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ORIGINAL ARTICLE

Platform shoulder arthroplasty: a systematic review

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Background: Platform shoulder arthroplasty systems may allow conversion to a reverse total shoulder arthroplasty (RTSA) without removing a well-fixed, well-positioned humeral stem. We sought to evaluate the complications associated with humeral stem exchange versus retention in patients undergoing conversion shoulder arthroplasty with a platform shoulder arthroplasty system.

Methods: PubMed, MEDLINE, CINAHL (Cumulative Index to Nursing and Allied Health Literature), and Embase were searched from database inception through October 9, 2016, for all articles comparing humeral stem retention versus exchange during conversion RTSA or that pertained to conversion RTSA with stem retention alone. All studies were screened in duplicate for eligibility. A methodologic quality assessment was completed for included studies. Pooled outcomes assessing complications, operative time, blood loss, and reoperations were determined.

Results: We included 7 studies (236 shoulders), including 1 level III and 6 level IV studies. Pooled analysis demonstrated significantly higher overall complications (odds ratio, 6.89; 95% confidence interval [CI], 2.48-19.13; $P = .0002$), fractures (odds ratio, 4.62; 95% CI, 1.14-18.67; $P = .03$), operative time (mean difference, 62.09 minutes; 95% CI, 51.17-73.01 minutes; $P < .00001$), and blood loss (mean difference, 260.06 mL; 95% CI, 165.30-354.83 mL; $P < .00001$) with humeral stem exchange. Stem exchange was also associated with increased risk of reoperation ($P = .0437$).

Conclusion: Conversion arthroplasty with retention of the humeral stem is associated with lower overall complications, blood loss, operative time, and reoperations in comparison with stem exchange.

Level of evidence: Level IV; Systematic Review

Keywords: Platform arthroplasty; modular arthroplasty; convertible arthroplasty; conversion shoulder arthroplasty; total shoulder arthroplasty; reverse total shoulder arthroplasty; shoulder

We did not need institutional review board or ethical committee approval.

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The number of shoulder arthroplasty procedures has demonstrated significant growth over the past decade,[8,18,19,28,32] with primary procedures increasing by more than 200% and revision procedures increasing by more than 300%.[8,18] The need

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for revision shoulder arthroplasty procedures is expected to further increase given expanding indications for primary procedures coupled with an increasingly active patient population. Component loosening or insufficiency of the rotator cuff following anatomic total shoulder arthroplasty (TSA) resulting in instability, pain, or decreased function may necessitate revision arthroplasty.[1,11,15-17,22,30,33,39] In addition, hemiarthroplasty (HA) procedures performed for fracture management may require revision because of tuberosity resorption, nonunion, or malunion.[2,21,23]

In cases of failed shoulder arthroplasty when anatomic revision is not optimal, revision to a reverse total shoulder arthroplasty (RTSA) may be used to establish a stable fulcrum to improve shoulder biomechanics and provide inherent stability. RTSA is an effective procedure for fracture sequelae and revision arthroplasty.[3,12,27,31,34]

Platform shoulder arthroplasty systems may allow for conversion of a TSA to an RTSA without necessitating the removal of a well-fixed, well-positioned humeral stem. Revision arthroplasty requiring exchanging a cemented or uncemented humeral stem is technically challenging and associated with high rates of iatrogenic fracture,[11,16] loss of proximal humeral bone stock, prolonged operative time,[7,9,37] increased blood loss,[7,9,37] high reoperation rates,[16,22] and other complications.[25,33]

The purpose of this systematic review was to comprehensively review the available literature evaluating conversion shoulder arthroplasty from either an HA or TSA to a reverse prosthesis. Specifically, we sought to evaluate the difference between humeral stem exchange and retention regarding blood loss, operative time, and complications in patients undergoing revision shoulder arthroplasty to an RTSA. Our hypothesis was that humeral stem retention would be associated with lower blood loss, operative time, and complications compared with revision procedures requiring stem exchange.

Materials and methods

This study was conducted according to the methodology described in the *Cochrane Handbook for Systematic Reviews of Interventions*[14] and is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[24]

Eligibility criteria

We included studies that (1) compared humeral stem retention versus exchange during conversion shoulder arthroplasty from either an HA or TSA to an RTSA or that pertained to conversion RTSA with stem retention alone, (2) had a minimum of 10 patients in whom the humeral stem was retained, and (3) had a minimum of 6 months of postoperative follow-up. There were no restrictions regarding the indication for primary or revision shoulder arthroplasty, previous treatment for shoulder pathology, publication date, or language of publication. The exclusion criteria consisted of case reports, editorials, reviews, expert opinion articles, and basic science papers.

Identification of studies

A systematic literature search of potentially eligible trials was conducted in CINAHL (Cumulative Index to Nursing and Allied Health Literature), PubMed, MEDLINE, and Embase from the database inception date through October 9, 2016. Investigators with methodologic and content expertise developed and performed the search. Medical Subject Headings (MeSH) and Emtree headings and subheadings were used in various combinations in Ovid and supplemented with free text to increase sensitivity. The PubMed search included articles published online ahead of print. A manual search of related references and cited articles was also performed. We searched conference proceedings from the previous 3 years and ClinicalTrials.gov to identify relevant unpublished trials.

Screening and assessment of eligibility

Two reviewers (J.M.K. and P.T.) independently screened the titles and abstracts of all studies for eligibility using piloted screening forms. Duplicate articles were manually excluded. Both reviewers evaluated the full text of all potentially eligible studies identified by title and abstract screening to determine final eligibility. All discrepancies were resolved by a consensus decision requiring rationale with the first author.

Data extraction and assessment of risk of bias

Data were extracted independently and in duplicate by both reviewers (J.M.K. and P.T.) using a piloted electronic data extraction form (Excel; Microsoft, Redmond, WA, USA). If essential data were unclear or not reported, authors were contacted for clarification. Critical outcomes were determined to be blood loss, operative time, and complications. Extracted data included, but were not limited to, year and journal of publication, number of patients, gender, age at the time of surgery, initial operation, demographic information, and reasons for being unable to retain a modular stem.

The 2 reviewers (J.M.K and P.T.) performed an independent assessment of the methodologic quality using the Methodological Index for Non-Randomized Studies (MINORS)[29] tool for all nonrandomized studies. The level of evidence was graded according to the criteria of Wright et al.[38]

Statistical analysis

Interobserver agreement for assessments of eligibility was calculated with the Cohen κ statistic. A κ of 0-0.2 represents slight agreement; 0.21-0.40, fair agreement; 0.41-0.60, moderate agreement; 0.61-0.80, substantial agreement; and greater than 0.80, almost perfect agreement.[20] Interobserver agreement for methodologic quality assessment was calculated using the intraclass correlation coefficient. Both κ and the intraclass correlation coefficient were calculated using SPSS software (IBM, Armonk, NY, USA).

Mean differences (MDs) were used to summarize identical continuous outcome measures, and odds ratios (OR) were used to assess the effect of dichotomous outcomes from individual studies.[14] The MDs were weighted by sample size using the random-effects model based on the inverse variance method.[14] Standard devia-

tions not available in the original article were calculated from confidence intervals (CIs), standard errors, *P* values, or ranges when possible or were otherwise estimated from trials within the same comparison with similar scales, outcomes, and periods.[13,14] Reported complications (overall complications, fractures, reoperations, and so on) were presented descriptively. The overall complication rate included reoperations; however, a Fisher exact test was used to evaluate the risk of reoperation between the 2 groups. Forest plots were created with RevMan 5.2 (The Cochrane Collaboration, London, UK).

Evaluation of heterogeneity and sensitivity analyses

Heterogeneity was quantified using the χ^2 test for heterogeneity and the I^2 statistic,[14] which estimates the proportion of total variability between studies due to heterogeneity rather than chance alone. I^2 values were interpreted according to the Cochrane handbook: 0%-40% might not be important whereas 30%-60% may represent moderate heterogeneity; 50%-90%, substantial heterogeneity; and 75%-100%, considerable heterogeneity.[14]

Results

Search results and study characteristics

The literature search generated 1159 relevant citations. Following duplicate removal and application of eligibility criteria, 950 articles from the electronic search underwent title and abstract screening. Following this, 28 articles underwent full-text review, ultimately producing 7 articles that met the inclusion criteria for this report (Fig. 1).[4,7,9,15,35-37] The κ value for overall agreement between reviewers for the final eligibility decision was 0.822, indicating almost perfect agreement.

This analysis included 236 shoulders. Of these, 113 underwent humeral stem exchange and 123 had the humeral stem retained during conversion shoulder arthroplasty. Five studies reported on patients with both HA and TSA undergoing conversion arthroplasty,[4,9,15,35,37] one study reported on patients only with HA undergoing conversion arthroplasty,[36] and one study reported only on patients with TSA undergoing conversion arthroplasty.[7] Demographic data were tabulated by

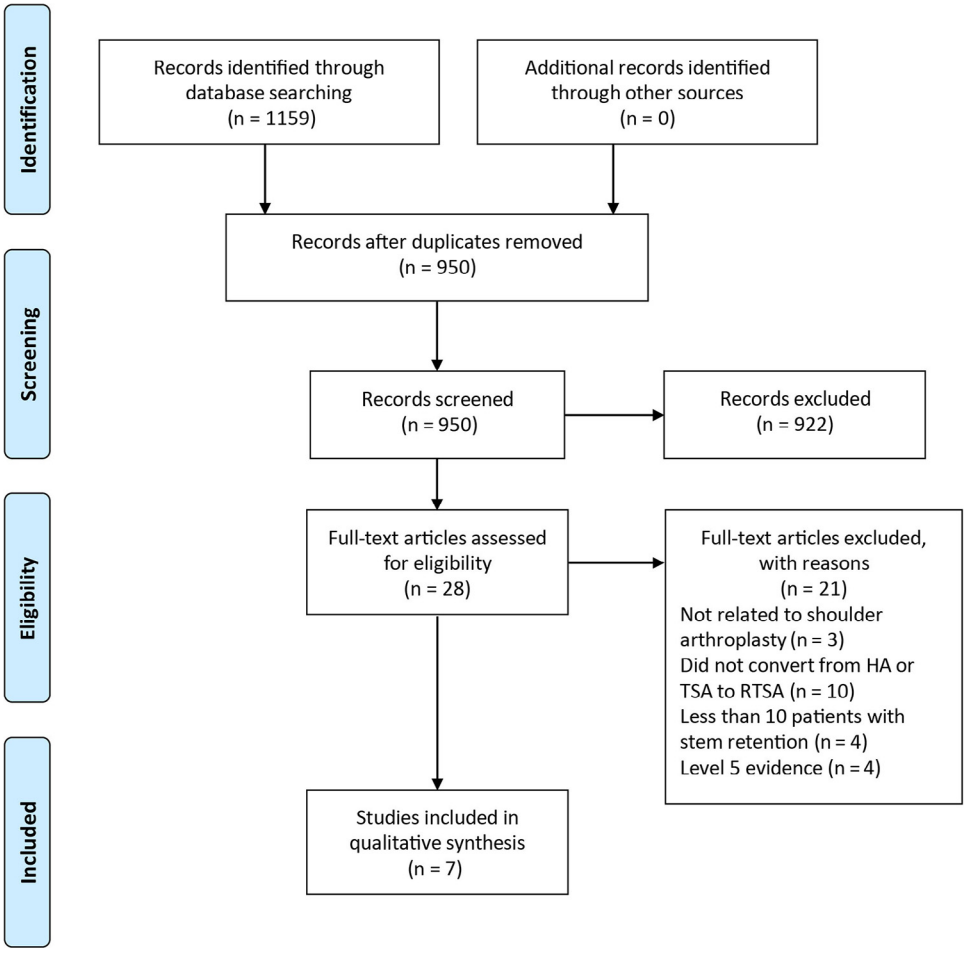

Figure 1 Selection of studies for inclusion in systematic review. *HA*, hemiarthroplasty; *RTSA*, reverse total shoulder arthroplasty; *TSA*, total shoulder arthroplasty.

Table I Study demographic data and quality

Study	Year of publication	Age, mean (range)/mean ± SD, y	Male patients	Total No. of shoulders	Level of evidence	Mean MINORS score
Wieser et al[37]	2015	Stem exchange: 67 (44-81) Stem retention: 68 (44-87)	Stem exchange: 13 (30.2%) Stem retention: 3 (23.1%)	56 HA: 48 TSA: 8	III	10 of 16
Werner et al[36]	2013	Stem retention: 70 (56-80)	1 (7.1%)	14 HA: 14 TSA: 0	IV	12.5 of 16
Weber-Spickschen et al[35]	2015	Stem retention: 70 (47-83)	6 (43%)	15 HA: 2 TSA: 13	IV	8.5 of 16
Kany et al[15]	2015	Stem retention: 67 ± 7.6	7 (24%)	26 HA: 5 TSA: 21	IV	10.5 of 16
Castagna et al[4]	2013	Stem retention: 72.7	9 (34.6%)	26 HA: 18 TSA: 8	IV	9 of 16
Crosby et al[7]	2015	Stem exchange: 69 (57-82) Stem retention: 65.8 (57-75)	Stem exchange: 15 (33%) Stem retention: 11 (39.3%)	73 HA: 0 TSA: 73	IV	9.5 of 16
Dilisio et al[9]	2015	Stem exchange: 66.86 ± 9.3 Stem retention: 69.67 ± 7.75	2 (7.7%)	26 HA: 19 TSA: 7	IV	11 of 16

HA, hemiarthroplasty; *MINORS*, Methodological Index for Non-Randomized Studies; *SD*, standard deviation; *TSA*, total shoulder arthroplasty.

treatment group (Table I). Overall complications as defined by the study along with some of the most notable complication characteristics were tabulated by treatment group and period (Table II). Intraoperative characteristics including blood loss, operative time, and humeral osteotomies were also tabulated by treatment group (Table III).

Study quality and risk of bias

All of the included studies were level IV evidence[4,7,9,15,35,36] with the exception of the study performed by Wieser et al,[37] which was level III. The mean Methodological Index for Non-Randomized Studies (MINORS) score was 10.14 of 16 for all included studies (Table I).

Complications

The rate of overall complications was significantly higher in the stem exchange group than in the stem retention group (OR, 6.89; 95% CI, 2.48-19.13; $P = .0002$), with low heterogeneity ($P = .80$, $I^2 = 0\%$) (Fig. 2). The pooled mean complication rate was 41.6% in the stem exchange group compared with 6.5% in the stem retention group. Conversion arthroplasty with stem exchange resulted in significantly more iatrogenic fractures compared with stem retention (OR, 4.62; 95% CI, 1.14-18.67; $P = .03$), with low heterogeneity ($P = .36$, $I^2 = 0\%$) (Fig. 3). The pooled mean rate of iatrogenic fractures was 15.9% in the stem exchange group compared with 1.63% in the stem retention group. Conversion shoulder arthroplasty requiring stem exchange resulted in significantly more reoperations compared with when stem retention was possible ($P = .0437$).

Intraoperative characteristics

Conversion arthroplasty with humeral stem exchange resulted in significantly more intraoperative blood loss compared with stem retention (MD, 260.06 mL; 95% CI, 165.30-354.83 mL; $P < .00001$), with low heterogeneity ($P = .25$, $I^2 = 27\%$). Stem exchange resulted in a significantly longer operative time compared with stem retention (MD, 62.09 minutes; 95% CI, 51.17-73.01 minutes; $P < .00001$), with low heterogeneity ($P = .77$, $I^2 = 0\%$). There were 15 humeral osteotomies required during stem exchange, whereas no osteotomies were performed when the stem was retained.

Discussion

We found that conversion shoulder arthroplasty from either an HA or TSA to a reverse prosthesis with retention of the humeral stem was associated with significantly lower complications, iatrogenic fractures, and need for reoperation compared with humeral stem exchange. Furthermore, there was a significant difference in mean blood loss (260 mL) and operative time (62 minutes), favoring humeral stem retention.

Shoulder arthroplasty is becoming increasingly common, and subsequently, the need for revision procedures has also increased.[8,19,28,32] Secondary rotator cuff dysfunction

Table II Complications

	Complications with stem exchange			Complications with stem retention		
	Intraoperative	Postoperative	Reoperation	Intraoperative	Postoperative	Reoperation
Study						
Wieser et al[37]	Total: 13 Characteristics: fracture in 10 and radial nerve palsy in 2	Total: 9 Characteristics: fracture in 5 (4 shaft and 1 acromion)	Total: 9 Characteristics: infection in 3 and wound healing in 2	Total: 1 Characteristics: fracture in 1 (greater tuberosity)	Total: 2 Characteristics: fracture in 1 (acromion)	Total: 1 Characteristics: infection in 1
Werner et al[36]	NA	NA	NA	Total: 0	Total: 0	Total: 1 Characteristics: infection in 1
Weber-Spickschen et al[35]	NA	NA	NA	Total: 0	Total: 1 Characteristics: dislocation in 1 (7 mo)	Total: 0
Kany et al[15]	NA	NA	NA	0	0	0
Castagna et al[4]	NA	NA	NA	0	0	0
Crosby et al[7]	Total: 1 Characteristics: nerve injury in 1	Total: 8 Characteristics: infection in 2	NA	0	0	NA
Dilisio et al[9]	Total: 5 Characteristics: fracture in 3, radial nerve palsy in 1, and cement extravasation in 1	Total: 1 Characteristics: nonunion in 1	Total: 1 Characteristics: ORIF of nonunion after intraoperative fracture in 1	Total: 0	Total: 1 Characteristics: transient nerve palsy	Total: 1 Characteristics: baseplate failure requiring revision
Total	Complications: 47 of 113 (41.6%) Fracture: 18 of 113 (15.9%) Reoperation: 10 of 113 (8.85%)			Complications: 8 of 123 (6.50%) Fracture: 2 of 123 (1.63%) Reoperation: 3 of 123 (2.44%)		

NA, not applicable; *ORIF*, open reduction internal fixation.

Table III Intraoperative characteristics

Study	Intraoperative characteristics with stem exchange			Intraoperative characteristics with stem retention		
	Blood loss, mL	Operative time, min	Osteotomy, n	Blood loss, mL	Operative time, min	Osteotomy, n
Wieser et al[37]	Mean EBL, 831 (range, 350-2000; SD, 400)	Mean, 176 (range, 120-300; SD, 42)	12	Mean EBL, 485 (range, 300-700; SD, 151)	Mean, 118 (range, 90-160; SD, 21)	0
Werner et al[36]	NA	NA	NA	NA	Mean, 141 (range, 88-215)	NA
Weber-Spickschen et al[35]	NA	NA	NA	NA	Mean, 64 (range, 45-75)	NA
Kany et al[15]	NA	NA	NA	NA	NA	NA
Castagna et al[4]	NA	NA	NA	EBL <300 in all cases	Mean, 62 ± 8	NA
Crosby et al[7]	Mean, 500	Mean, 211 (range, 123-311)	NA	Mean, 280	Mean, 145 (range, 115-187)	NA
Dilisio et al[9]	Mean, 596.43 ± 377.47	Mean, 237 ± 59.32	3	Mean, 468.18 ± 257.17	Mean, 178.92 ± 44.56	0

EBL, estimated blood loss; *SD*, standard deviation.

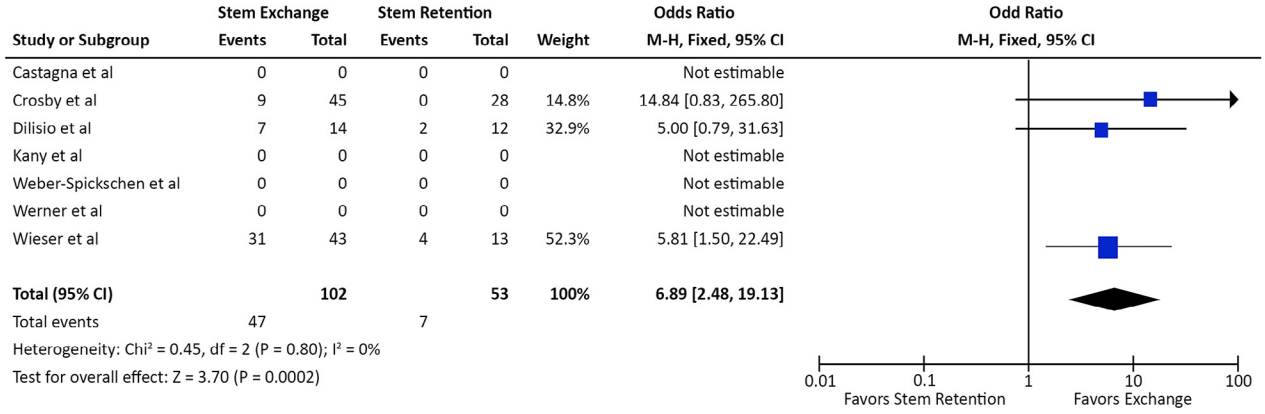

Figure 2 Pooled mean complications in patients undergoing conversion shoulder arthroplasty with stem exchange compared with stem retention. *M-H*, Mantel-Haenszel; *CI*, confidence interval.

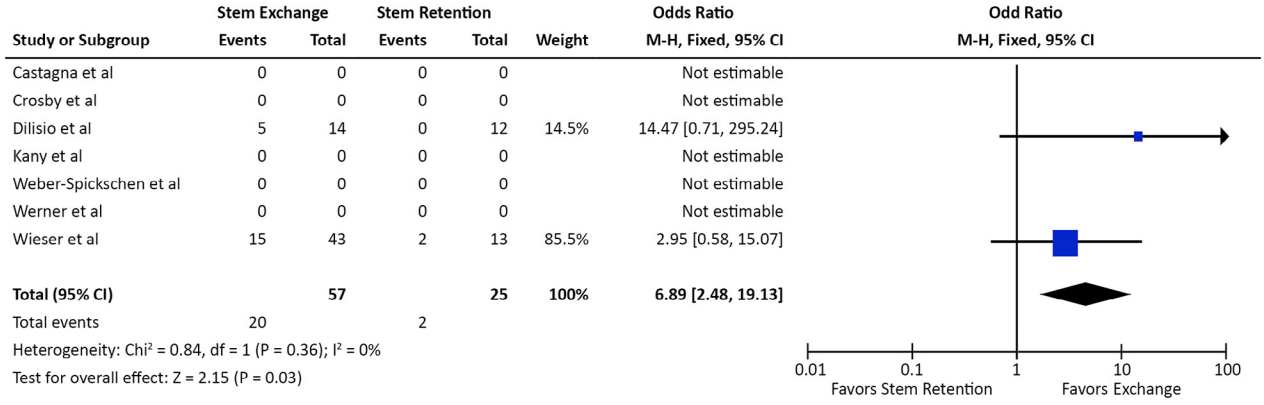

Figure 3 Pooled mean iatrogenic fractures in patients undergoing conversion shoulder arthroplasty with stem exchange compared with stem retention. *M-H*, Mantel-Haenszel; *CI*, confidence interval.

following shoulder arthroplasty resulting in instability or decreased function often necessitates revision arthroplasty.[1,17,25,30,33,39] Young et al[39] reported that the incidence of secondary rotator cuff dysfunction increased over time and was associated with poor functional outcomes. At 15 years' follow-up, 55% of patients in their series had evidence of rotator cuff dysfunction following shoulder arthroplasty; however, Young et al did not identify a significant

difference in revision rates between patients with and without subsequent rotator cuff dysfunction. Sperling et al[30] also reported a high rate of superior humeral head subluxation (28%) at 15 years following shoulder arthroplasty. Furthermore, revision shoulder arthroplasty in the setting of rotator cuff dysfunction is often unpredictable and can be associated with poor functional outcomes.[10,26]

Revision shoulder arthroplasty to an RTSA is an effective treatment in situations that may not be amenable to an anatomic revision procedure, such as in the setting of instability, rotator cuff insufficiency, or component malpositioning. Several authors have reported good functional outcomes following conversion to an RTSA in the setting of failed arthroplasty[11,16,21,25,33]; however, this is not without complications, the rates of which have ranged from 22%-43% in this setting.[11,16,21,25,33] Most of the reported complications involve humeral stem extraction, which can result in iatrogenic fracture or the need for humeral osteotomy.[5,16,25] The recent development of modular shoulder arthroplasty systems may allow for well-fixed, well-positioned humeral stems to be retained during revision arthroplasty in an attempt to minimize these devastating complications.

The presence of a modular shoulder arthroplasty system does not guarantee successful convertibility when performing revision procedures. The ability to retain the stem relies on it being well fixed and well positioned and requires the height of the stem to be compatible with conversion to RTSA. Several studies included in this review were unable to retain modular stems,[9,15,36,37] most commonly because of initial malpositioning of the stem.[15] Kany et al[15] noted that the most common reason for stem removal was proximal malpositioning. Werner et al[36] reported that 13 patients not included in their study had modular stems that were unable to be retained because of loosening or excessive soft-tissue contracture that prevented stem retention. In a recent series, Crosby et al[6] noted that 78% of convertible stems were able to be retained at the time of revision surgery.

The results of our study are consistent with other literature on this topic. Most recently, Crosby et al[6] published the largest series of patients undergoing conversion shoulder arthroplasty with retention of a modal humeral stem. They concluded that significantly decreased complications, blood loss, and operative time occurred with humeral stem retention, similar to the findings of our study. Furthermore, in our study we found that reoperation rates were also significantly lower with humeral stem retention, whereas this finding was not significant in the study by Crosby et al.[6]

There are several limitations with our study, the primary limitation being the quality of available evidence on which our conclusions are based. None of the included studies were randomized and all were retrospective in nature with the exception of the study by Werner et al.[36] These retrospective studies are at high risk of potential bias, for example, selection bias on the part of the operating surgeons by selecting patients with less severe shoulder pathology for a convertible prosthesis. Several studies consisted of a heterogeneous patient population, comprising patients initially treated with both modular and nonmodular components.[7,9,37] This heterogeneity limits more direct evaluation of the role of modular shoulder arthroplasty. In addition, as stated earlier, some convertible stems could not be retained because of incompatibility with length or appropriate positioning for RTSA. In this regard, the data may not capture these cases when the type of humeral stem was not reported.

This study has numerous strengths. This is a comprehensive review of the current clinical literature on this emerging topic performed in a methodologically rigorous manner with a high degree of agreement between reviewers regarding study eligibility, assessment, and data extraction. In addition, our findings had low statistical heterogeneity indicating that, across studies, the treatment effect was very similar. Our results are consistent with those of other smaller clinical series, and this study represents the largest pooled analysis on conversion shoulder arthroplasty with modular components.

Conclusion

This systematic review identified significantly lower complications, iatrogenic fractures, reoperations, blood loss, and operative time when stem retention was performed. Despite the initial use of modular humeral stems, conversion arthroplasty with stem retention was not always possible and should be critically evaluated on a case-by-case basis. Further research with prospectively randomized data in the setting of comparable shoulder pathology will further elucidate the potential role and limitations of convertible platform shoulder arthroplasty.

Disclaimer

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