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SYSTEMATIC REVIEW

Outcome and complications following revision shoulder arthroplasty

A SYSTEMATIC REVIEW AND META-ANALYSIS

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Aims

It is important to understand the rate of complications associated with the increasing burden of revision shoulder arthroplasty. Currently, this has not been well quantified. This review aims to address that deficiency with a focus on complication and reoperation rates, shoulder outcome scores, and comparison of anatomical and reverse prostheses when used in revision surgery.

Methods

A Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) systematic review was performed to identify clinical data for patients undergoing revision shoulder arthroplasty. Data were extracted from the literature and pooled for analysis. Complication and reoperation rates were analyzed using a meta-analysis of proportion, and continuous variables underwent comparative subgroup analysis.

Results

A total of 112 studies (5,379 shoulders) were eligible for inclusion, although complete clinical data was not ubiquitous. Indications for revision included component loosening 20% (601/3,041), instability 19% (577/3,041), rotator cuff failure 17% (528/3,041), and infection 16% (490/3,041). Intraoperative complication and postoperative complication and reoperation rates were 8% (230/2,915), 22% (825/3,843), and 13% (584/3,843) respectively. Intraoperative and postoperative complications included iatrogenic humeral fractures (91/230, 40%) and instability (215/825, 26%). Revision to reverse total shoulder arthroplasty (TSA), rather than revision to anatomical TSA from any index prosthesis, resulted in lower complication rates and superior Constant scores, although there was no difference in American Shoulder and Elbow Surgeons scores.

Conclusion

Satisfactory improvement in patient-reported outcome measures are reported following revision shoulder arthroplasty; however, revision surgery is associated with high complication rates and better outcomes may be evident following revision to reverse TSA.

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Introduction

The prevalence of shoulder arthroplasty has increased dramatically over the past decade, with a projected growth rate exceeding that for lower limb arthroplasty.[1] This is in part due to arthroplasty becoming the accepted primary or salvage treatment for diverse pathologies including arthritis, fractures, avascular necrosis, and rotator cuff tears. Furthermore, the success of modern shoulder arthroplasty and advances in prosthetic design has led to an expansion of shoulder arthroplasty surgery in younger patients.[2]

The lifetime risk of revision following shoulder arthroplasty is reported to be as high as one in four, with patients aged 60 and under having a fourfold higher risk of revision compared to those over 85 years of age.[2] Hence, the exponential rise in primary surgery has been associated with

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Table I. Grouping of selected complications used to classify indications and outcomes.

Complication	Description
Component loosening	Glenoid or humeral component dissociation, screw failure, malposition, migration, or material disassembly following arthroplasty.
Instability	Recurrent dislocations due to a defect in the prosthesis
Rotator cuff failure	Insufficiency or tear in rotator cuff muscles
Glenoid failure	Glenoid disease following hemiarthroplasty (arthritis/erosion/arthrosis) or glenoid component failure (polyethylene wear or broken hardware) following anatomical TSA
Baseplate failure	Polyethylene wear or broken hardware in baseplate of glenoid component following reverse TSA
Fracture sequalae	Nonunion, malunion, or failure following fracture fixation
Radiological complications*	Component or bone lucency, subsidence, scapular notching, or radiological loosening.
Wound problems	Wound infection or impaired healing post-surgery.

*Includes radiological inconsistencies reported as a complication and requiring reintervention as a result. Radiological outcomes were not studied in this systematic review.
TSA, total shoulder arthroplasty.

a corresponding increase in the demand for revision surgery. However, compared to hip and knee arthroplasty, this burden remains relatively low, which means most individual surgeons have limited experience and outcome data on revision arthroplasty.

Common indications for revision include glenoid wear, component loosening, infection, periprosthetic fracture, cuff failure, and instability. Many of the principles used in revision shoulder arthroplasty are derived from the more extensive lower limb literature, however revision shoulder arthroplasty poses some specific challenges such as the unique microbiological environment of the shoulder; the reliance on coordinated muscle function for stability; the proximity of neurovascular structures; and the relatively lower bone stock available.

There is currently no consensus for uniform implant selection in revision surgery, although there is a trend towards reverse total shoulder arthroplasty (TSA) as the favoured option.[3,4] Nevertheless, anatomical TSA continues to have a role in revision surgery for particular modes of failure where the rotator cuff remains intact.[5]

Although we know that inferior functional results[6-10] and a higher incidence of complications (up to 50%)[10-12] are associated with revision compared to primary shoulder arthroplasty, there is sparse data available on the specific outcomes and complications of revision arthroplasty. A recent systematic review provides some insight into this area, with comparisons made between European and North American practice.[13] The authors identified similar practice in most aspects of revision shoulder arthroplasty between European and North American surgeons with a 17% reported overall complication rate.

This study aimed to comprehensively search the literature and present the relevant collated data on revision shoulder arthroplasty with a focus on complication and reoperation rates, shoulder outcome scores, and comparison of these metrics between anatomical and reverse TSA, when used in revision surgery.

Methods

This systematic review was registered on the PROSPERO database (Registration ID: CRD42019150698) and conducted as per the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol.[14]

Search and data collection. All English language papers reporting clinical data for revision shoulder arthroplasty were included in this study. Abstracts from scientific meetings, unpublished reports, case reports, and review articles were excluded. Patients with a minimum of 24 months' follow-up after revision surgery were included in quantitative synthesis of PROMs, postoperative complication data, and reoperation data. Patients with inadequate or no follow-up were included for the purpose of studying intraoperative complications but were excluded when synthesizing postoperative outcomes.

Embase and MEDLINE databases were searched on 6 April 2021 for all articles published since 2001. References of all included studies were subsequently screened for further articles eligible for inclusion. For search strategy employed see Supplementary Material I. Search results and included papers were managed using spreadsheet software. One reviewer (VR) screened study titles followed by abstract and full manuscript review, where necessary, to determine appropriateness for inclusion. Three reviewers (RJM, MD, JP) assessed identified studies for confirmation of eligibility and any disagreement was resolved by consensus. One reviewer (VR) performed initial data collation followed by cross-checking by a second reviewer (MD).

Basic data collected from individual studies, where reported, included cohort demographics, indication for revision, index surgery, final implant used in revision, pre- and postoperative shoulder outcome scores, intra- and postoperative complications, and reoperations. Due to inconsistency in reporting terminology, some indications and complications were grouped to enable easier understanding and classification of reported data (see

Table I). In studies that reported outcomes for the same cohort at multiple timepoints, only data from the most recent timepoint was included.

Methodological Index for Non-Randomised Studies (MINORS) was chosen for risk of bias assessment; this was performed at outcome level. Each individual study included in this review was scored for its methodological quality and risk of bias using the 12-item index provided by MINORS,[15] which deems ideal global scores of 16 and 24 for non-comparative and comparative studies, respectively.

Statistical analysis. Pooled descriptive analysis of collected data was used to understand patient demographic details, indications for revision, and frequency of different index and revision surgical procedures. Complication rates used the number of patients with at least one complication/reoperation as the numerator and total number of patients studied as the denominator. Results were pooled across different studies using a meta-analysis of proportion;[16] which involves using a Freeman-Tukey transformation to calculate an overall rate, weighted according to the reported rates and sample size of each study. This was performed using MedCalc software (Belgium) and random-effects model was used to account for variability in effect estimates. Results are presented in the form of a forest plot, with each study represented by its weight, reported rate and 95% confidence interval (95% CI). Heterogeneity testing employed the I^2 statistic, describing the percentage variation between studies;[17] a value greater than 50% was considered 'substantial heterogeneity' for the purpose of this study.

PROMs were studied using minimal clinically important difference (MCID), a measure of responsiveness that represents the smallest subjective difference in shoulder outcome score corresponding to a clinically important change to the patient.[18] Change in mean score over follow-up duration for each reported study was used to identify proportion of studies that achieved MCID.

Sub-groups were defined as 1) shoulders revised to reverse TSA and 2) shoulders revised to anatomical TSA. Complication rates were compared using chi-squared and Fisher's exact test; with results summarized using percentages and odds ratio (OR). OR greater than 2 with a 95% CI not spanning null value (OR = 1) was considered clinically relevant. Shoulder outcome scores were pooled across reported studies using frequency-weighted means and compared between sub-groups using independent-samples *t*-test. Statistical tests were performed using SPSS software v26.0.0.0 (USA) and a p-value less than 0.05 was considered statistically significant for this study.

Results

Overall, 112 studies were deemed eligible for inclusion (Figure 1); 84 were level IV studies, 27 level III, and one level II, all of which reported clinical data for patients undergoing revision shoulder arthroplasty. All studies included cohorts with adequate follow-up periods apart from one,[19] which reported intraoperative data for a group of patients not followed up after revision surgery. This study was included in the systematic review as it was deemed eligible to study intraoperative complications; but was excluded for the purpose of analyzing postoperative outcomes. For a list of individual studies with cohort size and reported complications see Supplementary Table i.

A total of 57 of 112 (51%) studies achieved ideal global MINORS scores. Scores from the remaining studies ranged from 12 to 15 for level IV and 19 to 23 for level III studies. All studies were deemed eligible to be included in quantitative synthesis; for individual study scores see Supplementary Material II.

Overall, 5,379 shoulders in 5,225 patients having undergone revision shoulder arthroplasty were included. Complete demographic data for patients undergoing revision was reported in 85 out of 112 (76%) studies. Pooled demographic and clinical data with indications for revision are presented in Table II. The mean age of patients at revision surgery was 67 years (21 to 84) and 60% of patients were female. Follow-up duration was reported in 3,240 of 3,474 (93%) shoulders with adequate follow-up; the cohort was followed up for a mean of 48 months (24 to 113). Of the shoulders with available data regarding index and revision procedures (See Table II), the most common index procedure was hemiarthroplasty (50%, 1,645/3,295) and the majority of shoulders were revised to reverse TSA (67%, 3,341/5,004). Of the shoulders with available data regarding indication for revision (see Table II), the most common indications were component loosening (20%, 601/3,041), instability (19%, 577/3,041), rotator cuff failure (17%, 528/3,041), and infection (16%, 490/3,041).

Intraoperative complications were reported in 50 of 112 studies (45%). Of 2,915 shoulders, 230 (8%) had an intraoperative complication during revision shoulder arthroplasty; reported complications are presented in Table III. Of the 230 intraoperative complications, 162 (70%) were iatrogenic fractures and of these, 91 of 162 (56%) involved the humerus. The weighted global intraoperative complication rate was 7.9% (95% CI 5.5 to 10.6; see Supplementary Material III) with substantial heterogeneity between studies (I^2 = 77.7% (95% CI 70.9 to 82.9)).

Postoperative complications were reported in 111 of 112 studies. Of 3,843 shoulders included in this analysis, 825 (21%) reported a postoperative complication following revision shoulder arthroplasty; reported complications are presented in Table IV. Instability was the most commonly reported postoperative complication (26%, 215/825), followed by component loosening (19%, 158/825), infection (16%, 129/825), and

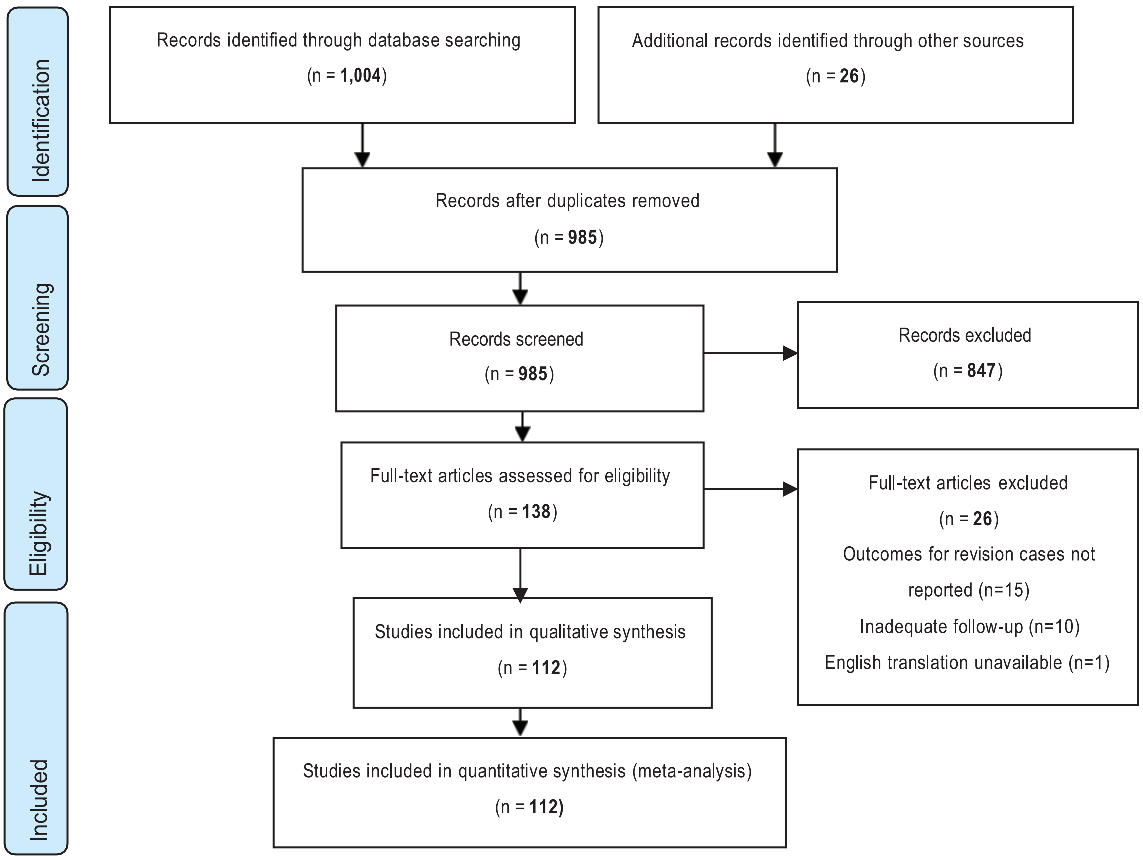

Fig. 1

Flowchart outlining the process of study selection for this systematic review.

periprosthetic fracture (12%, 100/825). The weighted global postoperative complication rate was 21.9% (95% CI 19.2 to 24.7, see Supplementary Material IV) with substantial heterogeneity between studies (I^2 = 76.4%, 95% CI 71.7 to 80.2).

Reoperation rate was reported in 111 of 112 studies. Of 3,843 shoulders, 584 (15%) shoulders underwent reoperation following revision shoulder arthroplasty; reported reoperations are presented in Table V. Of 533 reoperations, 232 (40%) reoperations stated need for revision of one or both components of the shoulder prosthesis, 45 (8%) reoperations did not require component revision, and 307 (58%) reoperation procedures were not specified. The weighted global reoperation rate was 13.3% (95% CI 11.5 to 15.3, see Supplementary Material IV) with substantial heterogeneity among studies (I^2 = 66.1% (95% CI 58.7 to 72.2)).

Shoulder outcome scores were reported pre- and postoperatively in 55 of 112 (49%) studies; these are presented in Table VI. The American Shoulder and Elbow Surgeons (ASES) score[55] was reported in 27 of 55 (49%) studies and Constant score[56] was reported in 28 of 55 (51%) studies. MCID was achieved in 48 of 55 (87%) studies; this required a 21- and eight-point improvement in ASES and Constant scores respectively.[18,57] ASES score was reported in 21 of 48 (44%) studies that achieved MCID and Constant score was reported in 27 of 48 (56%) studies that achieved MCID.

Reported postoperative complications were separated into subgroups of those occurring following revision to anatomical TSA or to reverse TSA from data provided in 81 of 111 (73%) studies that reported postoperative outcome data.[20–24,27,28,30–33,37,38,45–53,58–79,81–85,87,88,92–122] [123] [124] [125] [126] [127] [128–130] [131–133] This included 455 complications in 2,073 shoulders revised to reverse TSA and 174 complications in 601 shoulders revised to anatomical TSA. The incidence and OR of postoperative complications in the two groups is presented in Table VII.

In the group revised to anatomical TSA, compared to those revised to reverse TSA, there was a significantly higher incidence of postoperative complications using a chi-squared test (OR 1.5 (95% CI 1.2 to 1.8); $p < 0.001$), with a clinically relevant higher incidence of pain and stiffness (OR 5.3 (95% CI 2.7 to 10.5); $p < 0.001$) and rotator cuff failure (OR 42.7 (95% CI 13.1 to 139.2); $p < 0.001$) following revision.

In the group revised to reverse TSA, there was a clinically relevant higher incidence of periprosthetic fracture (OR 2.5 (95% CI 1.2 to 5.0); $p < 0.009$, chi-squared test) following revision.

Table II. Demographic data of the pooled cohort.

Variable	Reported studies (n = 112)	Shoulders with available data (n = 5,379)	Result		%
Mean age at revision, yrs (range)	105*	5,225	67 (21 to 84)		
Mean follow-up, mths	107†	3,609	48		
Sex	101‡	4,862	Female	2,925/4,862	60
			Male	1,910/4,862	40
Index surgery	100§	3,295	Hemiarthroplasty	1,645/3,295	50
			Anatomical TSA	1,152/3,295	35
			Revere TSA	402/3,295	15
Revision surgery	109¶	5,004	Reverse TSA	3,341/5,004	67
			Anatomical TSA	1,213/5,004	24
			Hemiarthroplasty	348/5,004	7
			Resection arthroplasty	43/5,004	<1
			Antibiotic spacer implantation	41/5,004	<1
Indication for revision surgery	90**	3,041	Component loosening	601/3,041	20
			Instability	577/3,041	19
			Rotator cuff failure	528/3,041	17
			Infection	490/3,041	16
			Glenoid failure	401/3,041	13
			Baseplate failure	83/3,041	3
			Pain and stiffness	62/3,041	2
			Fracture sequelae	59/3,041	2
			Periprosthetic fracture	58/3,041	2
			Tuberosity resorption	18/3,041	< 1

*Age was not reported in seven studies. [20–26]
†Mean follow-up duration was not reported in four studies,[23,27–29] all of which included cohorts followed up for longer than 24 months and one study[19] included a cohort that was not followed up.
‡Sex of patients undergoing revision was not reported in 11 studies. [23–26,30–36]
§Index surgery was not reported in 12 studies. [19,24,26,28,37–44]
¶Revision surgical procedure was not reported in three studies.[26,41,42]
**Indication for revision surgery was not reported in 22 studies. [19,20,23,24,27,30,32,34–37,44–54]
TSA, total shoulder arthroplasty.

Table III. Reported intraoperative complications during revision shoulder arthroplasty.

Intraoperative complication	Reported (n = 230)	%
Iatrogenic humeral fracture	91/230	40
Iatrogenic glenoid fracture	4/230	2
Unspecified iatrogenic fracture	67/230	29
Cement extrusion	17/230	7
Shaft perforation	10/230	4
Nerve injury	9/230	4
Humerus fissure	6/230	3
Antibiotic related complication	3/230	1
Iatrogenic cuff tears	2/230	< 1
Bony window	1/230	< 1
Vascular injury	1/230	< 1
Unspecified intraoperative complication	19/230	9

There was no clinically relevant difference in the incidence of instability, component loosening, infection, haematoma formation, fracture sequelae, radiological complications, nerve injuries, or wound problems between the two groups.

Reported shoulder outcome scores were separated into subgroups of those occurring following revision to anatomical TSA or to reverse TSA from data provided in 45 of 55 (82%) studies that reported PROMs. ASES score was reported in 22 of 45 studies,[20,28,32,48,50,52,53,58,60,61,63,68,70,72,74,76,77,79,81,83,85,87] and Constant score was reported in 23 out of 45 studies.[21,22,27,38,47,51,59,62,64–67,69,73,75,78,82,84,88,90–92,118] This included outcomes for 1,208 shoulders revised to reverse TSA (669 reported using ASES and 539 reported using Constant score) and 162 shoulders revised to anatomical TSA (42 reported using ASES and 120 reported using Constant score). Comparison of postoperative scores and changes in scores following revision to anatomical and reverse TSA are presented in Figures 2a and 2b, respectively.

When Constant scores were compared using an independent-samples *t*-test, the group revised to reverse TSA from any type of index prosthesis demonstrated a significantly higher postoperative score when compared to those revised to anatomical TSA ($p < 0.001$) (mean difference 6.1 (95% CI 3.7 to 8.5) and change in score ($p < 0.001$) (mean difference 21.2 (95% CI 18.1 to 24.3) following revision. When ASES scores were compared, there was no significant difference in the postoperative

Table IV. Reported postoperative complications following revision shoulder arthroplasty.

Postoperative complication	Reported (total = 825)	%
Instability	215/825	27
Component loosening	163/825	17
Infection	118/825	14
Periprosthetic fracture	101/825	13
Rotator cuff failure	52/825	7
Pain and stiffness	46/825	6
Haematoma	32/825	4
Radiological complications	12/825	2
Wound problems	12/825	1
Glenoid failure	17/825	1
Baseplate failure	11/825	1
Nerve injuries	9/825	1
Fracture sequelae	8/825	1
Graft failure	6/825	< 1
Heterotopic ossification	3/825	< 1
Deltoid insufficiency	2/825	< 1
Cement extrusion	2/825	< 1
Pulmonary embolism	2/825	< 1
Arthrofibrosis	1/825	< 1
Deep vein thrombosis	1/825	< 1
Pectoralis major rupture	1/825	< 1
Subacromial impingement	1/825	< 1
Hemarthrosis	1/825	< 1
Unspecified postoperative complication	9/825	1

Table V. Reported reoperations following revision shoulder arthroplasty.

Reoperation	Reported (total = 584)	%
Revision shoulder arthroplasty	181/584	40
Open/closed reduction under general anaesthetic	11/584	2
Irrigation and debridement	8/584	1
Arthroscopic excision	8/584	1
Open reduction internal fixation	7/584	1
Surgical drainage of haematoma	5/584	1
Subscapularis repair	2/584	< 1
Subacromial decompression	1/584	< 1
Surgical neurolysis	1/584	< 1
Cement removal	1/584	< 1
Open excision of heterotopic ossification	1/584	< 1
Reoperation not specified	307/584	58

score ($p = 0.571$) and change in score ($p = 0.072$) between the two groups.

Outcomes scores for shoulders revised from index anatomical TSA were reported in 14 of 112 (13%) studies; ASES score was reported in five (36%) studies,[68,70,72,77,81] and Constant score in nine (64%) studies.[22,27,62,64,67,69,73,84,91] This included outcomes for 216 shoulders with index anatomical TSA revised to reverse TSA (45 reported using ASES and 171 reported using Constant score) and 102 shoulders with index anatomical TSA revised to a second anatomical TSA (29 reported using ASES and 73 reported using Constant score). Comparison of postoperative score and change in score following revision is presented in Figures 2c and 2d, respectively.

When ASES and Constant scores were compared, the group with index anatomical TSA revised to reverse TSA, in comparison to those revised to anatomical TSA, reported a significantly higher postoperative score ($p < 0.001$) (ASES mean difference 9.6 (95% CI 5.7 to 13.4); Constant mean difference 11.6 (95% CI 7.7 to 15.5)) and change in score following revision (ASES mean difference 18.4 (95% CI 13.2 to 23.6); Constant mean difference 32.0 (95% CI 28.2 to 35.7); $p < 0.001$).

Discussion

The meta-analysis data demonstrated overall rates for intraoperative complications, postoperative complications, and reoperations following revision shoulder arthroplasty of 8%, 22%, and 13%, respectively. The most commonly reported intraoperative and postoperative complications were iatrogenic humeral fractures and instability, respectively. Overall, 87% of studies with reporting outcome scores demonstrated an improvement in PROMs of a greater magnitude than the MCID.

A higher incidence of postoperative complications was reported in shoulders that were revised to anatomical TSA, compared to reverse TSA, however this did not reach our predetermined clinically relevant threshold. There was a clinically relevant higher incidence of pain and stiffness, and rotator cuff failure following revision to anatomical TSA versus reverse TSA, although clear objective definitions of these two outcomes are difficult to ascertain from the literature investigated. Conversely, there was a clinically relevant higher incidence of periprosthetic fractures following revision to reverse TSA, versus anatomical TSA. Revision from any index prosthesis to reverse TSA, versus revision to anatomical TSA, resulted in greater absolute postoperative Constant score as well as perioperative improvement in Constant score. Furthermore, revision of index anatomical TSA to reverse TSA, versus revision to a second anatomical TSA, achieved greater absolute postoperative and perioperative improvement in both ASES and Constant scores.

Iatrogenic fractures during shoulder arthroplasty are relatively uncommon, although they can be a challenge to manage when they arise during revision surgery.[134] Reports indicate that intraoperative fracture results in increased operating time, higher blood loss, and poorer postoperative outcomes.[120,135] Our findings suggest that humeral fractures have a higher incidence compared to glenoid fractures, which is consistent with results from other studies.[12,120] Fracture during prosthesis explantation is the most likely cause, with removal of stemmed humeral components being the riskiest stage of the procedure according to our data. The fracture risk can occur when

Table VI. Functional outcome scores before and after revision shoulder arthroplasty.

Mean ASES score					**Mean Constant scores**				
Author and year of publication	**Cases**	**Preop**	**Postop**	**Change in score > MCID?**	**Author and year of publication**	**Cases**	**Preop**	**Postop**	**Change in score > MCID?**
Cox et al[58]	72	33.7	51.1	No	Jaiswal et al[59]	26	35.06	59.69	Yes
Crosby et al[60]	102	32.56	58.7	Yes	Werner et al[38]	50	11.1	39.5	Yes
Hernandez et al[61]	65	21.4	67.7	Yes	Antoni et al[62]	37	26.9	53.3	Yes
Kohan et al[63]	19	35	65	Yes	Cisneros et al[64]	40	16.79	58.09	Yes
Otto et al[50]	35	24.4	40.8	No	Ortmaier et al[65]	50	18.5	49.3	Yes
Stephens et al[28]	58	45.6	52.9	No	Wieser et al[66]	45	24	45	Yes
Kelly et al[48]	30	54.8	71.8	No	Melis et al[67]	37	31.6	75.6	Yes
Deutsch et al[68]	32	34	39	No	Valenti et al[69]	30	24.47	51.57	Yes
Walker et al 2012[70]	22	38.5	67.5	Yes	Kany et al[71]	29	27	60	Yes
Weber-Spickschen et al[72]	15	12	36	Yes	Bonnevialle et al[73]	42	54.2	79.3	Yes
Holcomb et al[74]	14	36	70	Yes	Werner et al[75]	14	8.9	41	Yes
Lee et al[40]	12	32.25	64.17	Yes	Farshad et al[30]	37	23	46	Yes
Budge et al[76]	15	38.2	68.3	Yes	Flury et al[21]	21	16.6	56	Yes
Schubkegel et al[77]	14	33	72	Yes	Beekman et al[78]	5	50.2	64.2	Yes
Wiater et al[53]	44	41.8	59.9	No	Postacchini et a[51]	16	38.7	50.6	Yes
Stephens et al[52]	32	29.7	70.6	Yes	Hoffelner et al[22]	11	24	40	Yes
Levy et al[79]	29	22.3	52.1	Yes	Geervilet et al[80]	11	67.1	96.1	Yes
Patel et al[81]	28	24	66	Yes	Natera et al[82]	23	24.26	84	Yes
Chacon et al[20]	25	31.7	69.4	Yes	Valenti et al[69]	10	39.4	71	Yes
Levy et al[83]	19	29.1	61.2	Yes	Castagna et al[84]	26	25.28	47.88	Yes
Holschen et al[85]	28	19.2	58.5	Yes	Muh et al[86]	26	25.2	27.3	No
Cuff et al[87]	17	31.9	57.0	Yes	Hartel et al[88]	19	19.8	38.7	Yes
Johnston et al[32]	13	19.6	58.9	Yes	Gohlke et al[47]	25	12.67	45.08	Yes
Andersen et al[25]	5	32	54.4	Yes	Pellegrini et al[89]		21.7	39.5	Yes
Franke et al[36]	123	31	55	Yes	Grubhofer et al[90]	48	26.8	43	Yes
Gorman et al[44]	98	35	58	Yes	Crosby et al[27]	73	24	71.91	Yes
Franke et al[35]	113	30	59	Yes	Elhassan et al[91]	21	27.80	65.09	Yes
					De Wilde et al[92]	4	14	66	Yes

ASES, American Shoulder and Elbow Surgeons; MCID, minimal clinically important difference.

removing a cemented stem, removing cement itself, or explanting an uncemented stem, however evidence to suggest which of these was the most likely was not demonstrable in our results due to lack of individual case data. Future use of exchangeable modular, short-stemmed, and stemless humeral prostheses may have an impact on reducing intraoperative fracture risk.

A high incidence of postoperative instability following revision was expected (6% in this meta-analysis) as it is commonly reported following primary reverse TSA,[136–138] and two-thirds of the shoulders included in the present study were revised to a reverse prosthesis. Despite this presumption, subgroup analysis found no difference in incidence of instability following revision to reverse or anatomical TSA. We speculate this may be due to inconsistency in terminology used by individual studies to report instability, as well as the differences in presentation of instability occurring in anatomical and reverse TSAs. The clinical relevance of this comparison may be limited.

The clinically relevant higher incidence of pain and stiffness following revision to anatomical TSA may be attributable to dynamic cuff dysfunction from chronic cuff disease. Less substantial soft-tissue release in anatomical arthroplasty or postoperative immobilization following subscapularis repair may also be factors contributing to stiffness in anatomical revision. There was a comparatively higher rate of cuff failure as a reported complication following anatomical TSA, which was a predictable finding and clinically unimportant when comparing complication rates.

The clinically relevant higher incidence of postoperative periprosthetic fracture following revision to reverse TSA was an unexpected finding; periprosthetic fractures are thought to be uncommon, with low incidence rates previously reported following reverse TSA.[12,139,140] We believe this is an incidental finding and acknowledge that the result is subject to bias, as multiple factors that increase risk of fractures have not been taken into consideration when comparing the two groups, such as age, bone density, and presence of other comorbidities. Surgical technique used in revision, individual prosthetic design, and preferential use of press fit stems could have contributed to this result. Additionally, fracture location

Table VII. Postoperative complications following revision to reverse total shoulder arthroplasty versus anatomical total shoulder arthroplasty: reported incidence and odds ratio.

Postoperative complication	RTSA cases (n = 2,073)	%	ATSA cases (n = 601)	%	p-value	OR* RTSA	OR* ATSA
Instability	134	6.46	51	8.49	0.084†		1.34 (0.96 to 1.88)
Component loosening	92	4.44	22	3.66	0.405†	1.22 (0.76 to 1.96)	
Infection	60	2.89	16	2.66	0.765†	1.09 (0.62 to 1.91)	
Periprosthetic fracture	75	3.62	9	1.50	0.009†	2.47 (1.23 to 4.96)	
Pain and stiffness	14	0.68	21	3.49	< 0.001†		5.33 (2.70 to 10.54)
Rotator cuff failure	3	0.14	35	5.82	< 0.001‡	42.67 (13.08 to 139.24)	
Haematoma	24	1.16	1	0.17	0.027‡	7.02 (0.95 to 52.06)	
Glenoid failure	-	-	5	0.83			
Baseplate failure	10	0.48	-	-			
Fracture sequelae	1	0.05	1	0.17	0.399‡		3.45 (0.23 to 55.30)
Radiological complications	12	0.58	0	0.00	0.080‡	7.29 (0.43 to 123.39)	
Nerve injuries	6	0.29	1	0.17	1.000‡	1.74 (0.21 to 14.50)	
Wound problems	6	0.29	1	0.17	1.000‡	1.74 (0.21 to 14.50)	
Others	15	0.72	6	1.00			
Unspecified	3	0.14	5	0.83			
Overall complication rate	455	21.95	174	28.95	< 0.001†		1.45 (1.18 to 1.78)

*Odds ratio (OR) with 95% confidence interval. OR greater than 2 with 95% CI not spanning null value (OR = 1) was considered clinically relevant.
†Compared using chi-squared test.
‡Compared using Fisher's exact test.
ATSA, anatomical total shoulder arthroplasty; OR, odds ratio; RTSA, revision total shoulder arthroplasty.

may have influenced this result, with tuberosity fractures perhaps more likely in reverse implants due to them occupying a larger proportion of the metaphysis, the lower neck cut required for implantation, and the increased retraction on the humerus required to implant a glenosphere.

Revision to reverse TSA from any index prosthesis resulted in better outcome scores versus revision to anatomical TSA. Previous studies have demonstrated better outcomes for revision to an anatomical prosthesis when used appropriately (i.e. revision for isolated glenoid arthrosis or failure in the presence of an intact rotator cuff).[68,101] Our findings raise the possibility that conversion to reverse TSA may result in equally good, if not better, outcomes even in these situations. This notion should be tempered by the fact that this systematic review did not specifically evaluate the use of anatomical and reverse TSA in this context and hence a definitive conclusion should not be inferred, given the heterogeneity of preoperative pathology and broad inclusion criteria used. Physical and functional integrity of the rotator cuff are distinct states that would influence outcomes following revision to anatomical TSA, hence it may be prudent to further investigate how to preoperatively differentiate these states in the setting of an existing arthroplasty.

The quality of our data is linked to the accuracy of studies used in this systematic review, all of which were retrospective in nature. Most of the studies used for quantitative synthesis were of level IV evidence (77% of all studies), highlighting the need for more robust studies on outcomes following revision shoulder arthroplasty.

The strength of our evidence is affected by strong heterogeneity among studies, affirmed from high I^2 values (range 69% to 76%) found in meta-analyses of complication and reoperation data. The random-effects model was used to help account for heterogeneity in reported rates, but the high variance indicates potential external bias if applied to other populations.[17]

The high heterogeneity indicates a significant degree of methodological or clinical variance in the included studies. Results from individual articles may have been influenced by hidden confounding factors that were not extractable from published data. An example of this is the operating surgeon's experience and surgical technique used in revision, which was not reported in most studies. Similarly, many shoulder implant systems have

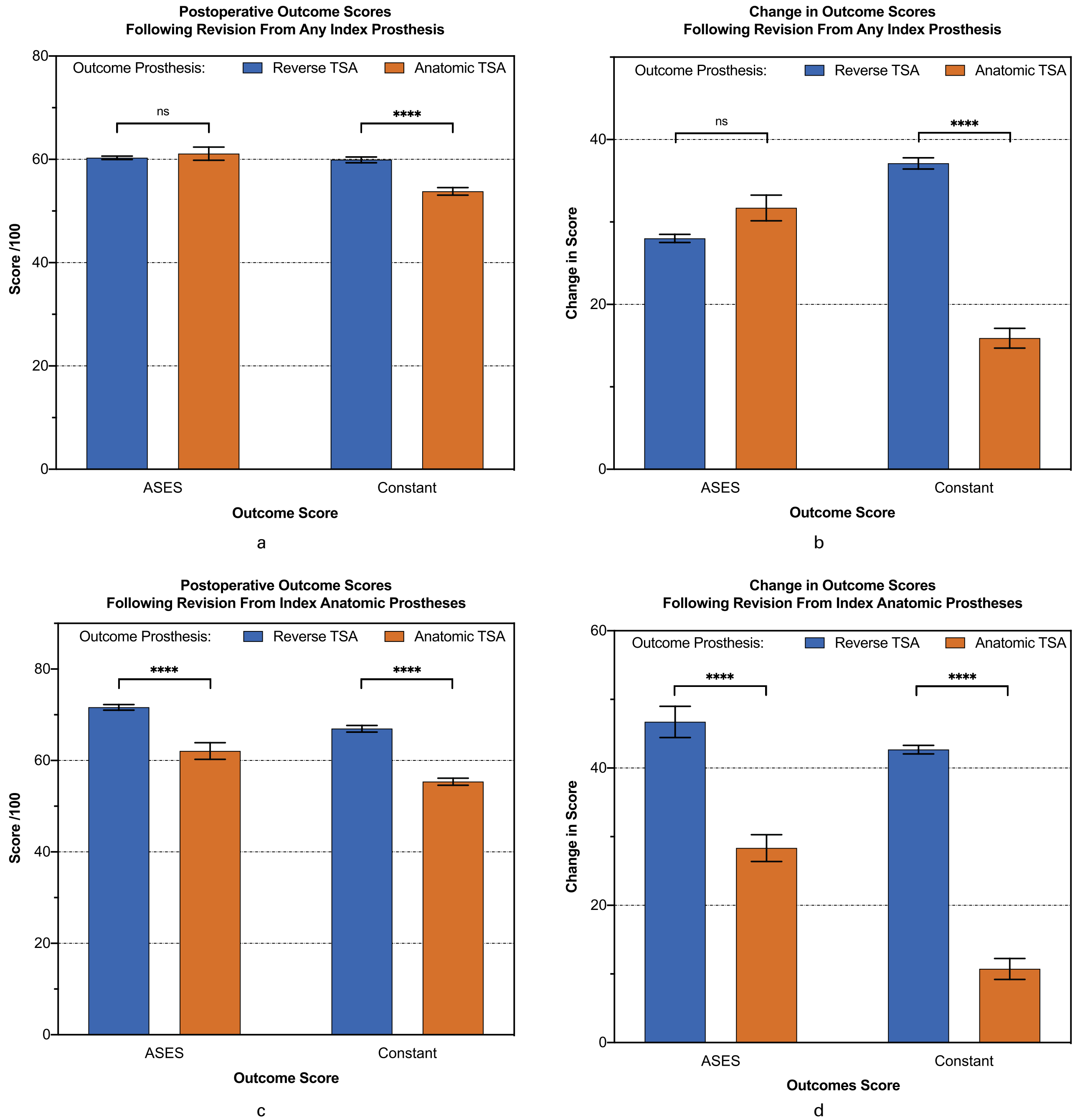

Fig. 2

American Shoulder and Elbow Surgeons (ASES) and Constant scores following revision shoulder arthroplasty. a) Postoperative scores (absolute score) following revision from any type of index prosthesis to reverse or anatomical total shoulder arthroplasty (TSA). b) Change in scores (postoperative score minus preoperative score) following revision from any type of index prosthesis to reverse or anatomical TSA. c) Postoperative scores (absolute score) following revision from index anatomical TSA only to reverse or anatomical TSA. d) Change in scores (postoperative score minus preoperative score) following revision from anatomical TSA only to reverse or anatomical TSA. Independent-samples *t*-test use for comparison of mean values (ns, no significant difference; ****, $p < 0.0001$).

been updated over time to address problems with the original implant design, and it was not possible to determine whether an original or updated design was used in revision from these articles.

This systematic review used a non-specific inclusion criterion to generate a generic analysis of all types of revision shoulder arthroplasty. Concomitant procedures performed during revision were not taken into consideration in this study, potentially introducing performance bias into our results. Intraoperative osteotomies, rotator cuff repairs, and use of bone grafts for complex reconstructions is associated with inferior outcomes following revision.[32,34,61,140] Thus, inclusion of these cases in our study might have resulted in underestimation of clinical outcome.

Outcomes for individual subgroups analyzed in this systematic review were not extractable from all studies, making our findings from subgroup analyses unrepresentative of every revision case. Statistical analyses were applied to pooled raw data collected from eligible studies, but a formal comparative meta-analysis of results was not appropriate due to lack of homogeneity in study types.

The findings from this systematic review suggest high complication and reoperation rates following revision shoulder arthroplasty, which warrants effective and open communication to patients contemplating both revision and primary shoulder arthroplasty. Our findings provide a greater insight into the available literature on outcomes following revision shoulder arthroplasty, but also illustrate the frailties of the existing literature, particularly in terms of informing decision-making around what type of revision prosthesis to consider.

In conclusion, in this systematic review we demonstrated that revision shoulder arthroplasty results in improved PROMs but is associated with a high incidence of intraoperative complications (8%), postoperative complications (22%), and reoperations (13%). It appears that revision to reverse TSA demonstrates superior outcomes than revision to anatomical TSA, however decision-making should still be on a case-by-case basis given the inherent flaws in the existing literature.

Take home message

- - Revision to reverse total shoulder arthroplasty is associated with better outcomes than revision to anatomical total shoulder arthroplasty (TSA).
- - Intraoperative complication rate was 8%, postoperative complications rate was 22%, and reoperation rate was 13% following revision shoulder arthroplasty.
- - Outcomes from revision shoulder arthroplasty show clinically important improvement in patient-reported outcome measures (PROMs).
- - Revision to reverse geometry TSA rather than to anatomical TSA from any index procedure appears to result in lower complication rates and better postoperative outcome scores.

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Supplementary material

Search strategy used for database search, MINORS score for individual studies, and forest plots from meta-analysis of proportion.

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