J Shoulder Elbow Surg (2022) 31, e120–e129

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

Treatment of rotator cuff tears: a systematic review and meta-analysis

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Background: There is ongoing controversy regarding optimal treatment for full-thickness rotator cuff tears. Given that the evidence surrounding the use of various treatment options has expanded, an overall assessment is required.
Objectives: The following were compared to determine which resulted in improved patient-reported function, pain, and reoperation rates for each: (1) double-row (DR) fixation and single-row (SR) fixation in arthroscopic cuff repair; (2) latissimus dorsi transfer (LDT) with lower trapezius transfer (LTT), partial rotator cuff repair, and superior capsular reconstruction (SCR); and (3) early and late surgical intervention.
Methods: Medline, Embase, and Cochrane were searched through to April 20, 2021. Additional studies were identified from reviews. The following were included: (1) All English-language randomized controlled trials (RCTs) in patients ≥18 years of age comparing SR and DR fixation, (2) observational studies comparing LDT with LTT, partial repair, and SCR, and (3) observational studies comparing early vs. late treatment of full-thickness rotator cuff tears.
Results: A total of 15 RCTs (n = 1096 randomized patients) were included in the meta-analysis of SR vs. DR fixation. No significant standardized mean differences in function (0.08, 95% confidence interval [CI] –0.09, 0.24) or pain (–0.01, 95% CI –0.52, 0.49) were observed. There was a difference in retear rates in favor of DR compared with SR fixation (RR 1.56, 95% CI 1.06, 2.29). Four studies were included in the systematic review of LDT compared with a surgical control. LDT and partial repair did not reveal any differences in function (–1.12, 95% CI –4.02, 1.78) on comparison. A single study compared arthroscopically assisted LDT to LTT and observed a nonstatistical difference in the Constant score of 14.7 (95% CI –4.06, 33.46). A single RCT compared LDT with SCR and revealed a trend toward superiority for the Constant score with SCR with a mean difference of –9.6 (95% CI –19.82, 0.62). Comparison of early vs. late treatment revealed a paucity of comparative studies with varying definitions of "early" and "late" treatment, which made meaningful interpretation of the results difficult.
Conclusion: DR fixation leads to similar improvement in function and pain compared with SR fixation and results in a higher healing rate. LDT transfer yields results similar to those from partial repair, LTT, and SCR in functional outcomes. Further study is required to determine the optimal timing of treatment and to increase confidence in these findings. Future trials of high methodologic quality comparing LDT with LTT and SCR are required.

Institutional review board approval was not required for this systematic review.

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1058-2746/$ - see front matter
https://doi.org/10.1016/j.jse.2021.11.002

Level of evidence: Level III; Systematic Review/Meta-Analysis

Keywords: Single row; double row; rotator cuff tear; latissimus dorsi transfer; lower trapezius transfer; partial repair; superior capsular reconstruction; systematic review

Surgical repair of full-thickness rotator cuff tears is the preferred treatment with failure of conservative therapy. Yet, failure of the rotator cuff repair is the most frequently observed complication, estimated to be between 20% and 68%.[29] Failure of the repair of the rotator cuff may occur secondary to poor tendon or bone quality, failure of suture or knots, inadequate fixation of tendon to bone, lack of tendon to bone healing, or inappropriate postoperative care.[20,22,62]

The most popular method of tendon repair using arthroscopic technique involves the use of suture anchors, either in a single-row or double-row configuration. In an effort to maximize contact area and improve healing rates, the double-row technique was described by Lo et al.[36] The first row is placed medially and sutures are threaded through the rotator cuff using mattress technique. The second lateral row is placed further laterally on the footprint.

The single-row repair involves placing anchors either in the lateral aspect of the tendon footprint or lateral to the footprint itself. Several basic science studies have compared the 2 techniques.[30,37,38,41,43,46,53,57] Although there is some conflicting evidence, most studies report higher load to failure and greater surface contact area with double-row fixation. Yet, comparative clinical studies have not consistently demonstrated superior outcomes with double-row repair,[33] and the relative healing rate of double-row fixation compared with single-row is still a matter of debate.

The optimal surgical treatment of large and massive rotator cuff tears is similarly not well established. Various surgical options exist including latissimus dorsi transfer (LDT),[1,12,18,19,44] lower trapezius transfer (LTT),[59] superior capsular reconstruction (SCR)[42] and partial rotator cuff repair. Although there are theoretical advantages to some treatments over others, heterogeneity between studies and limitations in study design has made interpretation of data challenging.[40]

A third area of controversy exists in the setting of traumatic rotator cuff tears. Although it is possible that earlier surgical intervention results in superior functional outcomes and higher healing rates compared with delayed surgical intervention, the optimal timing of surgical treatment of traumatic rotator cuff tears has not been clearly established.

With no consistent consensus in the literature, the specific management of rotator cuff tears remains highly variable, with various surgical options commonly used. Given the lack of consensus on optimal treatment, and conflicting low–quality of evidence reports, the aim of this systematic review and meta-analysis was to compare the functional outcomes, pain, and retear rates of single- vs. double-row fixation, LDT vs. LTT, SCR, and partial repair in massive tears and early vs. late surgical intervention in traumatic tears of the rotator cuff.

Methods

Inclusion and exclusion

We identified English-language randomized controlled trials (RCTs) in any setting comparing treatment with a control in patients aged ≥18 years with full-thickness rotator cuff tears, with a minimum of 6 months' follow-up. Three separate comparisons were considered. First, prospective randomized trials comparing single-row with double-row fixation were considered for inclusion. Second, studies comparing LDT to a surgical control group were considered in the setting of massive rotator cuff tears, including partial rotator cuff repair, LTT, and SCR. And third, studies that compared early and late surgical intervention in the surgical treatment of traumatic rotator cuff tears were included. The outcomes of interest were patient-reported function, patient-reported pain, and the incidence of retears (nonhealing).

This study adheres to the standards of the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) Statement[54] and was registered with Prospero registry of systematic reviews (PROSPERO 2021 CRD42021248053).

Study eligibility criteria

We established the review eligibility criteria based on the PICOS (population, intervention, comparators, and outcomes study design) framework comprising the following elements:

Population: studies enrolling adult patients aged 18-75 years with full-thickness tears of the rotator cuff receiving surgical interventions for their condition were sought.
Interventions/comparators: (1) single-row vs. double-row fixation; (2) LDT, LTT, SCR, and partial cuff repair the setting of massive rotator cuff tears; and (3) early vs. late surgical intervention in the setting of traumatic cuff tears.
Outcomes: Endpoints of interest included functional outcomes (eg, Constant score), postintervention pain (visual analog scale [VAS] for pain), and incidence of retear (nonhealing).

Information sources and search strategy

Using the OVID platform, we searched Ovid MEDLINE, including Epub Ahead of Print and In-Process & Other Non-Indexed Citations, Embase Classic + Embase, and the Cochrane Library. The latest search was conducted on April 20, 2021.

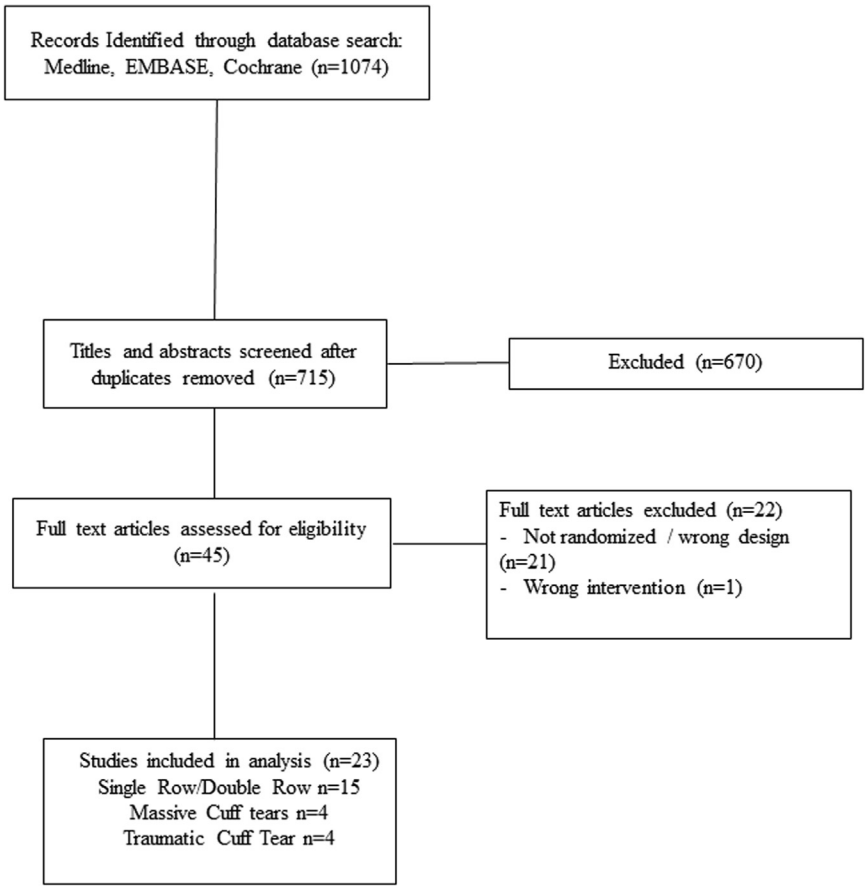

Figure 1 Flow diagram of search strategy.

Three different search strategies were used with a combination of controlled vocabulary (eg, ''double row fixation'') and keywords (eg, ''randomized controlled trial'') for single- vs. double-row fixation, treatment of massive tears (''latissimus dorsi''), and surgical timing in traumatic tears (''rotator cuff; traumatic'') respectively. Results were filtered using headings for systematic reviews, RCTs, and nonrandomized controlled trials as applicable for each database.

The bibliographies of published systematic reviews were inspected to confirm no relevant studies had been missed. No attempt was made to contact content experts to obtain information on unknown or ongoing studies.

Risk of bias assessment

We used the Cochrane Risk of Bias Tool for RCTs[27] to evaluate the risk of bias of each included RCT. The Grades of Recommendation, Assessment, Development and Evaluation (GRADE) approach was used to evaluate the quality of the included studies.[4,25]

Approaches to evidence syntheses

Criteria for quantitative synthesis

A pairwise meta-analysis for each intervention comparison was pursued to explore statistical heterogeneity (based on the I^2 statistic) if data permitted (<40%, low heterogeneity; and >75%, substantial heterogeneity). When observational studies were included (in comparisons of treatment for massive cuff tears and timing of surgical intervention in traumatic cuff tears), descriptive accounts of study findings were used if pooling of data was not possible.

Statistical analysis and assessment of heterogeneity

If different scales were used across studies (eg, differing functional outcome metrics), a model for estimating the effect size as a standardized mean difference (SMD) was considered. Estimates of effect sizes for binary endpoints was expressed as odds ratios. An SMD of 0.5 was considered a clinically significant improvement in function.[48] Fixed effects models were used in the presence of low or absent heterogeneity, and mixed effects models were used if heterogeneity was detected (I^2 of $>$ 40%).

Results

The search for studies comparing single-row with double-row fixation identified 1074 potential articles, and 715 after duplicates were removed. These were reviewed as full abstracts. Of these, 70 articles were reviewed as full texts, and 55 articles were excluded. Fifteen articles were included in the review that compared single- vs. double-row fixation in arthroscopic cuff repair. One RCT and 3 observational comparative studies that compared latissimus dorsi transfer with a surgical control group were included in the

Table I Study characteristics

Single- vs. double-row fixation	
Total number of trials	15
Age, yr, mean (range)	59 (55-65)
Duration of follow-up, mo, median (range)	24 (6-36)
Outcome measures	
Clinical outcome scores	
Constant	7
ASES	3
UCLA	4
Not reported	1
Pain	
VAS	2
Not reported	13
Trials reporting reoperation rates	11
Massive rotator cuff tears	
Total number of trials	4
Age, yr, mean (range)	63 (57-66)
Duration of follow-up, mo, median (range)	12 (12-24)
Outcome measures	
Clinical outcome scores	1
Constant	2
ASES	1
UCLA	
Pain	
VAS	3
Not reported	1
Trials reporting reoperation rates	1
Traumatic cuff tears	
Total number of trials	4
Age, yr, mean (range)	58 (53-60)
Duration of follow-up, mo, median (range)	9 (4-34)
Outcome measures	
Clinical outcome scores	
Constant	1
ASES	1
Oxford	1
WORC	1

Constant, Constant-Murley score; *ASES*, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form; *UCLA*, University of California, Los Angeles, shoulder score; *VAS*, visual analog scale; *Oxford*, Oxford Shoulder Score; *WORC*, Western Ontario Rotator Cuff index.

systematic review of on the treatment of massive rotator cuff tears. Observational studies that reported on the early vs. late surgical treatment (n = 4) were included in the systematic review of the surgical treatment of traumatic rotator cuff tears. The study flow is summarized in Figure 1. The sample sizes of individual studies ranged from 32 to 228 patients. Follow-up time was most commonly 2 years but ranged from 6 to 36 months. Study characteristics are summarized in Table I.

Single- vs. double-row fixation

Operative vs. nonoperative treatment was compared with data in 15 studies (1096 randomized patients) (Fig. 2).[3,5,8,9,14,15,17,23,28,31,33,39,47,60,66] The mean age was 59.2 years (range 55-65 years). Comparison of functional scores between the 2 treatment options revealed a standardized mean difference of 0.08 (95% confidence interval [CI] –0.09, 0.24). Moderate heterogeneity for function was detected ($I^2 = 42\%$). Postintervention pain as determined by the VAS was similar between groups (mean difference –0.01, 95% CI –0.52, 0.49) (Fig. 3). Heterogeneity for pain across studies was not detected ($I^2 = 0\%$). Comparison of the incidence of retear demonstrated a significant difference in favor of double-row (relative risk of retear 1.56 (95% CI 1.06, 2.29). This corresponds with a number needed to treat with double-row technique of 12 to have 1 fewer retear vs. single-row. The heterogeneity across studies for retear was low ($I^2 = 0\%$) (Fig. 4).

Massive rotator cuff tears: LDT vs. LTT, SCR, or partial repair

One randomized study and 3 observational studies[6,49,50,63] were included in the meta-analysis of massive cuff tears. Data comparing LDT to partial repair was pooled from 2 studies (n = 87).[6,50] Patients had a mean age of 64.7 years. The standardized mean difference for function between these 2 treatment options was nonsignificant at –1.12 (95% CI –4.02, 1.78) in favor of LDT (Fig. 5). There was a high level of heterogeneity between studies ($I^2 = 97\%$). Paribelli et al[50] reported a nonsignificant pain VAS difference of 0.2 (95% CI –0.27, 0.67) in favor of LDT compared with partial repair.

Woodmass et al[63] compared LDT and LTT. American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES) functional scores revealed a nonsignificant difference of 14.7 (95% CI –4.06, 33.46, $P = .14$) in favor of LTT. VAS pain scores were nonsignificantly different between the 2 groups, with a mean difference of –0.5 (95% CI –2.32, 1.32, $P = .61$) in favor of LTT.

In the only RCT comparing LDT to SCR, Ozturk et al[49] reported a trend toward superiority in ASES functional scores of –9.6 (95% CI –19.8, 0.6, $P = .08$) in favor of SCR. VAS pain scores had a nonsignificant mean difference of 1.40 (95% CI –4.09, 6.89) in favor of SCR.

Early vs. late repair of traumatic rotator cuff tears

Four studies compared the functional outcomes of early vs. late rotator cuff repair in the setting of traumatic rotator cuff tears.[11,26,51,67] The timing of early and late repair was different across the 4 studies; Duncan et al[11] compared the results of early repair (<6 months) vs. late (>6 months) repair. No significant differences were observed based on the Oxford Shoulder Scores. Hantes et al[26] compared the results of repair

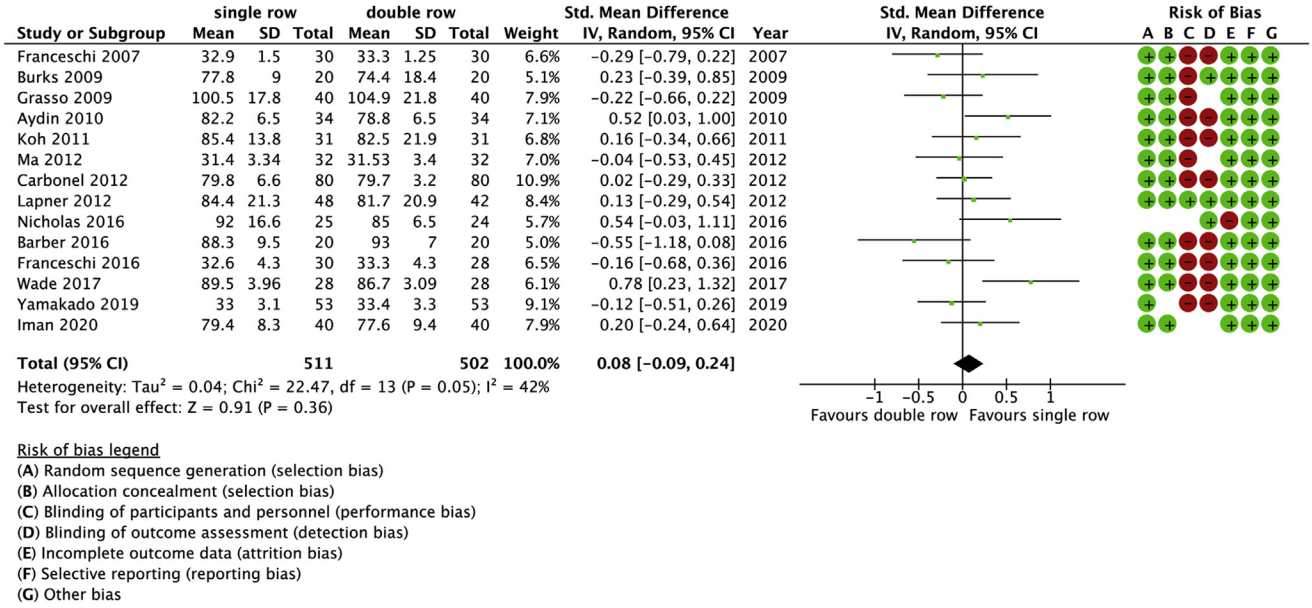

Figure 2 Forest plot of single row vs. double row for function.

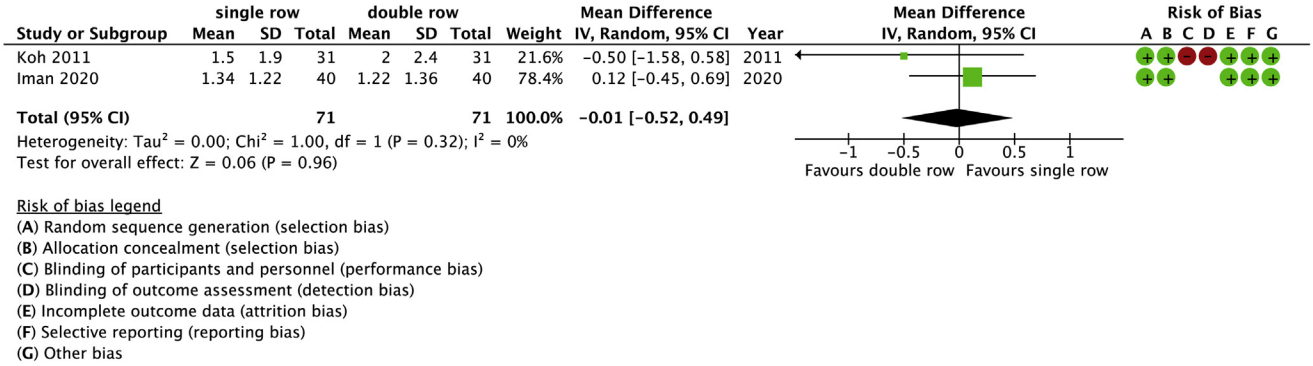

Figure 3 Forest plot for single row vs. double row for pain.

<3 weeks vs. >3 weeks. Superior Constant scores were observed in the early group (82 vs. 70, $P < .05$). Petersen et al[51] compared the results of 3 groups: 0-8 weeks, 9-16 weeks, and >16 weeks. Superior ASES scores (82 and 79 respectively) were seen in the early and middle groups compared to the late group (ASES score 65, $P < .05$). Zhaeentan et al[67] compared the results of early (<3 months) vs. late (>3 months) repair. A nonsignificant difference was found in the Western Ontario Rotator Cuff index between groups.

Risk of bias

Using the Cochrane Risk of Bias tool, 13 of the 15 studies (86%) included in the single-row vs. double-row meta-analysis were found to have a moderate risk of bias, and the remaining 2 had a low risk of bias (Figs. 2-4). There was complete agreement among reviewers (P.L. and K.M.). Please see Table II for the GRADE summary. The certainty of the GRADE assessments was "moderate" in most cases most commonly because of methodologic concerns related to lack of blinding.

Discussion

This systematic review and meta-analysis of 15 trials comparing single- vs. double-row fixation finds that functional results and pain scores at final follow-up were similar between groups. The relative risk of retear with double-row technique compared with single-row was 1.56 (95% CI 1.06, 2.29). Our systematic review found few comparative studies and only a single RCT comparing LDT to a surgical control. Pooled data from 2 studies comparing LDT to partial repair did not find any differences in pain or function. A single study compared arthroscopically assisted LDT to arthroscopically assisted LTT and found a clinically important (but not significantly different) difference in function between the 2 techniques. Two-year pain scores

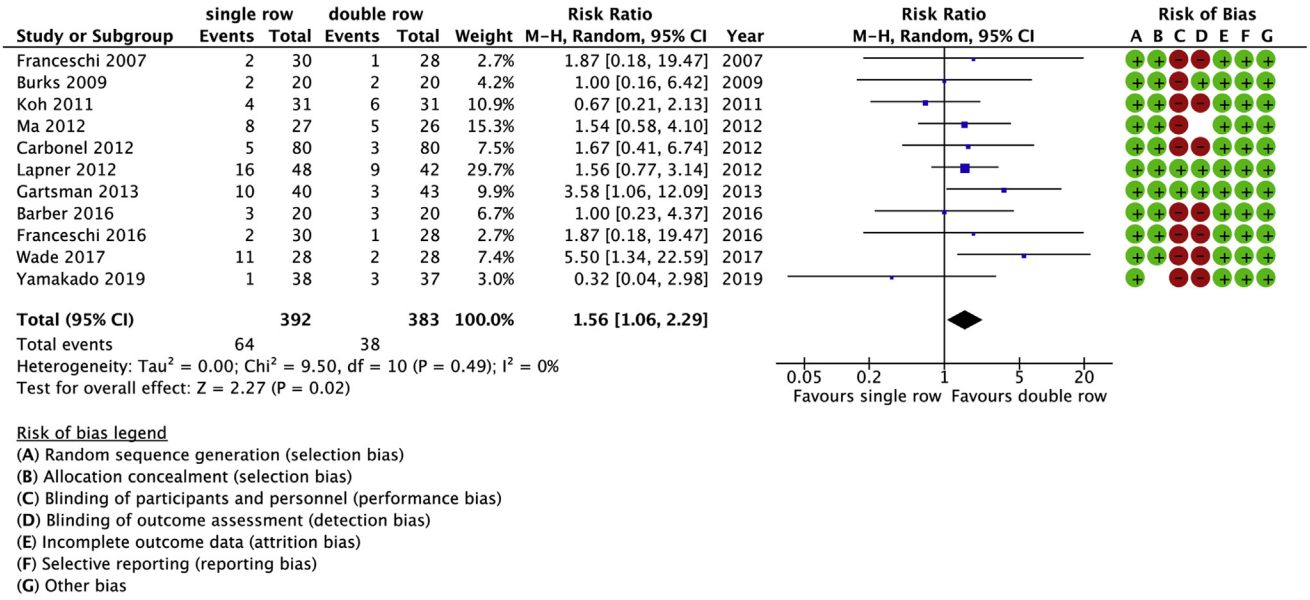

Figure 4 Forest plot for single row vs. double row for healing.

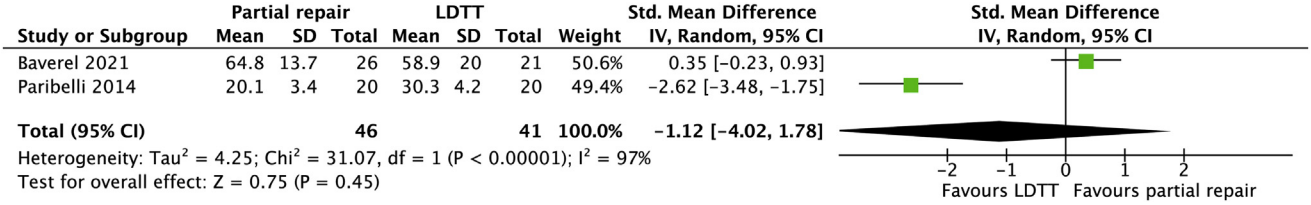

Figure 5 Forest plot for partial repair vs LDT for function.

were similar between groups. A single study comparing LDT to SCR demonstrated a trend toward superior functional scores with SCR. The systematic review of early vs. late surgical treatment of traumatic rotator cuff tears consisted of 4 observational studies. Differing definitions of early vs. late repair made data synthesis impossible. Although some studies found a difference in functional scores in favor of earlier repair, conflicting results across studies makes it difficult to reach a definitive conclusion regarding the optimal treatment approach.

The findings of the current study are consistent with a recent systematic review and network meta-analysis of RCTs, prospective, and retrospective studies that compared single- with double-row fixation as well as suture-bridge fixation in arthroscopic cuff repair by Xu et al.[65] The latter study found a significant difference in healing rates in single-row compared with double-row repair (OR 0.61, 95% CI 0.37, 0.99). No statistical differences in function were seen between groups.

We provide an updated analysis of the single-row vs. double-row literature, treatment of massive rotator cuff tears, and the timing of treatment of traumatic rotator cuff tears. Our findings of lower incidence of retears in double-row fixation compared with single-row fixation provides further confidence in double-row technique as a treatment option. The few comparative studies between LDT and partial repair, LTT, and SCR did not demonstrate any clear differences between treatments; however, trends toward superior functional scores in LTT compared with LDT and with SCR compared with LDT suggests that more high-quality comparative studies are needed to determine the optimal treatment approach between these 2 techniques. We were not able to draw any conclusions regarding the optimal timing of treatment of traumatic rotator cuff tears due to significant variation in the definitions of early and late timing of traumatic tears.

A strength of our review of single- vs. double-row fixation is that it focused exclusively on RCTs to limit the risk of bias, whereas many previously published systematic reviews included nonrandomized, retrospective, and noncontrolled studies, which substantially increases the risk of confounding.[2,7,10,13,16,21,24,32,34,35,45,52,55,56,58,61,64] Observational studies were included in our review of massive and traumatic cuff tears because of the lack of RCTs on these topics.

Although heterogeneity was identified in some comparisons, we had limited ability to carry out sensitivity analyses owing to the low number of studies available,

Table II Question: Single-row compared to double-row for full-thickness degenerative rotator cuff tears

Certainty assessment							No. of patients		Effect		Certainty
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Single row	Double row	Relative (95% CI)	Absolute (95% CI)	
Function											
14	Randomized trials	Serious[*,†,‡,§,‖]	Not serious	Not serious	Not serious	None	511	502	–	SMD 0.08 SD higher (0.09 lower to 0.24 higher)	⊕⊕⊕◯ Moderate
Pain (scale from 0 to 10)											
2	Randomized trials	Serious[¶]	Not serious	Not serious	Not serious	None	71	71	–	0.01 VAS lower (0.52 lower to 0.49 higher)	⊕⊕⊕◯ Moderate
Healing rates											
11	Randomized trials	Serious[#,**]	Serious[††]	Not serious	Not serious	None	320/392 (81.6%)	343/383 (89.6%)	RR 1.56 (1.06 to 2.29)	502 more per 1000 (from 54 more to 1000 more)	⊕⊕◯◯ Low

CI, confidence interval; *RR*, risk ratio; *SMD*, standardized mean difference; SD, standard deviation; VAS, visual analog scale.

[*] Unclear if treatment allocation random (Nicholas et al[51]).

[†] Unclear if treatment allocation concealed (Nicholas et al[51]).

[‡] No blinding of participants in most studies.

[§] No blinding of outcome assessors in 8 studies, unclear if assessors blinded in addition 2 studies.

[‖] Attrition bias high risk in 1 study (Nicholas et al[51]).

[¶] No blinding of patients or assessors, of unclear risk of blinding of patients or assessors.

[#] No blinding of assessors in 10 studies.

[**] No blinding of assessors in assessors in 7 studies, and unclear in an additional 2 studies.

[††] Moderate heterogeneity with I^2 of 51%, and χ^2 $P = .02$ with value of 20.57 with 10 degrees of freedom.

which was a study limitation. Further limitations included the fact that study quality was not uniformly high, and design limitations were identified in most trials. The relatively small number of patients in many of the trials limited conclusions that may be drawn by these individual studies.

There is a lack of data on the long-term durability of all surgical options, and this concern is particularly relevant with the treatment of massive rotator cuff tears. LDT, LTT, and SCR treatment approaches need to be further explored through rigorous comparative research. A further limitation of any analysis of aggregate data is our inability to determine whether certain patient subgroups with specific tear characteristics may preferentially benefit from specific surgical techniques.

Conclusion

This meta-analysis demonstrates that the highest-quality available evidence supports the use of double-row fixation for rotator cuff tear repair. LDT was found to be comparable to both partial repair, LTT, and SCR for the treatment of massive cuff tears. Further study is required to determine the optimal timing of traumatic rotator cuff tears. Moreover, high-quality trials should focus on LDT, LTT, and SCR to determine the optimal treatment option in massive cuff tears as well as on the optimal timing of surgical intervention in traumatic cuff tears.

Disclaimer

Peter Lapner is associated with a fellowship that receives educational and research support from ConMed Linvatec.

Peter MacDonald is a paid consultant for ConMed Linvatec and is associated with a Foundation that receives support from ConMed Linvatec, Biomet, Arthrex, and Ossur.

The other 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.

Acknowledgments

The authors would like to thank Katie McIlquham, clinical research coordinator, for assistance with PROSPERO registration and administrative details. The authors would also like to acknowledge special contributor Risa Shorr for literature search support.

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