J Shoulder Elbow Surg (2019) 28, 989–997

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

REVIEW ARTICLE

The effect of subscapularis repair on dislocation rates in reverse shoulder arthroplasty: a meta-analysis and systematic review

Graeme Matthewson, MD[a,*], Sahil Kooner, MD[b], Adam Kwapisz, MD, PhD[a,c], Jeff Leiter, PhD[a], Jason Old, MD, FRCSC[a], Peter MacDonald, MD, FRCSC[a]

[a]*Orthopaedic Surgery, Pan Am Clinic, University of Manitoba, Winnipeg, MB, Canada*
[b]*Orthopaedic Surgery, University of Calgary, Calgary, AB, Canada*
[c]*Clinic of Orthopedics and Pediatric Orthopedics, Medical University of Lodz, Poland*

Background: Reverse total shoulder arthroplasty is an effective treatment for patients with rotator cuff arthropathy; however, complication rates are relatively high (19%-50%), with implant instability and infection being particularly devastating to overall outcomes. The objective of this study was to analyze the highest level of data comparing dislocation rates and outcomes in reverse total shoulder arthroplasty with and without the subscapularis tendon repaired.

Methods: The databases MEDLINE, Embase, and CINAHL were searched using a sensitive search strategy for this meta-analysis/systematic review. Eligibility included any studies in which patients were treated with a reverse total shoulder arthroplasty in which the status of the subscapularis tendon could be determined. A data extraction form was developed to collect select data from the included studies. A meta-analysis was performed on pooled data of 5 studies comparing dislocation rates and 3 studies comparing postoperative forward elevation, rate of infection, overall complication rates, and fractures.

Results: Two independent researchers reviewed 1008 studies. Seven studies met inclusion criteria. A meta-analysis was performed on all level III studies, resulting in 1306 patients being analyzed. Results demonstrated lower dislocation rates in the subscapularis repair group (odds ratio, 0.19; $P < .001$). However, in patients without a subscapularis repair, lateralized center of rotation (COR) resulted in a significantly lower dislocation rate compared with medialized COR (odds ratio, 0.24; $P < .001$).

Conclusion: The results of our meta-analysis of the available data demonstrated a decrease in dislocation risk when the subscapularis tendon was repaired in medialized and lateralized designs. When subscapularis repair is not performed, lateralized COR, regardless of humeral socket design, may reduce the dislocation rates.

Level of evidence: Level III, Meta-analysis

Keywords: Reverse shoulder arthroplasty; subscapularis repair; dislocation; instability; center of rotation; meta-analysis

Institutional Review Board approval was not required for this systematic review.

*Reprint requests: Graeme Matthewson, MD, Pan Am Clinic, 75 Poseidon Bay, Winnipeg, MB, Canada R2M 1Y7.
E-mail address: graememattheWson@icloud.com (G. Matthewson).

1058-2746/$ - see front matter Crown Copyright © 2018 All rights reserved.
https://doi.org/10.1016/j.jse.2018.11.069

Reverse total shoulder arthroplasty is an effective treatment option for patients suffering from rotator cuff tear arthropathy, a type of arthritis that develops in a shoulder with large tears of the rotator cuff tendons. Indications for reverse shoulder arthroplasty have expanded to encompass related causes of shoulder arthrosis with rotator cuff deficiency, including osteoarthritis with rotator cuff tear, massive rotator cuff tear with pseudoparalysis, proximal humerus fracture, chronic instability, tumor, and failed hemiarthroplasty or total shoulder arthroplasty. Reverse shoulder arthroplasty has been shown to effectively reduce pain, to improve quality of life, and to increase range of motion, particularly forward flexion and abduction, although with inconsistent results in regard to external rotation. However, reverse shoulder arthroplasty has a high rate of reported complications ranging from 19% to 50%,[2,11,13] including infection, instability, scapular notching, periprosthetic fractures, and polyethylene wear.[2,27]

Instability in reverse shoulder arthroplasty is a potentially devastating complication. It can be due to a multitude of factors, including inadequate soft tissue, tissue tensioning, infection, and malposition of implants, with generally poor results after early instability episodes.[13] More recently, the role of subscapularis repair in implant stability has been questioned.

When reverse shoulder arthroplasty is performed through a deltopectoral surgical approach, the glenohumeral joint is entered and exposed by reflecting the subscapularis tendon off of the humerus by one of several methods, including a tenotomy in the substance of the tendon, a peel of the tendon off of the lesser tuberosity of the humerus, and an osteotomy of the tuberosity itself.[6] After the shoulder prosthesis is implanted, the subscapularis tendon is often repaired; but in some cases, it is not repaired for one of several reasons. The tendon may not be repairable after the operation because of lengthening or lateralization of the humerus as part of the operation, or it may be torn and permanently retracted before the operation. Some surgeons may also choose not to repair the tendon even when repair is technically possible as the importance of repairing the tendon remains poorly defined.

Some studies have shown a significant increase in dislocation rates when the subscapularis is not repaired.[4,11,28] However, other studies have shown no significant difference in dislocation rates between repair and nonrepair groups.[7,12,29,31]

It was with this question in mind that we performed a systematic review and meta-analysis to determine the effects of subscapularis repair on instability and overall outcomes in reverse shoulder arthroplasty.

Methods

A systematic literature search was completed by 2 reviewers (G.M. and S.K.) and is up to date as of November 9, 2017, in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.[24] The databases MEDLINE, Embase, and CINAHL were searched using engine-specific strategies unique to each database to maximize sensitivity (Appendix A). All search results were then compiled in a reference manager program, and duplicates were deleted. Studies were then screened on the basis of title and abstract for eligibility. Studies that were thought to be eligible then underwent full-text review, after which only primary articles that met all of the inclusion and exclusion criteria were included in the systematic review. References of included studies were also screened for eligible studies. Two reviewers independently selected the trials to be included from the compiled literature search, from which a κ value was ascertained. A meta-analysis was planned for any studies of level III or higher that reported the specific number of dislocation events in each group.

Eligibility included any studies in which it was determined whether patients had undergone reverse total shoulder arthroplasty with or without subscapularis repair and the rate of dislocation was also reported. If a study had multiple published interim results, only the most recent published data were included. Studies were excluded if patient outcomes were not reported or if group-specific outcomes were not specified. Exclusion criteria also included case reports, reviews, commentary pieces, rebuttals, cadaver studies, papers using a superior approach only, and studies and abstracts that were not available in English.

A data extraction form, which included authors, publication date, study design, level of evidence, average age, etiology, follow-up time, patients' characteristics, implant type, and specific outcome measurements, was developed to collect data from the selected studies. Qualitative and quantitative analysis was completed on the basis of the data available. Meta-analysis was then performed by pooling the results of selected high-quality studies using Review Manager 5.3 (The Nordic Cochrane Center, Copenhagen, Denmark). Continuous data were entered as means and standard deviations, and dichotomous outcomes were entered as number of events and odds ratio (OR). Statistical analysis was done by comparing mean differences of 3 or more studies when results were collected by similar measures or standardized mean difference when results were collected in a heterogeneous manner. In the case of missing data, standard errors were calculated on the basis of the P value after finding a corresponding t value and inputting it into the formula standard error = mean difference/t. A random-effects model was used for all analysis. Data were reported as mean difference or OR with 95% confidence intervals. Heterogeneity was assessed initially by visual inspection of the forest plots. In addition, an I^2 statistic was used to quantify risk of heterogeneity between studies. A $P > .1$ and an $I^2 \leq 50\%$ were considered of no statistical heterogeneity. When data could not be compared in a similar manner for outcomes of interest, the results were summarized and presented as best evidence available.

Variables of interest that were analyzed in regard to their effect on dislocation rates were subscapularis repair and implant design. Implant design was classified by the glenoid design (center of rotation [COR]) or by the humeral cup design (onlay vs. inlay). The COR describes the glenohumeral rotation point in relation to the glenoid surface. These are divided into medialized and lateralized COR; however, this is a slight misnomer in that both designs have a medialized COR compared with the native glenohumeral anatomy, meaning that the COR is more lateral in the lateralized design compared with medialized. Onlay vs. inlay design describes whether the humeral socket is recessed or not. In the case in which the humeral socket is recessed within the

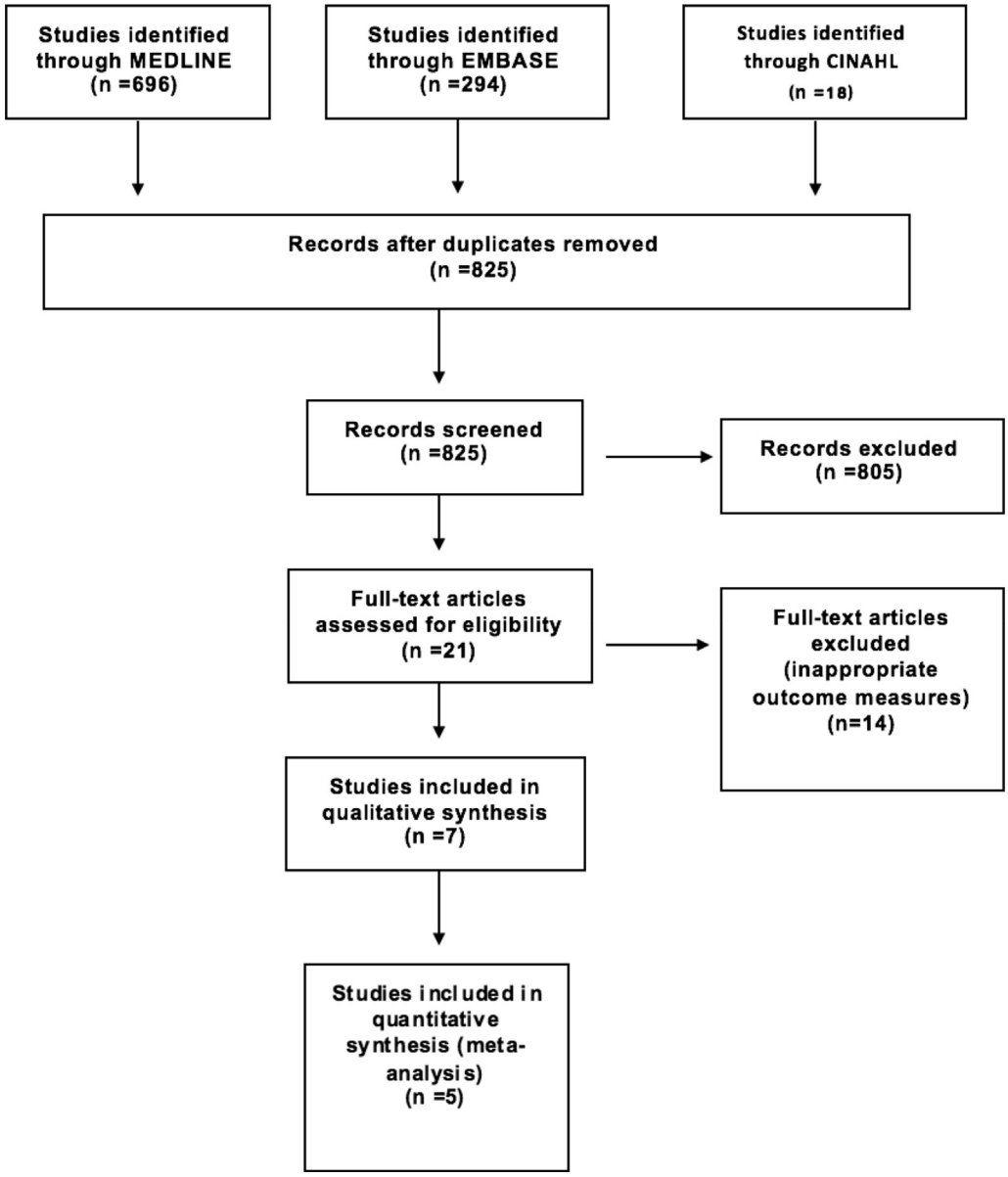

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram. (Modified from Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med 2009;6:e1000097. https://doi.org.uml.idm.oclc.org/10.1371/journal.pmed.1000097)

humerus, it is considered an inlay design; in the onlay design, the humeral socket is flush with the level of the humeral osteotomy.

Results

Our sensitive literature search produced 1008 studies. After the removal of duplicates, 825 studies remained. After the initial screening based on title and abstract, 21 studies were chosen to undergo full-text review (Appendix A). During this process, 14 studies were excluded for not meeting inclusion criteria, and the remaining 7 articles were included in our systematic review[7,11,12,28,29,31,32] (Fig. 1). Two reviewers independently assessed articles for inclusion, and consensus was reached on all articles with an initial κ value of 0.9. A recent level III article was published immediately before submission, and this paper was updated to include all of the latest level III studies as of March 1, 2018. This included 1 level II study, 5 level III studies, and 1 level IV study. In total, our systematic review included 1684 patients, of whom 1306 patients were included in the meta-analysis. The average age of the patients in the studies ranged from 66 to 73.8 years. The most commonly reported outcome measures were complications including instability

Table I Comparison of results between studies (meta-analysis)

Study (by year)	Level of evidence	Implants used	No.		Age (yr, average)			Sex		Follow-up (mo)		Dislocation		Complications (total)		Infection		Fracture	
			Repair	No repair	Total	Repair	No repair	M	F	Minimum	Average	Repair	No repair	Repair	No repair	Repair	No repair	Repair	No repair
Friedman et al, 2017[12]	III	Equinoxe rTSA (Exatech), lateralized/onlay	340	251	72.5	72.7	71.7	224	367	24	36.6	0	4	25	17	5	1	6	6
Clark et al, 2012[7]	III	Reverse shoulder prosthesis, lateralized/inlay	65	55	68.5	68.6	68.3	51	19	6	13.2	2	3	13	11	5	3	2	3
Vourazeris et al, 2017[29]	III	Equinoxe rTSA (Exatech), lateralized/inlay	86	116	71.35	71.6	71.1	NR	NR	NR	38.4	0	3	4	7	1	1	0	3

rTSA, reverse total shoulder arthroplasty; *NR*, not reported.

and infection, range of motion, strength, and validated functional outcome scores.

Meta-analysis

A meta-analysis was performed to analyze dislocation rates, including 5 studies with level III evidence comprising 723 patients in the subscapularis repair group and 583 patients in the nonrepaired group for a total of 1306 patients. The level II study was excluded for not reporting the number of dislocation events and was included in the narrative review. Three studies of level III evidence allowed comparison of postoperative forward elevation, overall complications, infections, and fracture involving 491 patients in the subscapularis repair group and 422 patients in the nonrepaired group, for a total of 913 patients (Table I). The rate of dislocation was found to be greater in the no repair group (24/583 [4.1%]) compared with the repair group (5/723 [0.7%]; OR, 0.24; $P = .04$; Fig. 2). However, a pooled comparison of the data from the 3 studies using prostheses with a lateralized COR showed no difference when the subscapularis was repaired (OR, 0.29; $P = .07$; Fig. 3). In the only study using a medialized COR,[28] the rate of dislocation was shown to be decreased when the subscapularis was repaired (0.62% compared with 11%; OR, 0.05; $P = .004$). Unfortunately, the study results from the most recent paper of Werner et al[32] could not be included in these separate analyses as they did not indicate the dislocation rates specifically according to the design COR. There were no other significant differences in any of the other outcome analyses, including forward flexion, fracture, infection, and total complications (Table I and Figs. 4-7).

Implant design was a mixture of medialized and lateralized COR implants; 913 patients received an arthroplasty with a lateralized COR, and 284 patients received an arthroplasty with a medialized COR. Overall, the lateralized design showed fewer dislocations (12/901 [1.33%]) compared with a medialized design (15/269 [5.6%]; OR, 0.24; $P < .001$). In addition, dislocation rates in the subscapularis repair group were lower (2/491 [0.4%]) in the lateralized design compared with the medialized design (1/161 [0.6%]; OR, 0.65; $P = .73$). In the no repair group, the lateralized design resulted in fewer dislocations (10/422 [2.4%]) compared with the medialized design (14/123 [11%]; OR, 0.189; $P < .001$).

Similarly, in looking at the effects of inlay vs. onlay design of the humeral socket in the lateralized prostheses, it was found that implants with an onlay design showed decreased risk of dislocation compared with inlay designs (OR, 0.06; $P < .001$). On subanalysis based on repair type, an onlay design had a decreased rate of dislocation over the inlay design only when the subscapularis was repaired (OR, 0.13; $P = .04$) compared with no repair (OR, 0.31; $P = .09$). However, there was a disproportionate number of

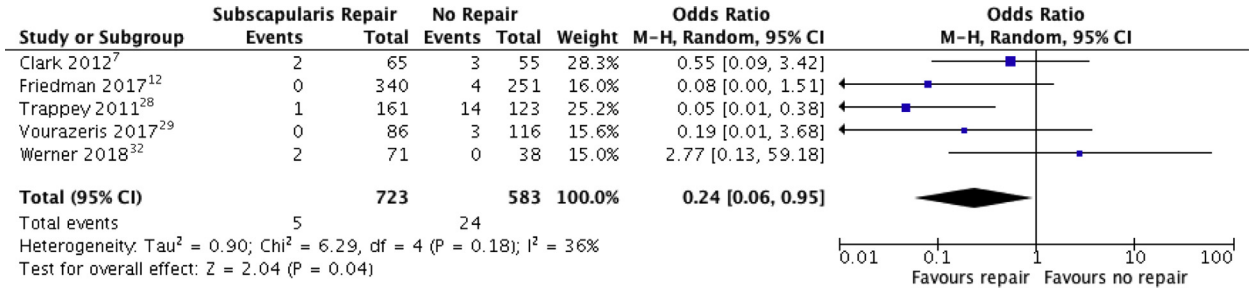

Figure 2 Forest plot for prevalence of dislocations in lateralized and medialized implant designs. *M-H*, Mantel-Haenszel test; *CI*, confidence interval.

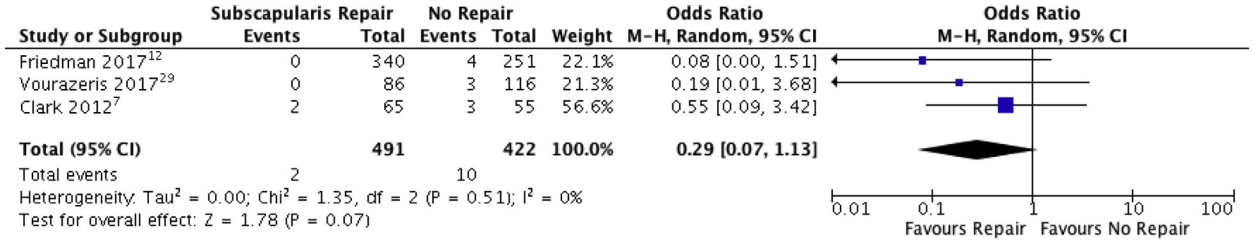

Figure 3 Forest plot for prevalence of dislocation in lateralized only implant designs. *M-H*, Mantel-Haenszel test; *CI*, confidence interval.

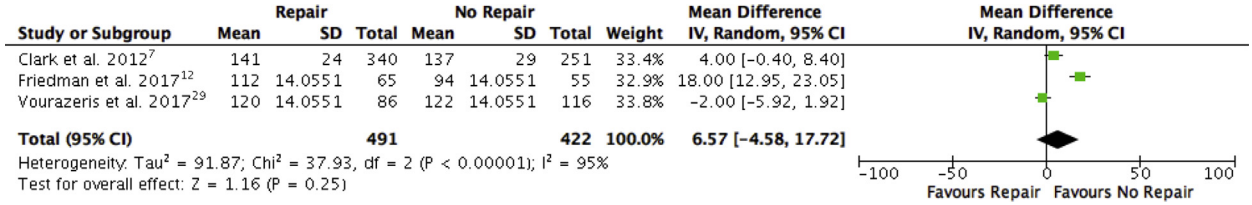

Figure 4 Forest plot for postoperative forward flexion. *SD*, standard deviation; *IV*, inverse variance; *CI*, confidence interval.

prostheses in the onlay group (426) compared with the inlay group (65), which can diminish the significance of these results.

Systematic review

As part of the systematic review, etiology leading to arthroplasty was inconsistently reported in the literature but ranged from rotator cuff arthropathy to massive rotator cuff tears with pseudoparalysis, acute fractures, inflammatory arthropathy, instability, postinfectious arthropathy, tumor reconstruction, postradiation arthropathy, revision arthroplasty (from anatomic total shoulder, hemiarthroplasty, and failed rotator cuff repair), humeral malunion or nonunion, avascular necrosis with rotator cuff tear, and glenohumeral arthritis with irreparable rotator cuff tear (Table II).

In terms of functional outcome measures, Werner et al[32] reported a significant difference in American Shoulder and Elbow Surgeons (ASES) scores based on lateralization and subscapularis repair. In their study, they analyzed ASES scores according to 4 groups: lateralized COR with and without subscapularis repair and nonlateralized (medialized) COR with and without subscapularis repair. They noted that there was a difference between repair groups only when the implant was lateralized in addition to repair of the subscapularis tendon, resulting in worse improvement in ASES scores with a significance of 0.002. In contrast, Friedman et al[12] were unable to show a difference in improvement in ASES score based on repair in the setting of a lateralized prosthesis. In addition, they reported results favoring subscapularis repair for Constant score, active external rotation, internal rotation score, and maximum weight lifted with a significance of $< .05$. Improvements in internal rotation were also reported by Wall.[31] All other outcomes among the studies, which included Simple Shoulder Test, University of California–Los Angeles score, Shoulder Pain and Disability Index, Western Ontario Osteoarthritis of the Shoulder

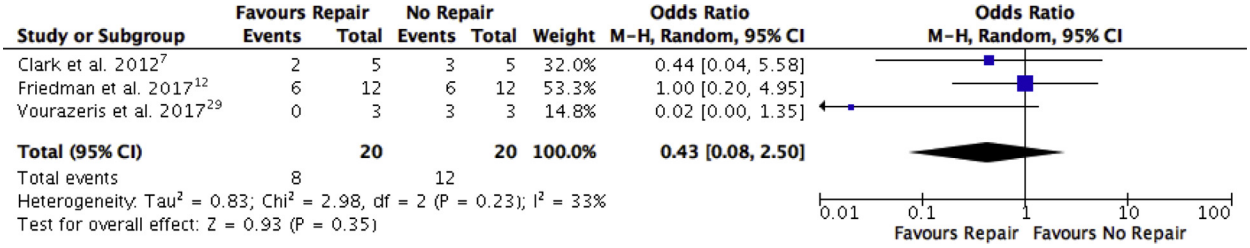

Figure 5 Forest plot for prevalence of postoperative fracture. *M-H*, Mantel-Haenszel test; *CI*, confidence interval.

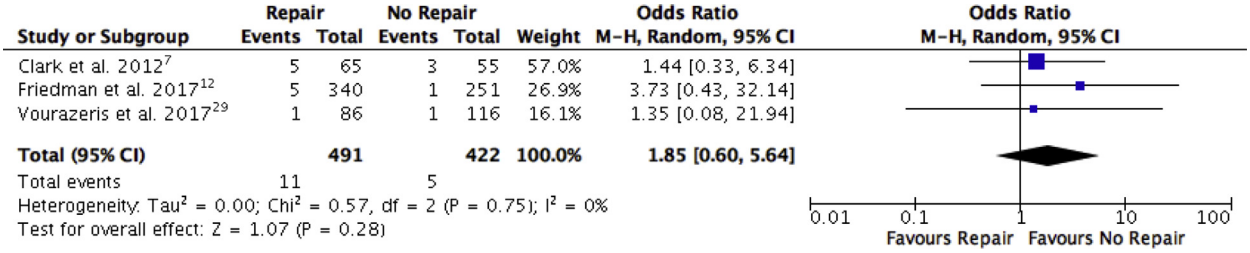

Figure 6 Forest plot for prevalence of postoperative infection. *M-H*, Mantel-Haenszel test; *CI*, confidence interval.

Index, visual analog scale score, range of motion, and strength, were similar between groups. Although we did not analyze the type of repair, in accordance with Choate et al,[6] the type of repair does have a significant effect on outcomes.

Discussion

Meta-analysis

The objective of this study was to complete a comprehensive literature review to assess the effect of subscapularis repair in the setting of reverse shoulder arthroplasty. The results of our study show that there is a paucity of high-quality literature regarding the role of subscapularis repair in reverse shoulder arthroplasty. However, the results of our meta-analysis, which included 1197 patients from level III studies, indicated that there is a decreased risk of dislocation when the subscapularis is repaired. On further analysis for design COR, the results varied on the basis of the COR of the prostheses; the medialized designs showed a significant difference in dislocation rates based on subscapularis repair, whereas the lateralized designs showed none. The results of this analysis support previous reports in which no difference in dislocation rates in lateralized designs has been found. In comparing the 2 designs based on COR, dislocation rates were significantly lower when the COR was lateralized. Further subgroup analysis showed that when the subscapularis could be repaired, there were no differences in dislocation rate between the medialized and lateralized designs. However, when the subscapularis could not be repaired, the lateralized designs showed a decreased risk of dislocation. On subgroup analysis of the lateralized design based on humeral socket, it was shown that the onlay prostheses had a lower rate of dislocation compared with inlay designs overall. However, when the repair type is taken into consideration, only the subscapularis repair group showed a decreased rate of dislocation. All other secondary outcomes were similar between groups. Our results are in keeping with computer simulations[9,23] and cadaveric studies,[21] which have postulated that lateralizing the COR would increase stability by increasing the compressive joint reaction forces; however, there are no clinical studies to date that have supported this theory.

In the past, there has been some speculation as to whether repair of the subscapularis would impede range of motion and abduction strength because of the opposite line of pull of the subscapularis tendon,[20] which has been shown in a cadaveric study by Giles et al.[15] However, to date, there are no clinical studies that definitively support this, although there is some suggestion that it may impede external rotation.[3] With this in mind, the operating surgeon should attempt to repair the subscapularis tendon when possible; however, many times, the tissue quality is too poor, and the tendon is not amenable to repair. In cases in which there are radiographic signs of an irreparable subscapularis tendon, such as a tendon tear with significant retraction[22] or fatty infiltration of the subscapularis muscle belly,[16] it may be beneficial to choose an implant with a more lateralized design as our data have shown there to be decreased dislocation rates in this setting. In addition, use

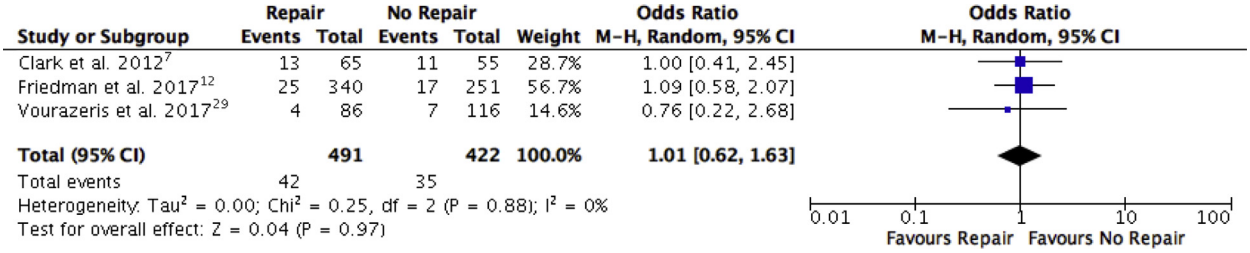

Figure 7 Forest plot for overall complications. *M-H*, Mantel-Haenszel test; *CI*, confidence interval.

Table II Indications for reverse shoulder arthroplasty for the studies included in the review

Indications for reverse shoulder arthroplasty included in review	
Rotator cuff arthropathy	Avascular necrosis with tear
Revision	Failed rotator cuff repair
Proximal humerus nonunion or malunion	Acute proximal humerus fracture
Massive rotator cuff tear with pseudoparalysis	Fracture sequelae
Rheumatoid arthritis with tear	Instability
Postinfectious arthropathy	Tumor
Glenohumeral arthritis with tear	Post-traumatic osteoarthritis
Postradiation osteoarthritis	Primary osteoarthritis

of a lateralized humeral socket should be considered as this has been shown to increase deltoid wrapping, theoretically decreasing the amount of deltoid force needed for abduction[14,18,25,30] as well as improving rotator cuff torque and function.[5,17]

Interestingly, a study by de Boer et al[10] showed that in reverse arthroplasties with subscapularis repair, up to 40% of repairs had failed at a mean follow-up of 36 months in a medialized design. This may give more support to the concept of using lateralized designs to reduce instability rates. However, the benefits of a lateralized COR should still be weighed against the potential increased risk of component loosening and revision surgery secondary to increased joint reaction forces. In a systematic review of 2049 patients, Samitier and Alentorn-Geli[1,26] found that a lateralized COR resulted in increased implant loosening (glenoid) and revision rates compared with a medialized COR (4.6% vs. 1.8% and 7.8% vs. 4.8%, respectively).

Systematic review

Unfortunately, there was insufficient detail to delineate results of subscapularis repair on outcomes in regard to implant COR position. Individually, only 2 papers[11,28] reported significant difference between groups for dislocation rates, both of which used implants with a medialized COR. There were no differences in overall complication rates between the 2 groups.

The functional outcomes of reverse total shoulder arthroplasty with or without subscapularis repair largely appear to be equivalent, although there is some weak evidence to suggest that subscapularis repair may be advantageous. Friedman et al[12] showed improvements favoring subscapularis repair in regard to Constant score, improved active external rotation, improved maximum weight lifted, and improved internal rotation score. This was supported by Wall,[3] who showed that subscapularis repair resulted in improved internal rotation. In regard to ASES score, we found contrasting results between papers. In the paper of Werner et al,[32] the investigators showed that an implant with a lateralized COR with subscapularis repair results in worse overall change in ASES score compared with no repair and a medialized design regardless of repair. This was opposed by Friedman et al,[12] who showed no difference in the change in ASES score for any of the groups; however, Friedman et al used implants with a lateralized COR only. Both groups used an onlay humeral implant design, but Werner et al used a humeral implant with a neck-shaft angle of 147°, whereas Friedman et al used an implant with a neck-shaft angle of 132.5°. The results of our study did not show any significant differences in functional outcomes between groups, although subscapularis repair did decrease the risk of dislocation.

The major limitations of this review were the heterogeneity and lack of high-quality studies. Outcome measures between studies were inconsistent, making analysis difficult. As such, we were able to carry out only 5 subgroup analyses in our meta-analysis. In comparing the results of the inlay vs. onlay humeral components, the discrepancy in group numbers between the 2 designs made reaching meaningful conclusion from the data difficult. An additional limitation is that our study looked at subscapularis repair only in isolation and did not consider additional factors that contribute to stability, such as glenosphere size and tilt,[8] use of constrained liners, and amount of compression achieved with soft tissue tensioning.[19] Another potential limitation in regard to subscapularis repair is the risk of bias as to which patients received a subscapularis repair on the basis of the

surgeon's preference as well as patient factors such as obesity and age, which may also contribute to instability of the final construct. Strengths of this study include the relatively large number of grouped patients used for subgroup analysis. To our knowledge, this is also the first systematic review and meta-analysis in the literature to critically appraise and to quantify the effect of subscapularis repair on stability in reverse total shoulder arthroplasty.

Conclusion

There is a paucity of literature and high-quality studies analyzing the effects of subscapularis repair in reverse shoulder arthroplasty. The results of our study suggest that whereas clinical outcomes are largely equivalent between those who undergo repair of the subscapularis and those who do not, subscapularis repair does significantly decrease the risk of dislocation. In the setting in which the subscapularis tendon can be repaired, the results between lateralized and medialized designs show no difference in dislocation rates. In addition, prostheses with lateralized glenosphere designs appear to be protective against dislocation when the subscapularis tendon is not repaired, with dislocation rates being significantly lower in this setting.

Disclaimer

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jse.2018.11.069

References

1. Alentorn-Geli E, Samitier G, Torrens C, Wright TW. Reverse shoulder arthroplasty. Part 2: systematic review of reoperations, revisions, problems, and complications. Int J Shoulder Surg 2015;9:60-7. https://doi.org/10.4103/0973-6042.154771
2. Boileau P, Watkinson D, Hatzidakis AM, Hovorka I. Neer Award 2005: the Grammont reverse shoulder prosthesis: results in cuff tear arthritis, fracture sequelae, and revision arthroplasty. J Shoulder Elbow Surg 2006;15:527-40. https://doi.org/10.1016/j.jse.2006.01.003
3. Boulahia A, Edwards TB, Walch G, Baratta RV. Early results of a reverse design prosthesis in the treatment of arthritis of the shoulder in elderly patients with a large rotator cuff tear. Orthopedics 2002;25:129-33.
4. Chalmers PN, Rahman Z, Romeo AA, Nicholson GP. Early dislocation after reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2014;23:737-44. https://doi.org/10.1016/j.jse.2013.08.015
5. Chan K, Langohr GD, Mahaffy M, Johnson JA, Athwal GS. Does humeral component lateralization in reverse shoulder arthroplasty affect rotator cuff torque? Evaluation in a cadaver model. Clin Orthop Relat Res 2017;475:2564-71. https://doi.org/10.1007/s11999-017-5413-7
6. Choate WS, Kwapisz A, Momaya AM, Hawkins RJ, Tokish JM. Outcomes for subscapularis management techniques in shoulder arthroplasty: a systematic review. J Shoulder Elbow Surg 2018;27:363-70. https://doi.org/10.1016/j.jse.2017.08.003
7. Clark JC, Ritchie J, Song FS, Kissenberth MJ, Tolan SJ, Hart ND, et al. Complication rates, dislocation, pain, and postoperative range of motion after reverse shoulder arthroplasty in patients with and without repair of the subscapularis. J Shoulder Elbow Surg 2012;21:36-41. https://doi.org/10.1016/j.jse.2011.04.009
8. Clouthier AL, Hetzler MA, Fedorak G, Bryant JT, Deluzio KJ, Bicknell RT. Factors affecting the stability of reverse shoulder arthroplasty: a biomechanical study. J Shoulder Elbow Surg 2013;22:439-44. https://doi.org/10.1016/j.jse.2012.05.032
9. Costantini O, Choi DS, Kontaxis A, Gulotta LV. The effects of progressive lateralization of the joint center of rotation of reverse total shoulder implants. J Shoulder Elbow Surg 2015;24:1120-8. https://doi.org/10.1016/j.jse.2014.11.040
10. de Boer FA, Van Kampen PM, Huijsmans PE. The influence of subscapularis tendon reattachment on range of motion in reversed shoulder arthroplasty: a clinical study. Musculoskelet Surg 2016;100:121-6. https://doi.org/10.1007/s12306-016-0401-8
11. Edwards TB, Williams MD, Labriola JE, Elkousy HA, Gartsman GM, O'Connor DP. Subscapularis insufficiency and the risk of shoulder dislocation after reverse shoulder arthroplasty. J Shoulder Elbow Surg 2009;18:892-6. https://doi.org/10.1016/j.jse.2008.12.013
12. Friedman RJ, Flurin PH, Wright TW, Zuckerman JD, Roche CP. Comparison of reverse total shoulder arthroplasty outcomes with and without subscapularis repair. J Shoulder Elbow Surg 2017;26:662-8. https://doi.org/10.1016/j.jse.2016.09.027
13. Gallo RA, Gamradt SC, Mattern CJ, Cordasco FA, Craig EV, Dines DM, et al. Instability after reverse total shoulder replacement. J Shoulder Elbow Surg 2011;20:584-90. https://doi.org/10.1016/j.jse.2010.08.028
14. Giles JW, Langohr GD, Johnson JA, Athwal GS. Implant design variations in reverse total shoulder arthroplasty influence the required deltoid force and resultant joint load. Clin Orthop 2015;473:3615-26. https://doi.org/10.1007/s11999-015-4526-0
15. Giles JW, Langohr GD, Johnson JA, Athwal GS. The rotator cuff muscles are antagonists after reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2016;25:1592-600. https://doi.org/10.1016/j.jse.2016.02.028
16. Goutallier D, Postel JM, Gleyze P, Leguilloux P, Van Driessche S. Influence of cuff muscle fatty degeneration on anatomic and functional outcomes after simple suture of full-thickness tears. J Shoulder Elbow Surg 2003;12:550-4. https://doi.org/10.1016/S1058-2746(03)00211-8
17. Greiner S, Schmidt C, König C, Perka C, Herrmann S. Lateralized reverse shoulder arthroplasty maintains rotational function of the remaining rotator cuff. Clin Orthop 2013;471:940-6. https://doi.org/10.1007/s11999-012-2692-x
18. Gutiérrez S, Comiskey CA, Luo ZP, Pupello DR, Frankle MA. Range of impingement-free abduction and adduction deficit after reverse shoulder arthroplasty. Hierarchy of surgical and implant-design-related factors. J Bone Joint Surg Am 2008;90:2606-15. https://doi.org/10.2106/JBJS.H.00012
19. Gutiérrez S, Keller TS, Levy JC, Lee WE, Luo ZP. Hierarchy of stability factors in reverse shoulder arthroplasty. Clin Orthop 2008;466:670. https://doi.org/10.1007/s11999-007-0096-0

20. Hansen ML, Nayak A, Narayanan MS, Worhacz K, Stowell R, Jacofsky MC, et al. Role of subscapularis repair on muscle force requirements with reverse shoulder arthroplasty. Bull Hosp Jt Dis (2013) 2015;73(Suppl 1):S21-7.
21. Henninger HB, Barg A, Anderson AE, Bachus KN, Burks RT, Tashjian RZ. Effect of lateral offset center of rotation in reverse total shoulder arthroplasty: a biomechanical study. J Shoulder Elbow Surg 2012;21:1128-35. https://doi.org/10.1016/j.jse.2011.07.034
22. Khair MM, Gulotta LV. Treatment of irreparable rotator cuff tears. Curr Rev Musculoskelet Med 2011;4:208-13. https://doi.org/10.1007/s12178-011-9098-3
23. Liou W, Yang Y, Petersen-Fitts GR, Lombardo DJ, Stine S, Sabesan VJ. Effect of lateralized design on muscle and joint reaction forces for reverse shoulder arthroplasty. J Shoulder Elbow Surg 2017;26:564-72. https://doi.org/10.1016/j.jse.2016.09.045
24. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med 2009;6:e1000097. https://doi.org/10.1371/journal.pmed.1000097
25. Roche CP, Diep P, Hamilton M, Crosby LA, Flurin PH, Wright TW, et al. Impact of inferior glenoid tilt, humeral retroversion, bone grafting, and design parameters on muscle length and deltoid wrapping in reverse shoulder arthroplasty. Bull Hosp Jt Dis (2013) 2013;71:284-93.
26. Samitier G, Alentorn-Geli E, Torrens C, Wright TW. Reverse shoulder arthroplasty. Part 1: systematic review of clinical and functional outcomes. Int J Shoulder Surg 2015;9:24-31. https://doi.org/10.4103/0973-6042.150226
27. Steenbrink F, Meskers CG, Nelissen RG, de Groot JH. The relation between increased deltoid activation and adductor muscle activation due to glenohumeral cuff tears. J Biomech 2010;43:2049-54. https://doi.org/10.1016/j.jbiomech.2010.04.012
28. Trappey GJ, O'Connor DP, Edwards TB. What are the instability and infection rates after reverse shoulder arthroplasty? Clin Orthop Relat Res 2011;469:2505-11. https://doi.org/10.1007/s11999-010-1686-9
29. Vourazeris JD, Wright TW, Struk AM, King JJ, Farmer KW. Primary reverse total shoulder arthroplasty outcomes in patients with subscapularis repair versus tenotomy. J Shoulder Elbow Surg 2017;26:450-7. https://doi.org/10.1016/j.jse.2016.09.017
30. Walker D, Wright TW, Banks SA, Struk AM. Electromyographic analysis of reverse total shoulder arthroplasties. J Shoulder Elbow Surg 2014;23:166-72. https://doi.org/10.1016/j.jse.2013.05.005
31. Wall B. Reverse total shoulder arthroplasty: a review of results according to etiology. J Bone Jt Surg Am 2007;89:1476. https://doi.org/10.2106/JBJS.F.00666
32. Werner BC, Wong AC, Mahony GT, Craig EV, Dines DM, Warren RF, et al. Clinical outcomes after reverse shoulder arthroplasty with and without subscapularis repair: the importance of considering glenosphere lateralization. J Am Acad Orthop Surg 2018;26:e114. https://doi.org/10.5435/JAAOS-D-16-00781