, OA, MIRCT, and RA groups were similar, ranging from 71 to 74 years. There was a higher prevalence of RTSA in women than in men among all preoperative diagnoses: CTA, 529 men (30%) and 1206 women (70%); OA, 82 men (41%) and 117 women (59%); MIRCT, 141 men (40%) and 211 women (60%); PHFx, 62 men (15%) and 344 women (85%); RA, 7 men (19%) and 30 women (81%); and Rev, 122 men (33%) and 243 women (67%).

The time to final follow-up among all preoperative diagnoses ranged from 36 months for the PHFx group to 52 months for the OA group. One study contained final endpoint analysis at >10 years for the CTA, OA, MIRCT, and Rev groups.[6]

Clinical outcomes

Internal rotation was not included in the data analysis because the method of reporting this motion did not use discrete numbers. We observed the greatest improvement in flexion-elevation in the RA group and the least in the OA group, with delta values of 68° (range, 61°-74°) and 54° (range, 28°-81°), respectively. Abduction delta values were within 2°-7° of flexion-elevation gains, with the exception of the Rev group, in which elevation increased by 10° more than abduction. ER0 was improved most in the OA group, with an increase of 21°, but this group also had the largest range, from 2° to 46°. Across all of the other groups, ER0 improved by 10°-17° and the ranges for the MIRCT and Rev groups contained negative values (–6° to 24° and –14 to 37°, respectively), indicating that some patients had a decrease in ER0 ROM following RTSA (Table III).

The final endpoint for flexion-elevation was 130°-134° for the CTA, OA, MIRCT, and RA groups, and there was a large range in this variable for CTA (80°), OA (38°), and Rev (40°). In comparison, the final endpoint for the PHFx and Rev groups was 122° and 110°, respectively. Abduction endpoints followed a similar trend to flexion across groups, with the CTA, OA, MIRCT, and RA groups reaching better mobility (116°-125°) compared with the PHFx and Rev groups (110° and 94°, respectively). The final ER0 mobility attained was very similar across all preoperative diagnoses, ranging from 20°-27°, with the exception of that for the MIRCT group, which was 36°. All groups had a large range

Table III Weighted means for clinical outcomes of range of motion according to preoperative diagnosis

Range of motion	Cuff tear arthropathy	Primary osteoarthritis	Massive irreparable rotator cuff tear	Proximal humeral fracture	Rheumatoid arthritis	Revision
Flexion						
No. of studies	23	7	5	12	2	12
Delta, °	62 (61-74)	54 (28-81)	65 (31-84)	NA	68 (61-74)	60 (44-80)
Final, °	130 (78-158)	134 (115-153)	132 (122-143)	122 (115-130)	132 (126-139)	110 (90-130)
Abduction						
No. of studies	16	2	3	5	2	6
Delta, °	60 (37-130)	58 (24-80)	63 (39-76)	NA	61 (no range)	50 (43-55)
Final, °	116 (90-145)	125 (116-140)	122 (109-129)	110 (101-113)	116 (no range)	94 (85-101)
ER0						
No. of studies	23	6	4	9	2	9
Delta, °	17 (2-32)	21 (2-46)	16 (−6 to 24)	NA	10 (5-14)	9 (−14 to 37)
Final, °	26 (7-40)	27 (9-47)	36 (8-51)	20 (5-37)	27 (20-33)	27 (1-50)
ER90						
No. of studies	3	3	2	2	1	2
Delta, °	27 (14-61)	25 (8-37)	19 (1-25)	NA	29 (no range)	−0.5 (−6 to 2)
Final, °	44 (40-63)	58 (39-64)	53 (41-57)	32 (32-36)	46 (no range)	24 (18-26)

NA, not applicable; *ER0*, external rotation with arm at side; *ER90*, external rotation at 90° of abduction.
The delta value indicates the change from before reverse total shoulder arthroplasty to after reverse total shoulder arthroplasty; the final value indicates range of motion reported at the final time point. Ranges are reported in parentheses.

(30°-40°) for final ER0. ER90 at final follow-up was greatest in the OA group (58°) and least in the Rev group (24°).

Patient-reported outcomes

Pain was improved across all preoperative diagnoses by 5-6. The final pain rating was lowest in the CTA group (0.4) and highest in the Rev group (1.8). The ASES score improved the least in the MIRCT group (35) and the most in the RA group (54). ASES score improvement was very similar for CTA, OA, and Rev (42-43). The final ASES score was similar for all groups, ranging from 78 to 81, with the exception of the Rev group, which showed a final score of 69 with little variance (range, 68-74). Improvement in the Constant score was very similar across all groups, ranging from 36 to 44, with small variance, with the exception of the Rev group, which had a variance range of 30. The final Constant score was highest in the OA group (76) and lowest in the Rev group (51) and was similar in the other groups (59-67). The SST improved by 4-6 across all preoperative groups, although a large variance was observed in the Rev group (3-11). The final SST score was 7-9 in all groups, with the exception of the Rev group, in which the final score was 6, with a range of 5-11 (Table IV).

Complications

The highest overall rate of complications was seen in the RA group, with a rate of 28%. The RA group also had the highest rate of each type of complication, with acromial or scapular spine fractures in 41% of patients, infections in 28%, dislocations in 26%, and nerve palsy in 10%. The lowest overall complication rate was seen in the OA group (1.4%), followed by the CTA group (7.4%). For the PHFx group, the aggregated rate for each category of complications was <2%. The most frequently occurring complication in the Rev and MIRCT groups was glenoid loosening (4% and 6.7%, respectively). Dislocation was reported as a complication in <2% of patients for all preoperative diagnoses, with the exception of the RA group (Table V).

Discussion

In all 6 preoperative diagnosis groups, shoulder elevation and abduction improved by ≥50°, ER0 improved by

Table IV Weighted means for patient-reported outcomes according to preoperative diagnosis

Patient-reported outcomes	Cuff tear arthropathy	Primary osteoarthritis	Massive irreparable rotator cuff tear	Proximal humeral fracture	Rheumatoid arthritis	Revision
Pain score						
No. of studies	8	1	2	1	1	4
Delta	5.3 (3.8-7.2)	6.4	4.5 (4.4-4.6)	NA	6 (no range)	5.2 (3.5-6)
Final	0.4 (0.8-3.5)	0.4 (no range)	1.4 (1-2.9)	1.4 (no range)	1 (no range)	1.8 (1-3)
ASES score						
No. of studies	13	3	4	4	1	5
Delta	42 (32-56)	43 (37-48)	35 (29-42)	NA	54 (no range)	42 (32-55)
Final	81 (65-90)	80 (73-84)	78 (75-83)	78 (68-89)	82 (no range)	69 (68-74)
Constant score (total unadjusted value)						
No. of studies	20	5	1	10	2	8
Delta	44 (35-52)	36 (33-45)	36 (no range)	NA	41 (40-42)	37 (25-55)
Final	67 (60-74)	76 (65-88)	63 (no range)	59 (57-71)	60 (54-65)	51 (39-56)
SST score						
No. of studies	4	2	4	3	1	6
Delta	5 (3-8)	4 (4-6)	4 (3-5)	NA	6 (no range)	4 (3-11)
Final	9 (8-10)	7.8 (7.7-7.9)	7.3 (6.5-8.3)	8.5 (7.4-9.2)	7 (no range)	6.3 (5-11.2)

NA, not applicable; *ASES*, American Shoulder and Elbow Surgeons; *SST*, Simple Shoulder Test.
The delta value indicates the change from before reverse total shoulder arthroplasty to after reverse total shoulder arthroplasty; the final value indicates the patient-reported outcome at the final time point. Ranges are reported in parentheses.

Table V Complications according to preoperative diagnosis, including 8 most common complications extracted from literature

Complications	Cuff tear arthropathy	Primary osteoarthritis	Massive irreparable rotator cuff tear	Proximal humeral fracture	Rheumatoid arthritis	Revision
No. of studies reporting	13	5	1	10	3	10
No. of patients pooled	668	213	60	1303	39	384
No. of complications	50	3	12	142	11	73
Total rate of complications, %	7.4	1.4	20	11	28	19
Hematoma, n (%)	0	0	1 (1.7)	4 (0)	0	8 (2)
Periprosthetic fracture, n (%)	1 (0)	2 (1)	0	11 (0.8)	1 (2.5)	5 (1.3)
Glenoid loosening, n (%)	1 (0)	1 (0)	4 (6.7)	24 (1.8)	1 (2.5)	15 (4)
Instability, n (%)	2 (0)	0	0	22 (1.7)	2 (5)	7 (1.8)
Dislocation, n (%)	10 (1.5)	0	1 (1.7)	3 (0)	10 (26)	7 (1.8)
Infection, n (%)	11 (1.6)	4 (2)	1 (1.7)	16 (1.2)	11 (28)	11 (3)
Nerve palsy, n (%)	4 (0.6)	5 (2.3)	0	6 (0.4)	4 (10)	6 (1.6)
Acromial or scapular spine fracture, n (%)	16 (2)	3 (1.4)	4 (6.7)	1 (0)	16 (41)	3 (0.8)

The total rate of complications is calculated as the number of complications reported divided by the pooled sample size for each diagnosis for studies that reported complications. For each type of complication, the number in parentheses is the rate of complication occurrence relative to the total number of patients within the pooled data.

approximately 10°, pain was reduced by 5-6 on the NPRS (which ranges from 0 to 10), and function improved by 4-6 on the SST as reflected by the delta values. All groups demonstrated improvements in ASES and Constant scores by $\geq$35, and the minimal clinically important difference (MCID) for these PROs after RTSA has been reported as 13-21 and 5.7, respectively.[78,84] The MCID has been reported as 1.6 for improvement in pain and 1.5 for the SST score, which was demonstrated among all preoperative diagnoses.[78,85] Therefore, RTSA is advantageous to patients

who have preoperative diagnoses of CTA, OA, MIRCT, PHFx, RA, and Rev.

There was a preponderance of low-quality evidence to inform this systematic review, with 36 of 53 studies (68%) being level IV retrospective case series and 34 of 53 (64%) having a high risk of bias on the MINORS tool. Case series are prone to bias that can limit generalizability to larger populations.[14] The 12 case-controlled studies (23%) had a moderate quality of evidence, which allowed for more direct comparison of outcomes. The dearth of randomized controlled trials reported (3 of 53, 6%) increases bias in the interpretation of the results.

The original indication for RTSA was CTA, which is reflected in the majority of the studies in this review reporting outcomes for this population. The age of the patients was comparable across all preoperative diagnoses; therefore, patient age does not preclude comparison among the aggregated group data. The observation of more women than men across all preoperative diagnoses has been reported in prior studies.[45,63,90] The higher incidence of RTSA in women with PHFx and with RA reflects that elderly women are more prone to PHFx injury because of osteoporosis and that women have a higher prevalence of RA than men.[29,96]

Patients who underwent RTSA for OA had a lower delta value for flexion, which may reflect a higher level of mobility prior to the procedure; however, there was high variance in this group's flexion outcome measure. Controversy exists regarding the influence of preoperative ROM on postoperative mobility following RTSA. One study reported a positive relationship between preoperative and postoperative motion.[28] In contrast, Clark et al[17] determined that less preoperative shoulder flexion resulted in greater delta values after RTSA as patients had more mobility to gain from surgical intervention. Reams et al[69] demonstrated no difference in preoperative flexion or abduction for patients undergoing RTSA for OA, CTA, and MIRCT, which is similar to the results in our project. Patients with OA attained the highest ER0 delta value and final ER90 measurement, which reflects the intact rotator cuff in this population and better preoperative status for this motion. This result conflicts with that of Wall et al,[90] who demonstrated decreased ROM for all values as well as lower Constant scores in the OA group compared with patients with other preoperative diagnoses. The surgical procedure in their study used a medialized Grammont prosthesis. Our systematic review includes studies with a variety of prosthetic designs, including lateralized implants, which have been shown to provide increased external rotation ROM and thereby may impact functional outcome.[35,43] CTA and MIRCT patients were often combined in studies reviewed for this systematic review, which therefore were not included in this analysis. Flexion and abduction ROM and ASES and Constant scores are comparable for these 2 groups; therefore, expectations of outcomes for RTSA are similar for CTA and MIRCT. Lindbloom et al[45] recently published outcomes of RTSA stratified by preoperative diagnosis and concluded that CTA, MIRCT, and OA patients all demonstrated clinically significant improvements in ROM and ASES, SST, and pain scores. The PHFx group did not have preoperative data owing to the nature of the injury; however, the final ROM for flexion, abduction, ER0, and ER90 was lower than that in all other groups, with the exception of the Rev group. RTSA is used for acute 3-part PHFx and 4-part PHFx, which often involve the tuberosities.[5] Patients undergoing RTSA and greater tuberosity repair have been reported to demonstrate better flexion and external rotation than when the greater tuberosity is not repaired.[5] This systematic review analyzed all PHFx data in aggregate, without stratifying tuberosity repair, which may have resulted in the lower mobility scores. Clinicians should be aware of the impact of tuberosity repair on outcomes in this population. An additional consideration is that the PHFx group had a proportionally higher distribution of women than men, and women have been shown to have poorer outcomes for pain, ASES and SST scores after RTSA.[84] The PHFx group had comparable ASES, Constant, and SST scores to the other preoperative diagnosis groups in this study. The reported ASES and Constant scores (76 and 59, respectively) were comparable to results in a previous systematic review of RTSA outcomes for PHFx (74 and 56, respectively).[5]

Patients who underwent RTSA for revision of an anatomic arthroplasty (hemiarthroplasty or TSA) attained a lower final endpoint of ROM for flexion, abduction, and ER90 and had higher postoperative pain and lower satisfaction scores than the other groups. Although the Rev group had a poorer outcome overall, the differential between the Rev and CTA final pain scores was 1.4 (1.8 and 0.4, respectively), which did not reach the MCID value of 1.6.[78] A report of short- and mid-term results after RTSA according to preoperative etiology of CTA and Rev demonstrated that the Rev group had lower Constant scores.[63] Wall et al[90] reported the results of RTSA for CTA, OA, MIRCT, acute fracture, Rev, and RA and also determined that Rev patients had poorer outcomes according to the Constant score and that, overall, the procedure was less predictable for this population. Clinicians can expect that although patients who undergo RTSA for revision of a failed anatomic shoulder replacement will improve after surgery, the amount of motion and function will be less than when surgery is performed for other preoperative indications. The rationale for the inferior results is likely related to soft-tissue attrition and scarring from repeated surgery, as well as poor bone quality.[60]

The low complication rate in the OA group coupled with the good outcomes observed may contribute to the increased utility of RTSA reported for this population.[13] The complication rate was highest in the RA group,

which may reflect the bone and soft-tissue degeneration surrounding the shoulder in this population.[62] This group also contained the lowest number of patients; therefore, the rate of complications should be interpreted with caution. Acromial or scapular spine fractures occurred at a high rate in the RA group, and these patients are reported to demonstrate a high rate of osteoporosis.[56] The dislocation rate was higher in this population, possibly related to subscapularis insufficiency, which has been associated with dislocation following RTSA with either a lateralized or medialized prosthetic implant.[12,47] Other authors have demonstrated that subscapularis repair does not impact the dislocation rate following RTSA with a lateralized prosthetic implant.[17] The studies with patients included in the RA group in this systematic review used a combination of lateralized and traditional Grammont prostheses; therefore, the influence of the implant on the dislocation rate may be less related to implant design and more related to lack of muscular stability. The infection rate was highest in the RA population, which may reflect the immunocompromised status of these patients.[70] Complication rates were also comparatively elevated in the MIRCT, Rev, and PHFx groups and were most prevalent for acromial or scapular spine fractures, glenoid loosening, and infection. Deltoid lengthening in RTSA patients places strain on the acromion and scapular spine, which likely have decreased bone density in this elderly population. Awareness and identification of this complication are important so that if stress fractures occur, patients can rest sufficiently to recover and attain successful outcomes after RTSA.[88] Glenoid loosening, dislocation, and infection were reported in prior comparative studies of RTSA for varied preoperative etiologies,[45,90] with 1 study reporting a higher rate of complications in the Rev group.[91] The rate of dislocation among the preoperative diagnosis groups in this systematic review, excluding the RA population, ranged from 0% to 1.8%, which is lower than the rates in other reports of $\geq$9%.[11,15] Therefore, the RTSA dislocation risk may not be as high as implicated in some studies. The dislocation rate has been reported to be higher in the male population, in patients who undergo RTSA for fracture sequelae, and in patients in whom the subscapularis is not repaired.[15] All of the preoperative diagnosis groups in this systematic review had a larger proportion of women than men, did not include fracture sequelae, and did not stratify the results with consideration of subscapularis repair, which may account for the lower reported dislocation rate.

Future research

Future research is needed that utilizes randomized controlled trials or high-quality case-controlled series to inform outcomes for varied preoperative diagnoses following RTSA. Globally applied methods of collecting clinical outcome and PRO measures would allow for more robust comparison of studies and aggregation of data. The trend in reporting results is for European studies to use the Constant or Oxford score as the PRO but for US studies to report the ASES score.[35] The variability in reporting patient outcomes precluded pooling data, which created a less robust analysis. ASES participates in a global registry that allows surgeons to collect and analyze patient outcomes in a unified manner.[4] Standardized data aggregation at this level would be advantageous for informing outcomes after RTSA.

Limitations

A significant limitation of this study was that varied prosthetic implants and surgical procedures were aggregated and analyzed together. Studies have shown differences between medialized and lateralized centers of rotation for prosthetic implants,[35] as well as variance in the neck-shaft angle.[40] The status of the teres minor and infraspinatus was not included in data extraction, and posterior rotator cuff integrity may impact motion and function after RTSA.[42] High variance was observed in the reported PROs, with the ASES score being used in American studies and the Constant score often being used in the Europe-based literature. When the Constant score was reported, the pain level was extracted from these data, which precluded the use of pain as a data point for these studies as the range is different from that of the NPRS (ie, 0-10). The complication rate was not described in all studies included in this systematic review; therefore, there may be a difference in the expected rate and type of complications for each preoperative diagnosis. Moreover, not all studies are equally represented in the aggregated data; therefore, the results cannot be weighed equally among the preoperative diagnoses. Although an attempt to manage this was made through the calculation of weighted means, there were more studies and therefore more robust data regarding CTA, PHFx, and Rev than OA, MIRCT, and RA. Across all studies, there was a preponderance of low-quality level IV studies, which limits the interpretation of the data. Finally, only English-language studies were included, which may have led to omission of studies that could have contributed meaningful results.

Conclusion

RTSA is a reliable solution for improving clinical outcomes and PROs for varied preoperative indications including rotator CTA, primary OA without rotator cuff tear, MIRCT without OA, acute PHFx, RA, and revision of anatomic shoulder arthroplasty. The majority of studies reporting outcomes following RTSA are level IV studies and have a low quality of evidence. Patients with OA may expect greater improvement in ER0 and final ER90 ROM and decreased shoulder flexion ROM

improvement compared with the other groups, depending on the preoperative status. Rev and PHFx patients may expect decreased ROM and lower functional scores than other groups. Although RA patients demonstrated good clinical outcomes and PROs, there were higher complication rates in this population. Other complications that occurred among all preoperative diagnoses included acromial and scapular spine stress fractures, glenoid loosening, and infection. Understanding the differences in outcomes of RTSA according to preoperative diagnosis can assist clinicians in establishing patient expectations regarding recovery.

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Supplementary data

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