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Clinical and functional outcomes of reverse total shoulder arthroplasty supplemented with latissimus dorsi transfer: a systematic review and meta-analysis

Jake X. Checketts, DO[a,*], Robert Steele, MS[b], Ashini Patel, BS[c], Josh Stephens, BS[c], Kate Buhrke, BS[d], Arjun Reddy, BS[a,e], Landon Stallings, DO[a], Jacob J. Triplet, DO[f], Brian Chalkin, DO[a]

[a]*Oklahoma State University Medical Center, Department of Orthopaedic Surgery, Tulsa, OK, USA*
[b]*Kansas City University College of Medicine, Kansas City, MO, USA*
[c]*Nova Southeastern University College of Medicine, Ft. Lauderdale, FL, USA*
[d]*Idaho College of Osteopathic Medicine, Boise, ID, USA*
[e]*Oklahoma State University Center for Health Sciences, Tulsa, OK, USA*
[f]*Mayo Clinic, Department of Orthopaedic Surgery, Rochester, MO, USA*

A R T I C L E I N F O

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Level of evidence: Level IV; Systematic Review and Meta-Analysis

Background: To optimize patients' functional external rotation outcomes, reverse total shoulder arthroplasties (rTSAs) including a latissimus dorsi tendon transfer were undertaken with promising early results and no significant increase in complications in comparison to traditional rTSAs. This was especially utilized for patients with a pronounced combined loss of elevation and external rotation. The purpose of this study is to evaluate and synthesize the findings of all relevant publications assessing the outcomes of rTSAs with associated latissimus dorsi transfer.

Methods: We thoroughly searched the literature within the PubMed database using a standardized methodology. For our inclusion criteria, we included any study regarding rTSAs that contained functional outcome scores for postoperative range of motion (such as elevation, external rotation, etc.) or postoperative outcomes such as complications (reoperation, infection, etc.) and patient satisfaction. For the extraction of data, we used pilot-tested Google Forms to record extracted data. These data were then converted to spreadsheets (Microsoft Excel [Microsoft, Redmond, WA, USA]). This was done on 2 separate scenarios by 2 authors to ensure accuracy. We used the modified Coleman Methodology Score to assess the methodological quality of the studies in our samples. Meta-analysis mathematics and statistical analysis were performed using Stata software 17 (StataCorp, College Station, TX, USA).

Results: Our search returned a total of 12 studies containing data of 213 shoulders receiving RTSAs with a latissimus dorsi transfer. Functional outcomes were available for 160 shoulders. The mean preoperative elevation of the affected shoulder was 73.57 degrees, and the mean postoperative elevation was 141.80 degrees. For external rotation, the mean preoperative average was −6.71 degrees, and the mean postoperative average was 22.73 degrees. The absolute Constant score average was 31.56 preoperatively, while the postoperative value was 68.93. In our sample, 25 patients (11.73%) required a revision of the RTSA implant due to complications.

Discussion: Combined loss of elevation and external rotation can be a severely debilitating condition for those with a glenohumeral pathology. Latissimus dorsi transfer for this condition has been proven to be an effective modality. The reoperation and complication rate appears to be sizable, and as such surgeons should consider this when considering this modality for their patients.

Pathologies of the shoulder, including end-stage osteoarthritis, proximal humerus fractures, avascular necrosis, and post-rotator cuff tear arthropathies are unfortunately common and occur at a rate of almost 15 per 1000 patients per year.[6,10,12,20] These pathologies are

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*Corresponding author: Jake X. Checketts, DO, Oklahoma State University Center for Health Sciences, 1111 W 17th St., Tulsa, OK 74107, USA.

E-mail address: jake.checketts@okstate.edu (J.X. Checketts).

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leading indications for shoulder arthroplasty procedures. In recent history, a variation of the total shoulder arthroplasty, the reverse total shoulder arthroplasty (rTSA), has gained popularity.[8] This is because patients do not need a functioning rotator cuff to qualify for this procedure, which is commonly seen in those with the above pathologies. It has also been shown that patients with rTSAs have reliable outcomes for reducing pain and maintaining function; however, restoration of external rotation has been less predictable.[1]

The ability to externally rotate and have strength in this position is a crucial function of the shoulder joint, and it is of the utmost importance to preserve this function whenever possible during shoulder arthroplasty procedures. Traditionally, Grammont-style rTSAs were associated with a combined loss of active elevation and external rotation (CLEER) even following the arthroplasty[26] for patients with fatty atrophy to their teres minor. To optimize patient functional external rotation outcomes, rTSAs including a latissimus dorsi tendon transfer were undertaken with promising early results and no significant increase in complications in comparison to traditional rTSAs.[9] This was especially utilized for patients with pronounced CLEER.[1]

With the recent popularity of the rTSA and increasing understanding of the indications for latissimus dorsi transfer, it is necessary to succinctly characterize the current state of the literature regarding clinical outcomes of this procedure.

Methods

Search strategy and selection criteria

This study adhered to the Preferred Reporting Items for Systematic Reviews and Meta-analyses checklist items.[13] We considered articles for inclusion if they were Level I-IV evidence. A search on June 25, 2021, using PubMed as our electronic database was conducted. PubMed was selected as the sole database for this work. The following search string was used: (reverse) AND ((Shoulder arthroplasty) OR (total shoulder arthroplasty) OR (shoulder replacement) OR (total shoulder replacement)) and included all studies to the present day. This search string is a published and validated sensitive search string for obtaining rTSA literature.[19]

For our inclusion criteria, we included any study that contained functional outcome scores for postoperative range of motion (such as elevation, external rotation, etc.) with ≥12 months of follow-up. We also included both postoperative and intraoperative complications for patients undergoing an rTSA with latissimus dorsi transfer. If a study had several cohorts and not all of them received an rTSA with latissimus dorsi transfer, we only included data from the cohorts meeting our inclusion criteria. Exclusion criteria include data from national registries, studies not in English language, Level V evidence studies, conference abstracts, case reports, studies in children, review articles, animal studies, cadaveric studies, and those with incomplete data.

The purpose of this study is to evaluate and synthesize the findings of all relevant publications assessing the outcomes of rTSAs with associated latissimus dorsi transfer. Our primary objective is to assess patient functional outcomes such as elevation and external rotation. Furthermore, we also aim to provide the most up-to-date literature regarding the acute and chronic complications (such as deep surgical site infection, nervous injury, prosthetic loosening/instability, and fractures) and their risk factors for patients receiving a latissimus dorsi transfer with their rTSA.

Screening

Two reviewers screened each study returned from our search string. Studies including data on rTSAs in the title or abstract were then flagged for full-text manuscript screening. Disagreements in this step resulted in the study automatically being included for full-text screening, and if further agreement could not be made, a tertiary senior author was consulted for a final say on inclusion vs. exclusion.

Data extraction

For the extraction of data, we used pilot-tested Google Forms to record extracted data. These data were then converted to spreadsheets (Microsoft Excel [Microsoft, Redmond, WA, USA]). This was done on 2 separate scenarios by 2 authors to ensure accuracy. Data extracted to our Google Form include indications, age, demographic variables, functional outcomes (elevation, external rotation, etc.), and associated complications (such as deep surgical site infection, nervous injury, prosthetic loosening/instability, and fractures) or outcomes.

To maintain the accuracy and consistency of data extraction, definitions and inclusion criteria were established for all complications and/or variables of interest. As an example, deep surgical site infection was only considered as such if it was reported to have affected the prosthesis. Superficial infection with no further clarification or necessitated revision was not considered as a deep surgical site infection. This was done according to a modification of the previously published literature[14] regarding periknee infections. If an article recorded an infection as a complication but did not clarify whether it is deep or superficial, it was considered a deep infection for the purpose of this study.

Risk-of-bias assessment

We used the modified Coleman Methodology Score (CMS), presented by Saleeb et al,[5,21] to assess the methodological quality of the studies in our samples. This risk-of-bias assessment is a comprehensive and multifactorial system created to evaluate the methodological quality of published surgical research. Scores span from 0 to 100 and are divided into 4 categories: poor (<50 points), fair (50-69 points), good (70-84 points), and excellent (85-100 points). CMS assesses predetermined factors such as study type, the number of surgical procedures, description of the subject-selection process, diagnostic certainty, postoperative rehabilitation description, surgical protocol description, description of desired outcomes, and description of how authors assessed outcomes.

Statistical analysis

Meta-analysis mathematics and statistical analysis were performed using the Stata software 17 (StataCorp, College Station, TX, USA). Data within each study were assumed to be parametric, including author, year, sample size (n), preoperative and postoperative flexion, and external rotation captured as continuous data in degrees. Null data reported were replaced with a numerical zero value, unless otherwise stated in the study. Descriptive and quantitative statistics were conducted. The data were lastly cleaned and formatted for Stata17 database input. *A priori* assumption of significance in confidence intervals is set at 95% and an alpha value of <0.05 for all test statistics.

The primary outcome is a comparison of flexion and external rotation of the patients' shoulder. Comparison groups include preoperative range of motion (degrees) and postoperative range of motion (degrees) to act as the control and treatment groups for the primary outcome. Manual calculation of the required input for STATA was necessary for literature that did not publish the explicit input criteria. Studies that were unable to have manual calculation for missing data were omitted.

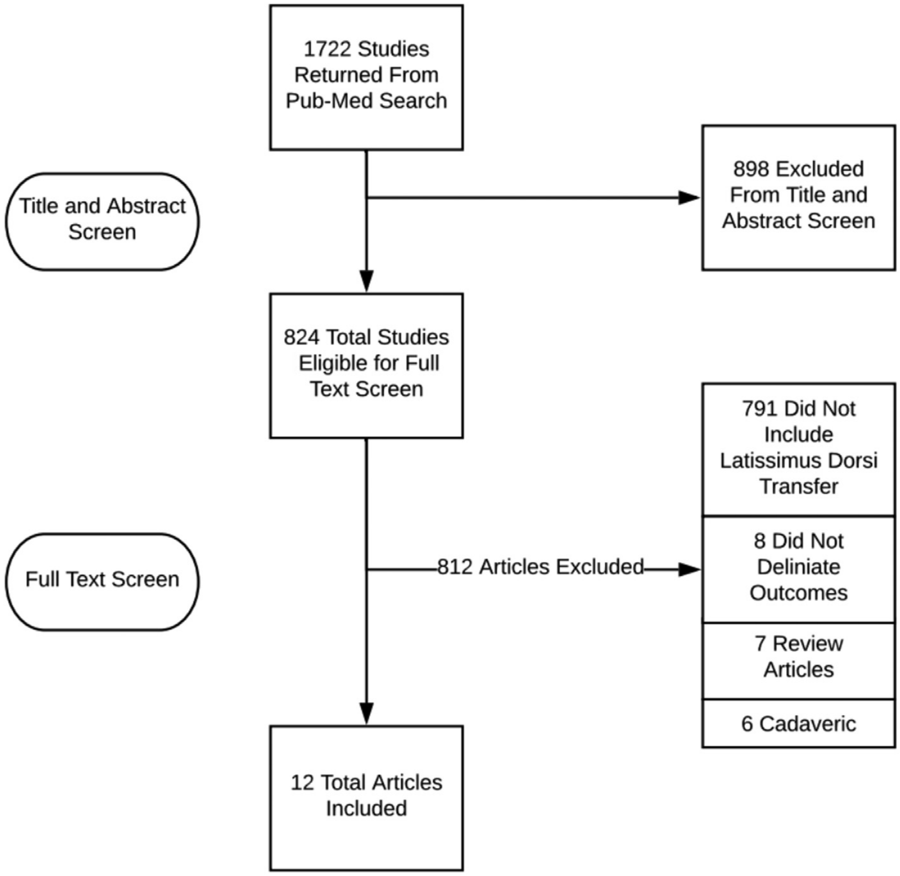

Figure 1 A flow chart demonstrating the study acquisition process.

Table I
Characteristics of included studies.

Study	Type of study	Level of evidence	Sample size	Gender	Mean age	Mean FU (mo)	Implant used
Gerber et al,[9] 2007	Case series	Level 4	12	10 F/1 M	73	18	Depuy Delta-III
Boileau et al,[2] 2008	Case control	Level 4	11	7 F/4 M	70	20	Tornier BIO-RSA
Shi et al,[23] 2015	Retrospective chart review	Level 4	21	17 F/4 M	66	44	Zimmer Anatomical Shoulder Inverse/Reverse
Boughebri et al,[4] 2013	Case series	Level 4	15	-	68	33	Arrow reverse shoulder prothesis, FH Orthopedics
Puskas et al,[18] 2014	Case series	Level 4	32	18 F/13 M	70	53	Depuy Delta-III & Zimmer Anatomical Shoulder Inverse/Reverse
Flury et al,[7] 2018	Retrospective chart review	Level 3	13	8 F/5 M	69	60	Smith & Nephew Promos Reverse Prosthesis
Ortmaier et al,[15] 2014	Case series	Level 4	13	-	71	65	Depuy Delta-III
Young et al,[27] 2020	Randomized control trial	Level 1	16	7 F/9 M	68	-	Zimmer Trabecular Metal Reverse Shoulder System & Biomet Comprehensive Reverse Arthroplasty
Spapens et al,[24] 2020	Prospective cohort	Level 2	29	-	-	-	DePuy Synthes Delta Xtend
Boileau et al,[3] 2010	Case series	Level 4	17	10 F/7 M	71	23	Aequalis Reverse System
Popescu et al,[17] 2019	Case series	Level 4	10	6 F/4 M	73	57	DePuy Synthes Delta Xtend
Klein et al,[11] 2020	Case series	Level 4	24	6 F/18 M	71	16	Unspecified

F, female; *M*, male; *FU*, follow-up.

A fixed inverse-variance statistical model meta-analysis was chosen given the small number of eligible studies. A random effects model in this analysis may generate an output that has a confidence interval and *P* values too narrow given the current breadth of research on this topic.

χ^2 and I^2 Test statistics were conducted to assess the heterogeneity of the data, and a *P* value <.05 was considered a significant result.

Galbraith and funnel plots were created to analyze potential outliers and publication bias. The former was used to observe heterogeneity across effect sizes and the studies' precision. The later assessed the treatment effects from individual studies against the size of the study.

Results

The search string yielded 1722 studies from PubMed, and after conducting the title/abstract screen, we were left with 824 studies. Our full-text screen found 12 studies meeting our inclusion criteria

Table II
Preoperative and postoperative range of motion.

Study	No. of patients	External rotation before operation	External rotation after operation	Flexion before operation	Flexion after operation	Internal rotation before operation	Internal rotation after operation	Abduction before operation	Abduction after operation
Gerber et al,[9] 2007	12	12	19	94	139	-	-	87	145
Boileau et al,[2] 2008	11	-18	18	70	148	6	2	-	-
Shi et al,[23] 2015	21	6	38	56	120	-	-	-	-
Boughebri et al,[4] 2013	15	-8.7	27.3	64.7	126	4.4	5.5	-	-
Puskas et al,[18] 2014	32	4	27	82	144	5.6	4.3	79	137
Flury et al,[7] 2018	13	-12	18	87	137	-	-	86	133
Ortmaier et al,[15] 2014	13	-16	21	55	138	-	-	45	129
Young et al,[27] 2020	16	-10	25	85	160	-	-	-	-
Spapens et al,[24] 2020	32	-	-	-	-	-	-	-	-
Boileau et al,[3] 2010	17	-21	13	74	149	6	2	-	-
Popescu et al,[17] 2019	10	0	21	68	163	4.2	3.6	64	150

Table III
Constant-Murley shoulder outcome scores.

Study	No. of patients	Absolute CMS		CMS pain		CMS activity		CMS mobility		CMS strength	
		Preop	Postop	Preop	Postop	Preop	Postop	Preop	Postop	Preop	Postop
Gerber et al,[9] 2007	12	34	70	-	-	-	-	-	-	-	-
Boileau et al,[2] 2008	11	28	63	5	13.4	6.5	15.3	15.2	28	0.8	6.7
Shi et al,[23] 2015	21	-	-	-	-	-	-	-	-	-	-
Boughebri et al,[4] 2013	15	23.7	61.1	-	-	-	-	-	-	-	-
Puskas et al,[18] 2014	32	45	89	-	-	-	-	-	-	-	-
Flury et al,[7] 2018	13	37	67	-	-	-	-	-	-	-	-
Ortmaier et al,[15] 2014	13	20.4	64.3	4.6	13.7	5.6	15.9	11.1	30.8	0.31	3.7
Young et al,[27] 2020	16	-	-	-	-	-	-	-	-	-	-
Spapens et al,[24] 2020	32	39.1	72.1	7.3	14.1	10.4	18.7	21.2	34.3	0.9	5.4
Boileau et al,[3] 2010	17	27	62	6	13	6	14	14	27	1	8
Popescu et al,[17] 2019	10	29.8	71.9	-	-	-	-	-	-	-	-

CMS, Coleman Methodology Score; *Preop*, preoperation; *Postop*, postoperation.

(Fig. 1). The studies included in our sample were published between 2007 and 2020. Of the 12 included studies, 7 were case series, 1 was a case control, 2 were retrospective chart reviews, 1 was a prospective cohort, and 1 was a randomized prospective trial. A total of 213 shoulders received RTSAs with a latissimus dorsi transfer. The average sample size in each study was 17.75 shoulders (range 10-32). The mean age of the study participants was 70.0 years (range 66-73 years) (Table I)

Study quality

The CMS score of our included studies ranged from 41 to 80 (mean [standard deviation], 62.45. [10.02]; median [interquartile range], 61 [59.00-67.50]). Only 1 (9.09%) study in our sample scored a poor CMS score, while 8 (72.73%) studies scored fair and 2 (18.18%) were interpreted as good. The categories receiving significantly fewer points were those evaluating the level of evidence, as a majority of the studies evaluated were retrospective in nature, and the mean follow-up period of the studies, as nearly all studies had either a follow-up period of less than 2 years or a period that was not clearly stated. All the studies received a lower score in the category assessing study size, with a majority assessing only 20-40 patients and the rest not clearly stating the number of patients. High-scoring items included the number of surgical procedures, the use of diagnostic studies, and explanation of the surgical procedure given.

Functional outcomes

Functional outcome scores were assessed in 10 of the studies in our sample with a total of 160 patients.[2–4,7,9,15,17,18,23,27] All 10 studies reported a mean preoperative and postoperative active elevation and external rotation range of motion. The mean follow-up period in our studies ranged from 16 to 65 months, with all having more than 12 months of follow-up. The mean preoperative elevation of the affected

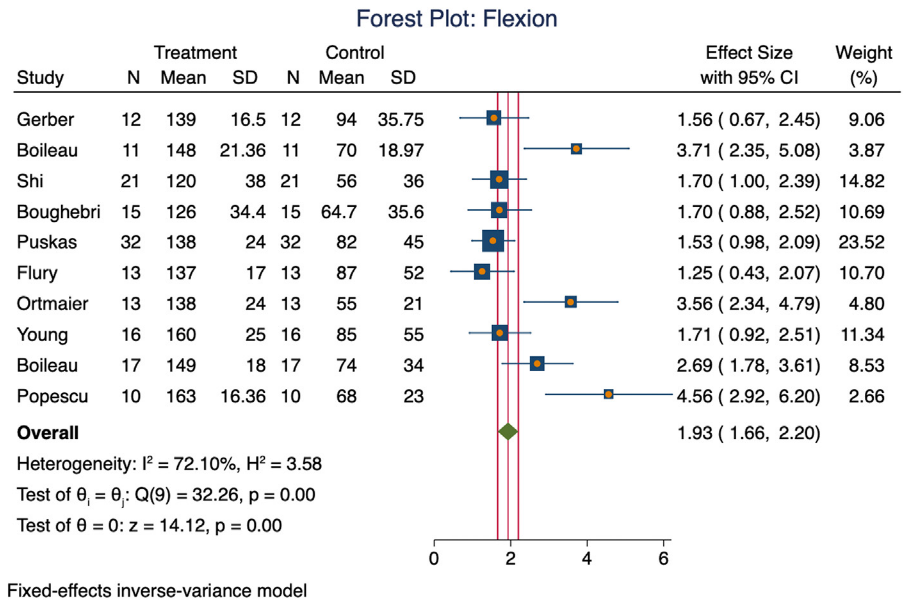

Figure 2 A forest plot demonstrating the postoperative flexion effect. *SD*, standard deviation; *CI*, confidence interval.

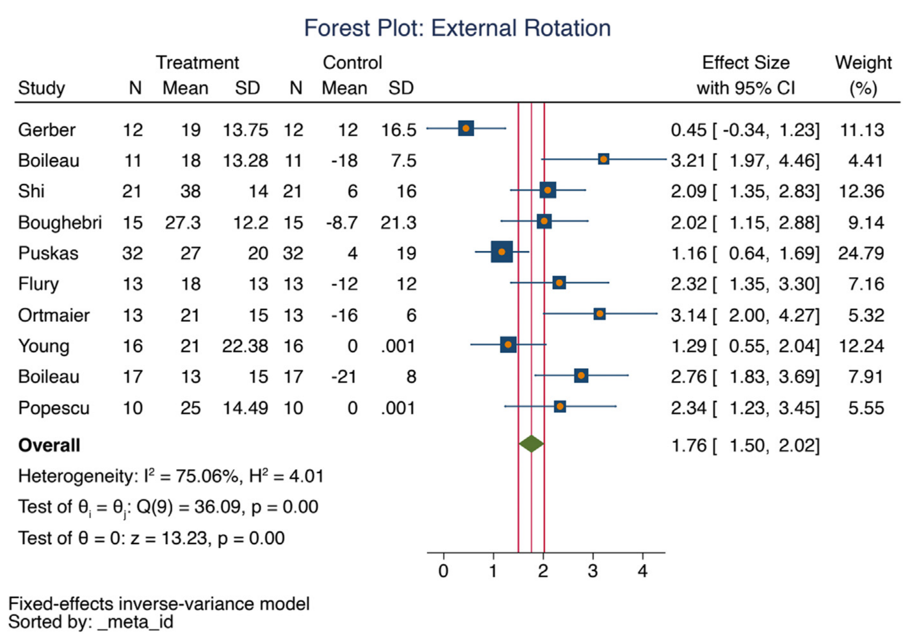

Figure 3 A forest plot demonstrating the postoperative external rotation effect. *SD*, standard deviation; *CI*, confidence interval.

shoulder was 73.57 degrees, and the mean postoperative elevation was 141.80 degrees.[2–4,7,9,15,17,18,23,27] For external rotation, the mean preoperative average was −6.71 degrees, and the postoperative average was 22.73 degrees (Table II).[2–4,7,9,15,17,18,23,27] For abduction, the preoperative average was 72.20 degrees, while the postoperative average was 138.8 degrees. Finally, the preoperative absolute Constant score average (Table III) was 31.56, while the postoperative value was 68.93.[7,9,15,17,18,25]

Statistical evaluation of postoperative elevation and external rotation

In the evaluation of our primary outcome, our statistical analysis demonstrates moderate heterogeneity between studies and an overall positive effect regarding both elevation and external rotation of the shoulder following RTSAs with latissimus dorsi transfer.

In evaluating study homogeneity, our analysis demonstrates elevation and external rotation I^2 of 72.10% and 75.06%, respectively. This correlates to a medium level of heterogeneity. Additionally, our statistical analysis demonstrates an elevation and external rotation H^2 of 3.58 and 4.01, respectively. Neither of these values cross the null of 5.0, which would indicate a high degree of heterogeneity. The test of homogeneity of study-specific effect sizes is also rejected for elevation and external rotation with a chi-squared test statistic of 32.26 ($Q = \chi^2\ (9) = 32.26$, $P > Q = 0.00$) and 36.09 ($Q = \chi 2\ (9) = 36.09$, $P > Q = 0.00$), respectively. This is demonstrated in our Forest and Galbraith plots (Figs. 2-5)

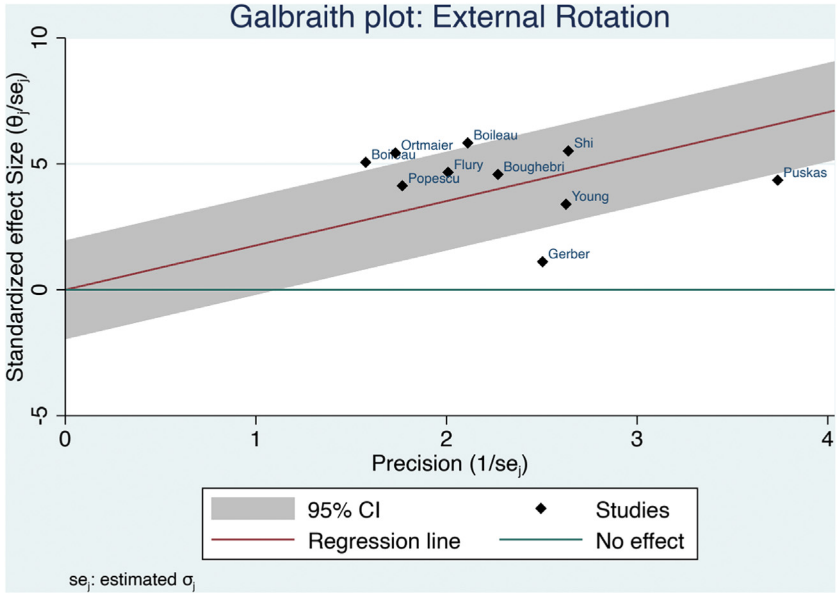

Figure 4 A Galbraith plot demonstrating the postoperative flexion effect. *CI*, confidence interval.

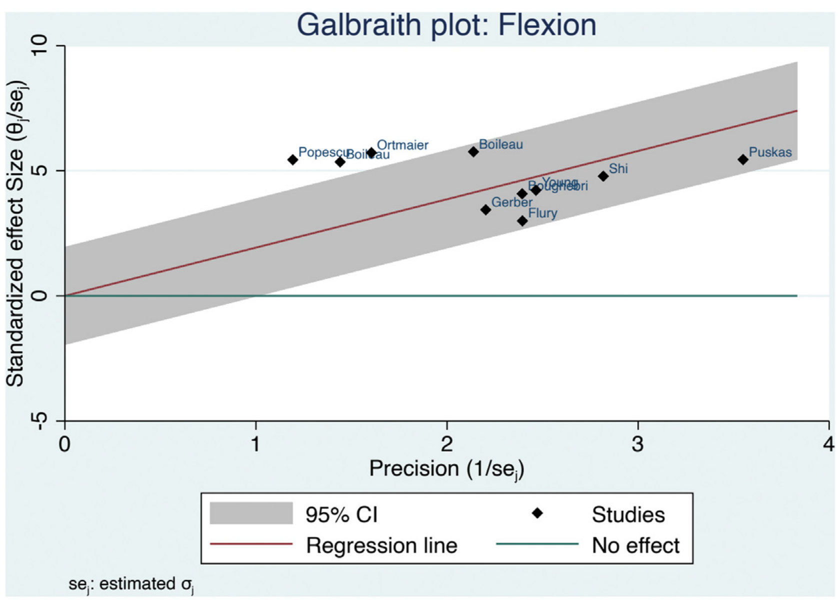

Figure 5 A Galbraith plot demonstrating the postoperative external rotation effect. *CI*, confidence interval.

For effect size, our statistical analysis demonstrates a Z statistic of 14.12 and 13.23 for elevation and external rotation, respectively, indicating a positive effect from latissimus dorsi transfer for patients with CLEER. Our overall weighted average effect for elevation and external rotation was 1.93 and 1.76, respectively, (Figs. 2-7).

Complication rates

The complications discussed below can be found in Table I.

Neurologic injury

Among our sample, reported neuropraxias occurred in 9 of the 213 shoulders (4.23%). Of the 9 shoulders with neuropraxias, the published study reported specific nerve injuries for 6 of the shoulders. There were 4 (66.7%) radial nerve injuries and 2 (33.3%) axillary nerve injuries (Table IV).

Infection rates

Among our sample, deep surgical site infections were reported in 8 of the 213 shoulders (3.76%). Of the 8 shoulders, 6 (75.0%) underwent a revision. Only 3 of the 8 infections had the specific bacteria causing the infection reported, which was *Staphylococcus aureus* (2) and *Propionibacterium* (1).

Postoperative fracture rates

Fractures were reported in 9 of the 213 shoulders (4.23%), with 7 of the fractures resulting in a revision surgery (77.77%). Of the

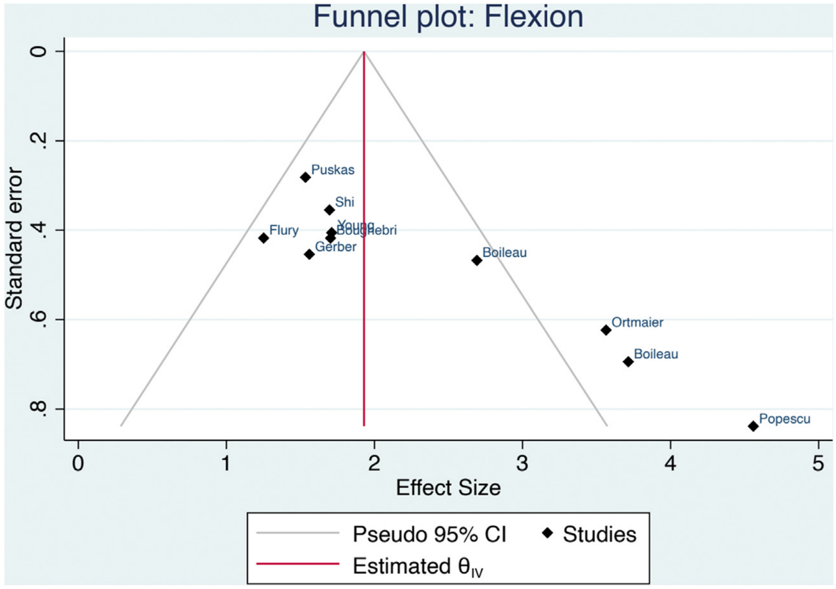

Figure 6 A funnel plot demonstrating the postoperative flexion effect. *CI*, confidence interval.

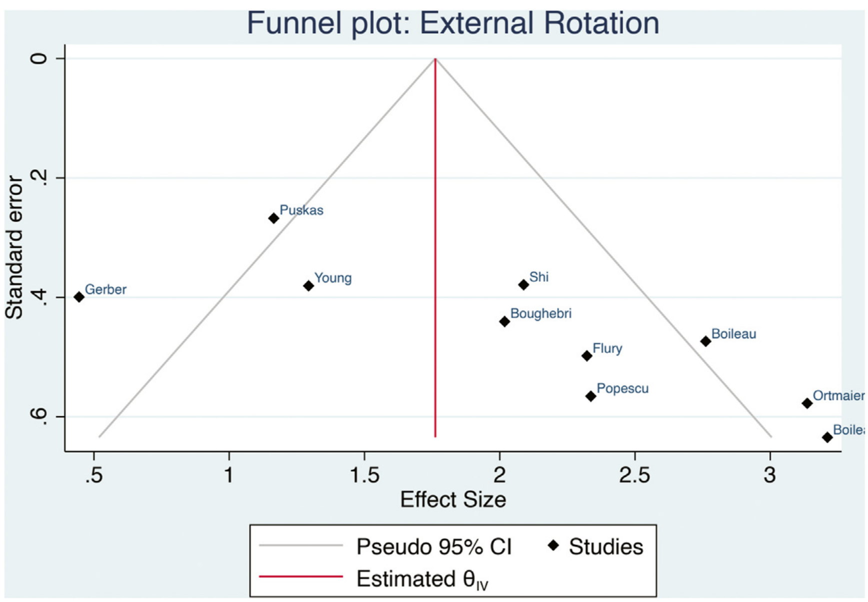

Figure 7 A funnel plot demonstrating the postoperative external rotation effect. *CI*, confidence interval.

fractures, 4 were humeral fractures, 1 was an acromion fracture, 1 was a scapula fracture, and 3 were periprosthetic fractures.

Hardware loosening, instability, and dislocation rates

Among our sample, 8 shoulders (3.76%) experienced hardware loosening, instability, and dislocations. Of these, the glenoid component was loose in 1 shoulder (12.5%), which required a revision. Dislocation occurred in 7 shoulders (87.5%), of which 5 required a revision.

Revision rates

Of our sample, 25 patients (11.74%) required a revision on the RTSA implant due to complications. Of the 25 shoulders that required a revision, 19 were given an indication. Of the indications, postoperative fractures (28.0%, 7/25), infections (24.0%, 6/25), and dislocations (20.0%, 5/25) were of the highest incidence.

Discussion

rTSA has been an effective way for treating patients with rotator cuff arthropathy and other shoulder pathologies. However, for patients with CLEER, resolution of external rotation deficits postoperatively has not been satisfactory or predictable.[22] Because of this, latissimus dorsi transfer during RTSAs is performed to theoretically improve postoperative external rotation in patients with CLEER. The purpose of our study was to evaluate the effects of latissimus dorsi transfer with RTSAs for patients with CLEER regarding elevation and external rotation. Furthermore, we

Table IV
Complication rates among included studies.

Study	Sample size	Mean age	Neuropraxia	Deep infection	Superficial infection	Hardware loosening/ instability	Reoperation	Acromial fracture	Humeral fracture	Dislocation
Gerber et al,[9] 2007	12	73	0	1	0	0	1	0	0	0
Boileau et al,[2] 2008	11	70	2	1	0	0	2	0	0	0
Shi et al,[23] 2015	21	66	1	0	0	0	7	1	3	1
Boughebri et al,[4] 2013	15	67.5	1	0	0	0	1	0	0	1
Puskas et al,[18] 2014	32	70	3	2	0	1	3	0	1	2
Flury et al,[7] 2018	13	73.3	1	0	0	0	0	0	1	0
Ortmaier et al,[15] 2014	13	71.1	0	2	0	0	3	0	0	1
Young et al,[27] 2020	16	67.5	0	0	0	0	1	0	0	1
Spapens et al,[24] 2020	32	-	0	0	0	0	2	0	1	1
Boileau et al,[3] 2010	17	71	1	1	0	0	1	0	0	0
Popescu et al,[17] 2019	10	73	0	0	0	0	0	0	0	0
Klein et al,[11] 2020	24	71	0	1	0	0	4	0	2	0

sought to evaluate the complications associated with this procedure.

Based on the available data in published literature, performing a latissimus dorsi muscle transfer in patients undergoing RTSAs with concomitant CLEER proves to be an effective adjuvant. Demonstrated by the data of 10 articles and 160 patients, the mean preoperative elevation of the affected shoulder was 73.57 degrees, and the mean postoperative elevation was 141.80 degrees.[2–4,7,9,15,17,18,23,27] For external rotation, the mean preoperative average was −6.71 degrees, and the mean postoperative average was 22.73 degrees.[2–4,7,9,15,17,18,23,25,27] Furthermore, absolute Constant scores improved dramatically from 31.56 to 68.93 (Table III). A robust statistical analysis of these data corroborated this positive effect, as there was a statistically significant improvement in both elevation and external rotation values following the surgery.

However, adding a latissimus dorsi transfer for RTSAs does appear to increase the incidence of revisions and complications. In our sample, there was an overall revision rate of 11.74%, most commonly due to postoperative fractures. In recently published literature, the overall revision rate for 4158 RTSAs without latissimus dorsi transfer was 2.5%.[16] The revision rate for our sample was even higher than the revision rate of 10.7% for converting hemiarthroplasty to RTSAs.[19] Furthermore, the incidence of postoperative fracture in the included studies was 4.23%, which is higher than the 2.5% reported in the literature for traditional RTSAs.[16] It is our postulation that the increased complications stem from the excess soft-tissue stripping/transfer of the latissimus, which likely results in more violation of tissues and possibly periosteum about the shoulder. While this comparison should be taken with caution due to variances in study design and patient population, the point remains that there is some degree of increased complications following RTSAs with tendon transfer, and this should be discussed with patients prior to the surgery.

The positive effect seen in our included studies demonstrates that latissimus dorsi transfer with RTSAs can effectively restore elevation and external rotation range of motion in patients with CLEER. However, other authors have postulated that RTSA designs with a more lateralized center of rotation could potentially restore external rotation without the need for a latissimus dorsi transfer.[1] Their data demonstrate that external rotation can be improved significantly in patients with CLEER without latissimus dorsi transfer (from −21° preoperatively to 28° postoperatively; $P < .001$). Furthermore, there is a concern that latissimus dorsi transfer can be associated with cortical humeral bone defects, which would be avoided by using lateralized center-of-rotation implants rather than latissimus dorsi transfer.[11] Patient and implant selection for patients with CLEER must be stringent as our data show latissimus dorsi transfer in RTSAs is very effective but is not without its potential complications.

Our study is not without limitations. First, the robustness of the studies in this evaluation varied greatly as seen in our figures above. There is notable heterogeneity among the studies, and therefore, our data must be interpreted with this in mind. Although we had a large number of shoulders in our sample, a majority of our studies were case series and retrospective cohort studies. This introduced heterogeneity into our study. Furthermore, the majority of the studies included in our sample were of “fair” quality on the CMS scale. As a result, there is a need for studies with a higher level of evidence for evaluating outcomes of latissimus dorsi transfers with RTSAs or for further comparing RTSAs with latissimus dorsi transfer against newer lateralized implants. Although we created our search to be as inclusive as possible, it is possible that studies relevant to this subject were not returned by our search.

Conclusion

CLEER can be a severely debilitating condition for those with a glenohumeral pathology. Latissimus dorsi transfer for this condition has been proven to be an effective modality. Our data corroborate this; however, latissimus dorsi transfer seems to be associated with sizable complication and revision rates. Patient and implant selection in those with CLEER should be carefully evaluated when making decisions in patient care.

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