J Shoulder Elbow Surg (2017) ■■, ■■–■■

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

ORIGINAL ARTICLE

Reverse shoulder arthroplasty for irreparable massive rotator cuff tears: a systematic review with meta-analysis and meta-regression

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Background: Massive rotator cuff tears (MRCTs) are very large tears that are often associated with an uncertain prognosis. Indeed, some MRCTs even without osteoarthritis are considered irreparable, and non-anatomic solutions are needed to improve the patient's symptoms. Reverse shoulder arthroplasty (RSA) is an option that can provide a more predictable pain relief and recovery of function. Nonetheless, outcomes after RSA for irreparable MRCTs have not been well defined. The aim of this study was to quantitatively aggregate the findings associated with the use of RSA in this subset of patients and analyze the effect on patient functional status and pain.

Methods: A comprehensive search was performed until October 2015 using MEDLINE, Scopus, Cochrane Database of Systematic Reviews, and Central Register of Controlled Trials databases. Studies that assessed the outcomes of RSA in patients with irreparable MRCT without osteoarthritis (with at least 2 years of follow-up) were included. If the results of MRCT without osteoarthritis were not possible to subgroup, the study was excluded. Methodologic quality was assessed using the Coleman Methodology Score.

Results: Included were 6 studies (266 shoulders) with a follow-up ranging from 24 to 61.4 months. The mean Coleman Methodology Score was 58.2 ± 11.8 points. There was an overall improvement from preoperative to postoperative assessments of the clinical score (Cohen $d = 1.35$, $P < .001$), forward flexion ($d = 0.50$, $P = .009$), external rotation ($d = 0.40$, $P < .001$), function ($d = 1.04$, $P < .001$), and pain ($d = –0.89$, $P < .001$).

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1058-2746/$ - see front matter
http://dx.doi.org/10.1016/j.jse.2017.03.039

Conclusion: Patients with irreparable MRCT without presence of osteoarthritis have a high likelihood of achieving a painless shoulder and functional improvements after RSA.
Level of evidence: Level IV; Meta-Analysis

Keywords: Massive; chronic; irreparable; rotator cuff tears; pseudoparalytic shoulder; reverse shoulder arthroplasty

Massive rotator cuff tears (MRCTs) are very large tears that are difficult to repair and are often associated with an uncertain prognosis.[55] They are usually chronic lesions and associated with myotendinous retraction,[47,69,70] atrophy, and fatty infiltration of the muscles.[20,28] The clinical presentation typically includes a painful and pseudoparalytic shoulder, which is defined as a shoulder with active shoulder elevation of less than 90° in the presence of free passive anterior elevation.[25,66] However, some patients with irreparable MRCTs are able to maintain elevation of more than 90° but have intractable pain.[51]

The degenerative changes of the musculotendinous unit increase over time and are associated with loss of elasticity and poor biologic and mechanical tissue properties. These changes adversely affect and, in some cases, hamper the surgical reattachment and healing of the musculotendinous unit to the bone.[23,26,28-31,44,46,58]

The definition of MRCT lesion is still not consensual,[10,11,14,23,25,56,64,70] and the 2 most widely used systems are based on the dimension of tendon retraction (with a diameter >5 cm) [11,14] and based on the number of tendons affected, with a minimum of 2 complete tendon tears.[23,25,64,70] Following these criteria, MRCTs have been reported as ranging from 10% to 40% of all rotator cuff tears and 80% of recurrent tears.[1,9,15,16,33,36,37,42,45,63] Moreover, Hamada et al[34] radiographically classified MRCTs by the acromiohumeral distance (AHD), degenerative changes of the acromion, and narrowing of the glenohumeral joint space. The 5-grade classification presumes to reflect the temporal evolution of rotator cuff tears and is as follows: in grade 1 the AHD is maintained (≥6 mm) and narrows in grade 2 (≤5 mm); in grade 3, an acetabulization in addition to the grade 2 narrowing is seen; in grade 4, narrowing of the glenohumeral joint is added to the grade 3 features, and grade 5 comprises a humeral head collapse. Only Hamada grade 1, 2, or 3 patients are considered to have a MRCT without associated arthritis.

Computed tomography scanning[27,28] and magnetic resonance imaging[20] have been proposed as critical tools to detect MRCTs and to grade the associated prognostic factors such as the tear size, tendon retraction, and fatty infiltration. The information obtained can be used to estimate the quality and, consequently, the reparability of the torn musculotendinous unit.[36,52,57,68] However, determining which rotator cuff tears constitute an irreparable MRCT can be difficult and somewhat arbitrary.[51] Nevertheless, in the presence of severe and fixed retraction of the musculotendinous unit (grade 3 on the classification system of Patte[54]), severe cuff muscle fatty infiltration (grade 3 or 4 on the Goutallier classification for computed tomography scan[27,28] or Fuchs classification for magnetic resonance imaging[20]), or proximal humeral migration with narrowing of the acromiohumeral space (<6 mm) on the anteroposterior view in neutral rotation,[65] the RCT can be considered chronic and irreparable.

Surgical treatment is advised in an irreparable MRCT without arthritis (Hamada grade 1-3), associated with significant pain, and when nonoperative treatment has failed to improve the symptoms. However, surgical treatment remains a challenge owing to the technical difficulties and unpredictability of the results of the repair, which has led orthopedic surgeons to seek alternative options to treat MRCTs.

Many palliative interventions have been proposed, including long head of the biceps tenotomy or tenodesis,[4,61] subacromial débridement,[21] tendon transfers,[22,24,50,52] superior capsular reconstruction,[48,49] partial rotator cuff repair,[3,13] rotator cuff débridement,[17,21,53] and reverse shoulder arthroplasty (RSA).[7,18,38,51,59,62] Nevertheless, the appropriate surgical intervention for the specific individual patient has not been widely agreed upon, and currently, strong scientific data to support any of the available surgical options is lacking.

RSA is presented as an option that can provide a more predictable pain relief and recovery of function.[7,38,51] Nonetheless, outcomes after RSA for irreparable MRCTs have not been well defined in the scientific literature. Therefore, the purpose of the current work was to conduct a systematic review and a meta-analytic procedure on the outcomes of RSA to treat adult patients presenting with chronic, irreparable MRCTs. The hypothesis was that RSA would improve pain and function of patients presenting with chronic, irreparable MRCTs that had failed to improve after nonoperative treatment.

Materials and methods

Search strategy

The systematic review of the literature was conducted according the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, which aims to improve the standard of reporting of systematic reviews and meta-analyses.[43] The protocol was a priori registered at the International Prospective Register of Systematic Reviews (PROSPERO) (http://www.crd.york.ac.uk/PROSPERO 2015:CRD42015026902).

In October 2015, a comprehensive database search was performed of the MEDLINE, Scopus, the Cochrane Database of

Systematic Reviews, and the Cochrane Central Register of Controlled Trials databases. The reference lists of the most relevant original studies were scanned for additional studies. Original studies that assessed the clinical and radiologic outcomes of RSA treatment in patients with MRCTs were included. The search terms included "rotator cuff," "massive," "irreparable," "arthroplasty," and "reverse" using the Boolean operators (*and* and *or*).

The search was performed independently by 2 reviewers (N.S. and N.F.). In case of disagreement, a third reviewer (P.S.M.) was consulted for a final decision.

Study selection

All of the titles from the database searches were screened, and the duplicates were identified and removed. Once titles were screened for potential relevance to the RSA treatment of MRCTs, pertinent abstracts of the selected titles were screened for further detail to ensure that the study satisfied the eligibility criteria. If insufficient information within the title or abstract was provided, the manuscript was automatically considered for full-text review.

After potential relevant studies were identified, these were retrieved, and the respective full text was analyzed for eligibility according to the following inclusion criteria: (1) live adult human subjects; (2) primary RSA performed on rotator cuff tears classified as "massive" and "irreparable" by the authors of the original study; (3) follow-up of at least 24 months; and (4) studies published in the English language. Studies that included revision surgery after previous failed repair attempts were allowed. Only primary RSA procedures were included. Exclusion criteria encompassed (1) studies not containing a succinct description of the criteria for the definition of "massive"; (2) studies including patients with rheumatoid arthritis; (3) studies not specifying the surgical technique; (4) studies including patients with rotator cuff arthropathy (patients with Hamada classification system >3) and not presenting separate data for the MRCTs without osteoarthritis; or (5) other reviews or meta-analyses, clinical commentaries, expert opinions, biomechanical studies, technical notes, single case studies, or case reports.

Data collection and extraction

The information from individual eligible studies was independently extracted and recorded into separate databases. A third team member (P.S.M.) was responsible for combining the databases and for solving potential disagreements between the independent reviewers.

The data from the original studies were collected into 4 categories: research characteristics, patient demographics, procedural details, and surgical outcomes.

Research characteristics included type of study, year of publication, number of shoulders enrolled, follow-up duration, patients lost to follow-up, dates of recruitment period, and the method by which the authors classified the tear pattern as "massive" or "irreparable."

Patient demographics collected included age, sex, handedness, and preoperative duration of symptoms.

Procedural details collected included surgical approach (deltopectoral vs. superolateral), performance of concomitant procedures (eg, biceps tenotomy or tenodesis, and tendon transfers), and duration of postoperative immobilization.

When available, preoperative and postoperative functional outcome scores, pain, measures of strength, and active range of motion with respect to external rotation, internal rotation, abduction, and forward flexion were collected. Satisfaction, surgical complications (as noted by the authors), and revision surgery were also used as end points.

Methodological quality assessment

The level of evidence was assigned to each paper, accordingly.[67] The methodological quality of the included original studies was evaluated with the Modified Coleman Methodology Score (MCMS),[12] which has been used previously in shoulder surgery publications.[19,35,39] The MCMS is a 10-item questionnaire, divided into A and B sections, based on the subsections of the Consolidated Standards of Reporting Trials statement for randomized controlled trials but modified to allow for other study designs. Scores of 85 to 100 are considered excellent, 70 to 84 good, 55 to 69 fair, and less than 55 poor.

Statistical analysis

The meta-analytic procedures were implemented with RStudio 3.3.1 software (RStudio, Boston, MA, USA). Preoperative and postoperative measures were extracted from individual studies. When the provided parameters were not sufficient to compute effect sizes for individual studies, the corresponding authors were contacted and asked to provide additional information.

When obtaining this information was impossible and with the goal of increasing the number of studies included in the meta-analytic aggregation, different strategies were used to input missing information. In particular, for studies in which measures of dispersion (ie, variance, standard deviation [SD], or standard error [SE]) were not provided, an approximation of the significance level (when the actual P value was not reported) was used to estimate the corresponding t statistic. Thereafter, a dispersion measure—the SE—was calculated according to the formula:

$$SE = \frac{MeanDifference}{t}$$

and the corresponding SD was estimated by:

$$SD = SE * \sqrt{n}$$

The Cohen d and d variance were calculated as a means to define the effect size and the confidence interval for each study, using the MBESS package.[41] Afterward, the meta-analytic procedure was performed. Meta-analytic results are summarized with pooled d measures. Before the results were pooled, the heterogeneity level between studies was estimated based on the Cochran Q test and I^2 statistic. I^2 was calculated as

$$I^2 = \frac{Q - degrees\ of\ \ freeedom}{Q} * 100,$$

where Q is the Cochran statistic. I^2 values of 25, 50, and 75 represent low, medium, and high heterogeneity, respectively.[40] In the case of significant heterogeneity, a random-effects model (the restricted maximum-likelihood method) was used to estimate the overall, pooled effects. Alternatively, a fixed-effects model (the Mantel-Haenszel method) was performed. With the aim of assessing the effect of individual studies on the overall, pooled results, sensitivity

analyses were conducted, with a leave-one-out strategy (ie, multiple meta-analyses were conducted with 1 study being left out). Subgroup and meta-regression analyses were conducted to assess the influence of specific factors (eg, preoperative severity, patients' satisfaction, study quality) on the overall results. Finally, the presence of potential publication bias was examined through the visual inspection of funnel plot asymmetry and statistically tested using the Begg and Mazumdar rank correlation method[2] ($P < .05$ represents statistically significant publication bias). The analytical implementation of the meta-analytic was performed, using the Metafor (Meta-Analysis Package for R) package.[60]

Results

Study selection

The database and hand search yielded 362 titles and abstracts. Duplicated articles were removed, and 256 articles were screened based on their title and abstract. A total of 35 full-text articles were screened according to the inclusion and exclusion eligibility, yielding 6 studies[7,18,38,51,59,62] eligible for inclusion in the qualitative synthesis. Search strategy steps and reasons for exclusion are displayed at the PRISMA flow chart (Fig. 1).

The results of the 6 included studies are summarized in Table I. Three studies[18,38,51] presented data that allowed pooling the analysis in separate subgroups, and the results are summarized in Tables II–IV. Thus, to account for the effect of the patients' characteristics on the outcomes, these groups were considered separate studies in the meta-analytic procedure.

Research characteristics

The region where the studies were performed showed a moderate homogeneity, including Europe (4 studies) [7,18,59,62] and America (2 studies).[38,51]

The mean Coleman Methodology Score was 58.2 ± 11.8 points (Table V). The level of evidence varied across the studies: Level II (1 study),[62] Level III (3 studies),[7,18,38] and Level IV (2 studies).[51,59]

Major limitation issues were small sample sizes ($n < 60$)[7,18,51,59,62]; low level of evidence, because none of the included studies provided a prospective cohort design,[7,18,38,51,59,62] limited description of the outcome assessment procedures,[7,18,38,51,59,62] and insufficient description of subject selection process.[18,38,51,59]

Patient demographics

After screening the original studies' samples for MRCTs, a total subgroup of 266 shoulders in 257 patients was available. The method of classification used in all studies was defined by the number of tendons involved (involvement of at least 2 tendons). The mean follow-up was 47.4 months (range, 34-61.4 months). The complications rate ranged between 4.1% and 20%,[18,35,48] and the revision rate ranged from a minimum of 1.4%[35] to 8.3%.[48] A more detailed description is provided in Table I.

Quantitative analysis

With respect to the analysis of the clinical score, significant heterogeneity was observed between studies ($Q_{(9)} = 18.25$, $P = .032$), accounting for 52.76% of the variance ($I^2 = 52.76$). The pooled results revealed an overall improvement (weighted average difference of 35.1) of the clinical score from preoperative to postoperative assessments ($d = 1.35$, $P < .001$; Fig. 2). Similarly, the aggregation of studies evaluating forward flexion yielded a significant overall postsurgical improvement (weighted average difference of 41.8) on this parameter ($d = 0.50$, $P = .009$), again noting that there is a large and highly significant heterogeneity between studies ($I^2 = 75.53$, $Q_{(5)} = 23.83$, $P < .001$). In contrast, regarding the external rotation, the heterogeneity between studies was negligible ($I^2 = 0.02$, $Q_{(4)} = 5.49$, $P = .240$), which enabled the use of a fixed-effects model. Following the results of the previously described parameters, the pooled effects revealed significant beneficial effects of RSA on the level of external rotation (weighted average difference of 12; $d = 0.40$, $P < .001$). The postsurgical assessment was also found to be associated with a significant improvement on the function parameter (weighted average difference of 4), as revealed by the random-effects model ($d = 1.04$, $P < .001$; $I^2 = 62.48$, $Q_{(3)} = 8.35$, $P = .039$). The last tested parameter—pain—significantly improved (weighted average difference of −5.2) from before to after surgery ($d = 0.89$; $P < .001$; $I^2 = 19.63$, $Q_{(4)} = 4.16$, $P = .384$). Results of the different clinical parameters are summarized in Fig. 3.

The sensitivity analyses for each parameter revealed that no single study contributed to significant alterations in the pooled, overall, results. Nevertheless, it is important to note that for the forward flexion parameter, the exclusion of the study of Boileau et al[7] or the study of Mulieri et al[51] led to a decrease of the significance level to the limits of statistical significance ($P = .048$). Finally, the quality of a study (MCMS section B) had a significant effect on the overall findings. In particular, the quality was inversely associated with the effect's magnitude ($\beta = -0.04$, $SE = 0.02$, $P = .013$); that is, studies with higher quality had a reduced effect size. This association is graphically displayed in Fig. 4. In contrast, neither patients' satisfaction nor preoperative parameters had a significant effect on the overall findings.

Discussion

The systematic review and a meta-analytic investigation showed that the RSA significantly improved the shoulder outcomes in patients with irreparable MRCTs. More specifically, the parameters evaluated, such as pain, function, and mobility, significantly improved from the preoperative to postoperative status. Of note, to the best of our knowledge, this

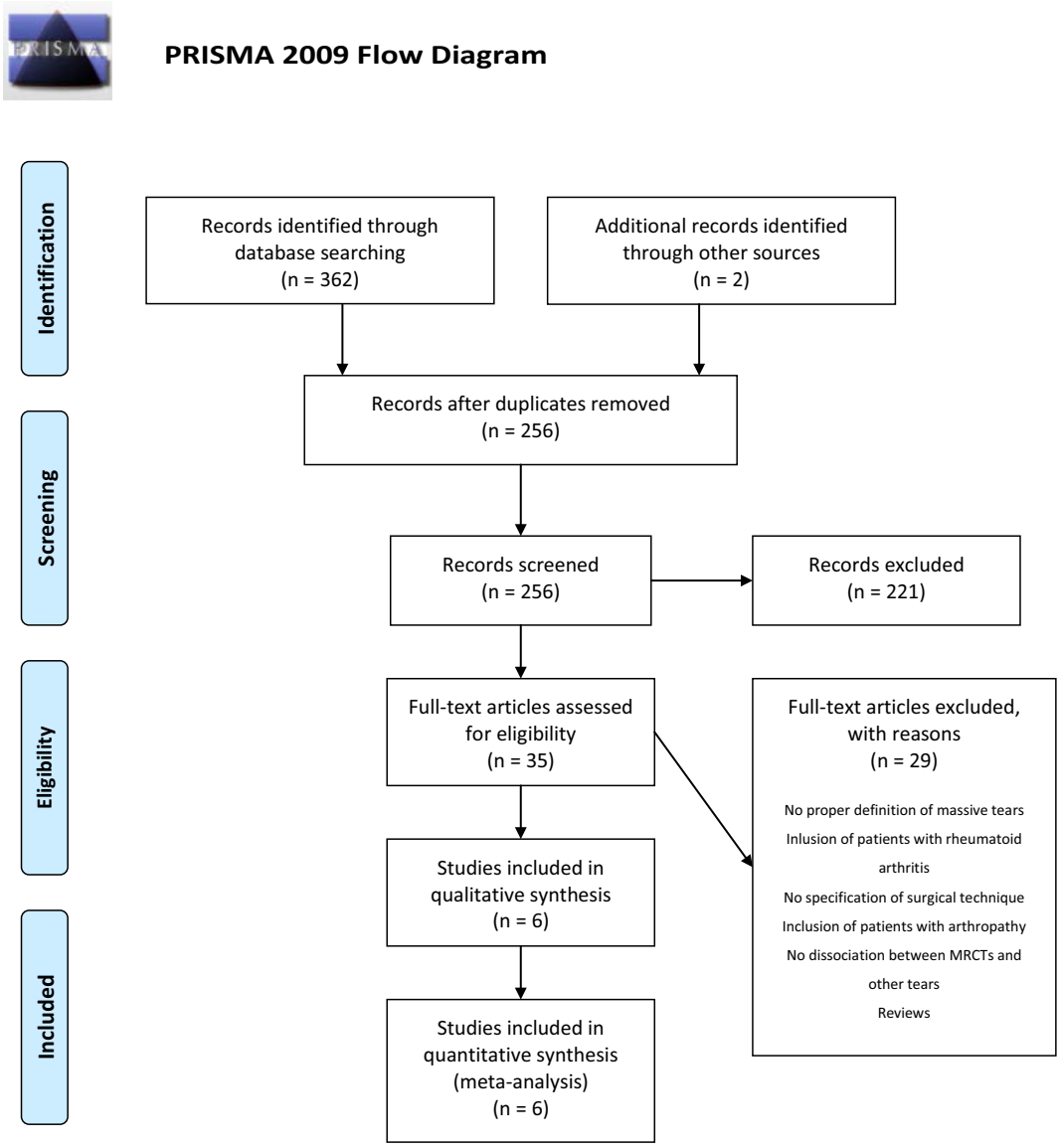

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (*PRISMA*) diagram. Flow chart displays the search and eligibility strategy. *MRCT*, massive rotator cuff tear.

is the first report to quantitatively aggregate the findings associated with this topic.

Currently, an anatomic clinical solution is not available to effectively treat chronic irreparable MRCTs. Paul Grammont introduced a new reverse prosthesis concept imposing a new biomechanical environment for the deltoid muscle to act, thus allowing it to compensate for the deficient rotator cuff muscles.[32] The revolutionary design minimizes torque on the glenoid component and helps in recruiting more fibers of the anterior and posterior deltoid to act as abductors. Several indications emerged, based on the clinical experience showing that the RSA restores active elevation above 90° in patients with a cuff-deficient shoulder.[8]

Despite the theoretical advantages of RSA helping to solve the challenging problem of irreparable MRCTs without arthritis, there is no strong evidence in the literature specifically reporting the results of RSA in this setting. Moreover, only 1 study[18] has reported the results of different techniques treating MRCT patients without osteoarthritis (aged <65 years), and the authors found that the reverse shoulder prostheses subgroup showed better outcomes in functional benefits. Nevertheless, the study was retrospective, without

Table I Summary of the results analysis in the 6 different included studies

Author	Region of origin	LOE	No.	Mean FU (mo)	Mean age (y)	Male (%)	Clinical score gain	Forward flexion gain	External rotation gain	Internal rotation gain	Function gain	Pain evolution	Revision rates	Complications	Conclusions
Favard et al[18] (2009)	France (Europe)	III	49	61.4	58.8	NR	35.9†	NR	NR	NR	NR	NR	NR	4.1%: 2 infections	RSA suggested to more initially handicapped patients. Patients who received a RSA showed a higher improvement of their Constant score.
Boileau et al[7] (2009)	France (Europe)	III	25	50	NR	NR	28.4†	36	NR	NR	NR	−7.4§	NR	NR	RSA can improve function in patients with cuff-deficient shoulders. RSA when the patient maintains >90° of preoperative AAE risks loss of AAE and lower patient satisfaction.
Wall et al[62] (2007)*	France (Europe)	II	41	34	NR	NR	35.6†	49	−6	−1	NR	−8.4§	NR	NR	RSA can produce good results in MRCTs.
Mulieri et al[51] (2010)	USA (America)	III	60	52	71	29%	42.1‡	81	24	4	3.9	−4.4‖	5 (8.3%)	20%: 1 early infection, 1 dislocation, 4 baseplate failures (11.8%) among the 34 shoulders with the original baseplate design. Among the 26 shoulders with the 5.0-mm locking screws, there were no baseplate failures.	RSA provides reliable pain relief and return of shoulder function in patients with MRCT without arthritis. Patients with preserved motion (>90° of elevation) had a higher complication rate.

(*Continued on next page*)

Table I (*Continued*)

Author	Region of origin	LOE	No.	Mean FU (mo)	Mean age (y)	Male (%)	Clinical score gain	Forward flexion gain	External rotation gain	Internal rotation gain	Function gain	Pain evolution	Revision rates	Complications	Conclusions
Hartzler et al[38] (2015)	USA (America)	III	74	43	72	50%	30.8‡	−0.9	12	NR	4.1	−3.3‖	1 (1.4%)	17%: 9 patients (12%) experienced a major complication: instability and acromial fracture. 4 patients (5%) experienced a minor complication: lower extremity deep venous thrombosis, reflex sympathetic dystrophy, wound dehiscence, and postoperative aspiration. 1.4% revision rate at minimum 2-year follow-up.	Young age, high preoperative function, and neurologic dysfunction were associated with poor functional improvement. Concurrent latissimus dorsi transfer was successful in restoring active external rotation in a subgroup of patients.
Valenti et al[59] (2011)*	France (Europe)	III	17	44	NR	NR	NR	80.5	13.3	0.56	NR	NR	NR	NR	Less medialization of reverse shoulder arthroplasty improves in external and medial rotation, thus facilitating the activities of daily living of older patients.

AAE, active anterior elevation; *FU*, follow-up; *LOE*, level of evidence; *MRCT*, massive rotator cuff tear; *NR*, not reported; *RSA*, reverse shoulder arthroplasty; *VAS*, visual analog scale.

* Measures of dispersion could not be estimated for these studies. As such, these studies were included in the analysis of average differences between preoperative and postoperative stages, but not in the pooled meta-analytic results.

† Clinical gain assessed with the Constant score.

‡ Clinical gain assessed with American Shoulder and Elbow Surgeons score.

§ Pain improvement measured with Constant score.

‖ Pain improvement measured with the visual analog scale.

Table II Specific subgroups analysis in the Favard et al[18] study

Favard et al[18] (2009)	No.	Mean FU (mo)	Mean age (y)	Male (%)	Pain improvement (VAS)	Clinical score gain	Forward elevation gain	External rotation gain	Internal rotation gain	Complications
A: Subgroup without pre-op functional deficit	3	61.4 ± 35.8*	58.8 ± 4.6*	NR	NR	17†	NR	NR	NR	4.1*
B: Subgroup with pre-op loss of elevation	31	61.4 ± 35.8*	58.8 ± 4.6*	NR	NR	42.5†	NR	NR	NR	4.1*
C: Subgroup with pre-op loss external rotation	3	61.4 ± 35.8*	58.8 ± 4.6*	NR	NR	39†	NR	NR	NR	4.1*
D: Subgroup with pre-op loss of elevation and external rotation	12	61.4 ± 35.8*	58.8 ± 4.6*	NR	NR	23.5†	NR	NR	NR	4.1*

FU, follow-up; *NR*, not reported; *VAS*, visual analog scale.
* The characterization is presented for the total sample and not for each specific subgroup.
† Clinical score gain represented as the difference in the Constant score between preoperative and postoperative assessments.

Table III Specific subgroups analysis in Mulieri et al[51] study

Mulieri et al[51] (2010)	No.	Mean FU (mo)	Mean age (y)	Male (%)	Pain improvement (VAS)	Clinical score gain	Forward elevation gain	External rotation gain	Internal rotation gain	Complications (%)
A: Subgroup without previous surgery	34	52*	71*	38.1*	4.9	43.9†	82	27	4	20*
B: Subgroup with previous surgery (failed rotator cuff repair)	26	52*	71*	38.1*	4	39.9†	74	23	4	20*
C: Subgroup without pre-op functional deficit (>90° elevation pre-op)	4	51	65	100	–	29.5†	29.25	7	2.75	50

FU, follow-up; *NR*, not reported; *VAS*, visual analog scale.
* The characterization is presented indiscriminately for both subgroups with and without previous surgery.
† Clinical score gain represented as the difference in the American Shoulder and Elbow Surgeons score between preoperative and postoperative assessments.

Table IV Specific subgroups analysis in Hartzler et al[38] study

Hartzler et al[38] (2015)	No.	Mean FU (mo)	Mean age (y)	Male (%)	Pain improvement (VAS)	Clinical score gain	Forward elevation gain	External rotation gain	Internal rotation gain	Complications (%)
A: Subgroup cases (patients in the poor improvement group)	13	45	69	61.50	NR	3*	NR	NR	NR	17
B: Subgroup control (patients had improvement of ≥2 points)	61	43	73	47.50	NR	37*	NR	NR	NR	17
C: Subgroup with latissimus dorsi transfer	10	57.8	73.7	50	1.8	20.2*	−2.8	39	NR	17
D: Subgroup without latissimus dorsi transfer	64	40.8	72.7	NR	3.5	32.4*	−0.6	7.8	NR	17

FU, follow-up; *NR*, not reported; *VAS*, visual analog scale.
* Clinical score gain represented as the difference in the American Shoulder and Elbow Surgeons score between preoperative and post-operative assessments.

a randomization of the procedures and including patients with different baseline characteristics.

The indications for RSA within this population were significant persistent shoulder pain, dysfunction despite at least 6 months of nonoperative treatment, the presence of at least a 2-tendon tear, and Hamada stage 1, 2, or 3 changes in a patient for whom a nonarthroplasty option did not exist.[51] Other authors preferred to reserve this procedure for patients with chronic loss of elevation, particularly in young active patients.[18,62] In fact, it has been suggested that preoperative mobility higher than 90 degrees of forward flexion could be associated with worse outcomes, more specifically, with a higher complication rate[51] and even with a decrease of shoulder mobility.[7]

In our analysis, it was not possible to confirm the hypothesis of a negative association between MRCTs patients with

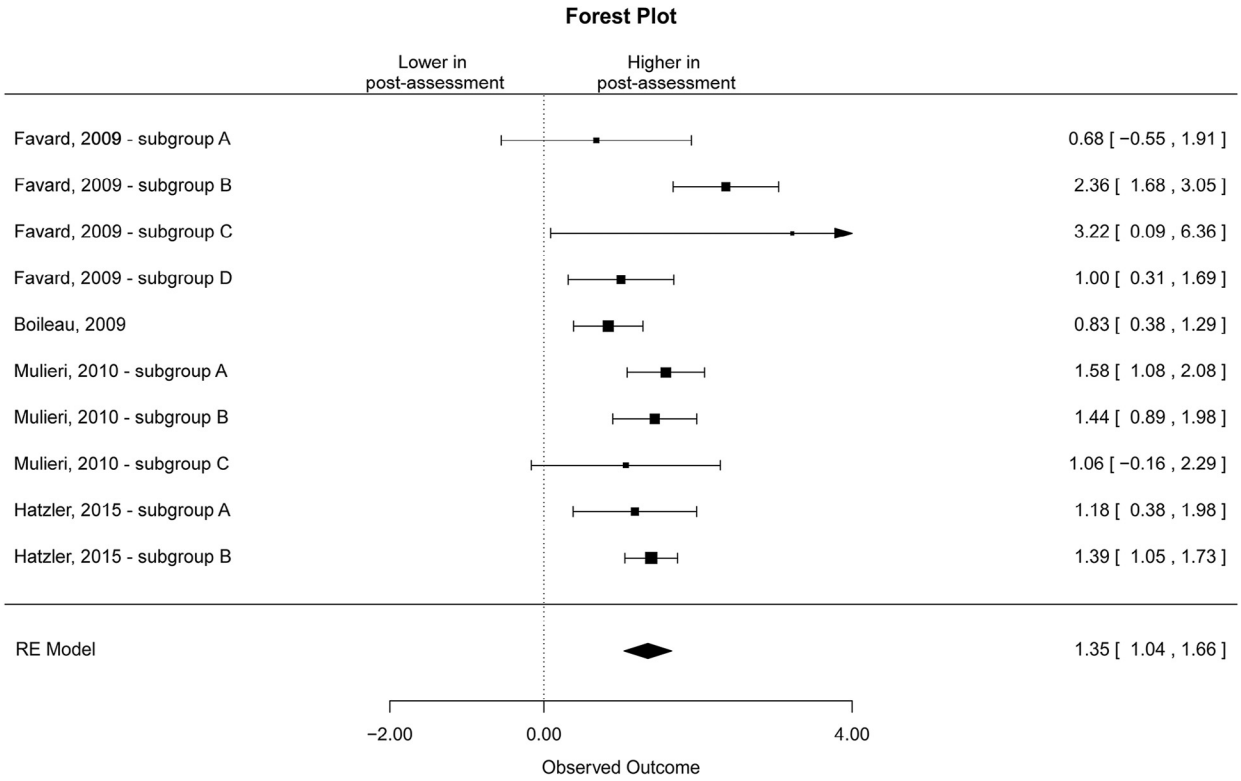

Figure 2 Forest plot. Overall effect of shoulder arthroplasty for irreparable massive rotator cuff tears on clinical score. The *horizontal lines* represent the confidence interval for the studies included in the meta-analysis. The *solid squares* indicate the mean difference and are proportional to the weights used in the meta-analysis. The *gray line* indicates the absence of significant effect (ie, no significant differences in clinical scores between preassessment and postassessment). The *diamond* represents the aggregated pooled effect. The diamond does not cross the line of null effect, indicating an overall significant improvement after the surgical intervention. The characteristics of the distinct subgroups are presented in Tables II–IV. *RE*, random effects.

Table V Methodological quality according Modified Coleman Methodology Score

Modified Coleman Methodology Score	Score	Mean (SD)
Part A		
Study size	10	5.8 (3.4)
Mean duration follow-up	5	5.0 (0.0)
Treatment procedures , No.	10	10.0 (0.0)
Type of study	15	0.0 (0.0)
Diagnostic certainty	5	5.0 (0.0)
Description of surgical procedure	5	3.7 (1.0)
Rehabilitation & compliance	10	6.7 (5.2)
Part B		
Outcome criteria	10	10.0 (0.0)
Outcome assessment	15	3.7 (4.4)
Selection process	15	8.3 (6.1)
Total part A	60	36.2 (6.6)
Total part B	40	22.0 (9.9)
Total score	100	58.2 (11.8)

SD, standard deviation.

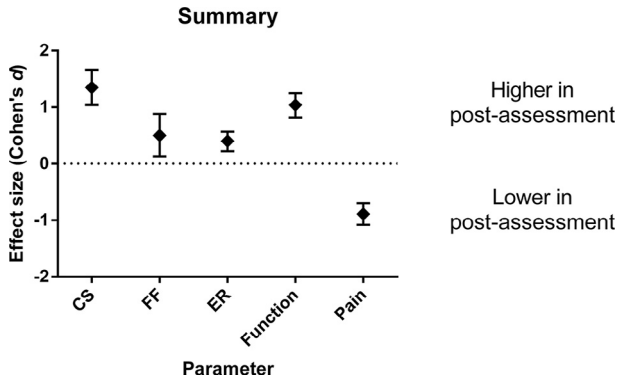

Figure 3 Summary of the pooled effects of the shoulder arthroplasty on distinct clinical parameters. *CS*, clinical score; *ER*, external rotation; *FF*, forward flexion; *function*, function score (visual analog scale), *pain*, pain score (visual analog scale). The *horizontal dotted line* indicates the line of null effects (ie, no significant differences between preassessment and postassessments. The *positive values* indicate increases from baseline to postsurgery; *negative values* indicate reductions. The *diamonds* represent the pooled estimates; *vertical lines* correspond to the confidence interval of each estimate. As can be observed, none of the vertical bars cross the null-effects line, indicating that all the effects are significant—there are overall significant improvements in all the assessed clinical parameters.

painful shoulder, good preoperative mobility, and loss of mobility after RSA. Moreover, none of the studied preoperative parameters had a significant effect on the overall findings. Thus, even this subset of patients with good mobility may

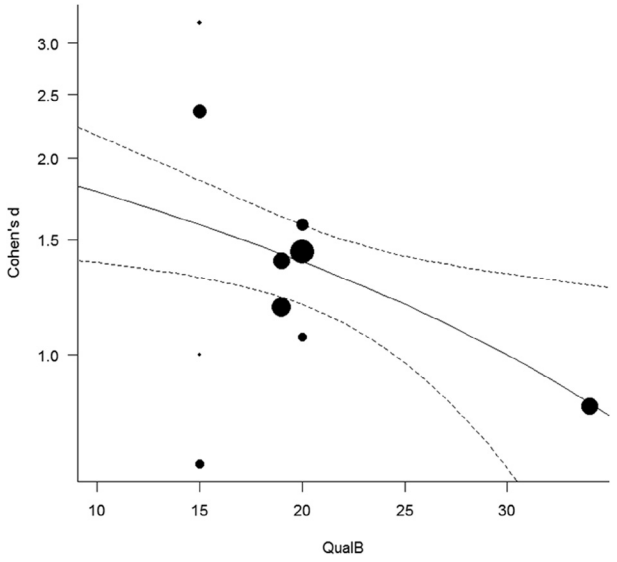

Figure 4 Meta-regression plot. The *bubbles* represent individual studies, with the size of the bubbles corresponding to the weight of the study: studies with higher samples have larger weights for the estimation of the pooled effects. The plot suggests that studies with higher quality present the lower estimates of overall effect sizes (higher score of modified Coleman Methodology Score section B [*Qual B*]).

benefit from this surgical option after a failed conservative treatment attempt. Nevertheless, it is important to note that the low number of included studies in the meta-analysis may not be enough to statistically demonstrate this association. Furthermore, it is also relevant to consider that the postoperative outcomes were not consistently provided according the preoperative mobility and that measurements of preoperative mobility were not reported for all the included studies.

External (particularly in patients with an absent or fat-infiltrated teres minor) and internal rotation of the shoulder often remain limited after an RSA.[8] Moreover, Boileau et al[5,6] showed that if the patient has a deficit of external rotation associated with an MRCT without osteoarthritis, only a tendon transfer can restore it. The authors advocated that in cases of isolated loss of active external rotation related to an irreparable posterosuperior cuff tear, the latissimus dorsi (alone or in association with the teres major) tendon transfer should be performed in isolation. In cases with combined loss of active elevation and external rotation, the tendon transfer should be performed with an RSA.

From the meta-analysis of individual parameters, we observed that whereas RSA yielded larger pooled estimates for the clinical scores (eg, Constant score), pain and function, these effects were less pronounced for the external rotation and forward flexion. Indeed, Hartzler et al[38] found that the subgroup of patients with latissimus dorsi transfer had significantly higher external rotation gain. This raises the hypothesis that RSA may be more selectively effective for improving pain than mobility.

However, it should be emphasized that the complications rate can be as high as 1 in each 5 RSAs. Moreover, the revision rate is approximately 1 in each 12 patients at short- to medium-term. Furthermore, these rates were observed in specialized centers where surgeons have substantial experience using RSA for this specific population, which means that these rates could be even higher in less experienced hands. Finally, providing this information to patients when counseling this therapeutic option is essential.

It is important to explicitly discuss some of the shortcomings associated with this work. Lack of appropriate reporting was evident for a great number of studies. For several studies, measures of dispersion (eg, SD, SE, or confidence intervals) were not properly reported. Instead, most of the studies only included range, which is not enough to robustly compute measures of effect-sizes. Some strategies of estimating confidence intervals based on range have been reported. However, this requires that strong assumptions be met, such as the normal distribution and absence of outliers. For this reason, imputing dispersion measures based solely on range values is not recommended. This highlights the importance of adequate reporting to ensure a proper aggregation of studies to estimate overall effects.

Another aspect pertains to the high dispersion levels in postoperative outcomes compared with preoperative levels. As a consequence, it is plausible not to exclude the hypothesis that some studies included participants displaying very high improvement values and thus contributing to an enlargement of the overall effects for individual studies.

Some methodological considerations related with the experimental design are important to highlight. In particular, none of the included studies performed randomization in the patients' allocation. Furthermore, because there are a multitude of available surgical procedures, it would be of upmost relevance to compare RSA with other surgical approaches, which was not verified in most of the studies.

Conclusion

Patients with irreparable MRCTs without the presence of osteoarthritis have a high likelihood of achieving a painless shoulder and functional improvements after RSA. Therefore, in older patients with symptomatic MRCTs without osteoarthritis that had failed to improve with conservative treatment and presenting signs revealing that the cuff is not reparable or would not heal back to bone (eg, decreased AHD and advanced fatty muscle degeneration), RSA may result in significant improvement of the patient's functional status and relief of pain symptoms and thus should be recommended. Nonetheless, high-quality studies (Level I) with randomization procedures and control groups that compare different options to treat irreparable MRCTs without osteoarthritis are required.

Disclaimer

This study received support from the Portuguese Foundation for Science and Technology: IF Development Grant to António J. Salgado (IF/00111/2013) and a predoctoral scholarship to Pedro Moreira (PDE/BDE/113601/2015) from the PhD-iHES program. This work has been funded by Fonds Européen de Développement Économique et Régional (FEDER) funds, through the Competitiveness Factors Operational Programme (COMPETE), and by National funds, through the Foundation for Science and Technology (FCT), under the scope of the project POCI-01-0145-FEDER-007038.

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.

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