Systematic Review

Is Double-Row Rotator Cuff Repair Clinically Superior to Single-Row Rotator Cuff Repair: A Systematic Review of Overlapping Meta-analyses

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Purpose: Multiple meta-analyses of randomized clinical trials, the highest available level of evidence, have been conducted to determine whether double-row (DR) or single-row (SR) rotator cuff repair (RCR) provides superior clinical outcomes and structural healing; however, results are discordant. The purpose of this study was to conduct a systematic review of meta-analyses comparing SR and DR RCR to elucidate the cause of discordance and to determine which meta-analysis provides the current best available evidence. **Methods:** In this study we evaluated available scientific support for SR versus DR RCR by systematically reviewing the literature for published meta-analyses. Data were extracted from these meta-analyses for patient outcomes and structural healing. Meta-analysis quality was assessed with the Oxman-Guyatt and Quality of Reporting of Meta-analyses (QUOROM) systems. The Jadad algorithm was then applied to determine which meta-analyses provided the highest level of evidence. **Results:** Eight meta-analyses met the eligibility criteria: 4 including Level I evidence and 4 including both Level I and Level II evidence. Six meta-analyses found no differences between SR and DR RCR for patient outcomes, whereas 2 favored DR RCR for tears greater than 3 cm. Two meta-analyses found no structural healing differences between SR and DR RCR, whereas 3 found DR repair to be superior for tears greater than 3 cm and 2 found DR repair to be superior for all tears. Four meta-analyses had low Oxman-Guyatt scores (<3) indicative of major flaws. After application of the Jadad algorithm, 3 concordant high-quality meta-analyses were selected, all of which found significantly better structural healing with DR compared with SR RCR. **Conclusions:** According to this systematic review of overlapping meta-analyses comparing SR and DR RCR, the current highest level of evidence suggests that DR RCR provides superior structural healing to SR RCR. **Level of Evidence:** Level II, systematic review of Level I and II studies.

Rotator cuff tears occur in over 30% of individuals aged older than 60 years, with 150,000 to 200,000 rotator cuff repairs (RCRs) performed annually in the United States.[1,2] Although numerous case series have shown excellent clinical outcomes,[3-7] failure rates after RCR vary widely from 5% to 94%.[3-9] Although RCR was historically[10] performed by an open approach,[8] surgeons have transitioned to the arthroscopic approach to reduce surgical morbidity. Early comparative studies showed high failure rates with arthroscopic repairs,[8] which were thought in part to be due to the inability of single-row (SR) repairs to restore the footprint.[6,11-14]

Double-row (DR) RCRs came about in response to these concerns. DR repair uses both medial- and lateral-row anchors to facilitate improved coverage of the rotator cuff footprint with the supraspinatus,[15] and early reports showed retear rates of 11% to 22%.[3,6,7] More recently, several authors have recommended augmenting DR repairs with suture connections between the medial and lateral rows using a transosseous-equivalent

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(TOE) technique to compress the tendon to the footprint.[13,16-19] Although some biomechanical analyses have shown DR and TOE repairs to have increased contact area, decreased gap formation, and increased load to failure,[12,16,20] others have been less conclusive.[13,17,21,22] Randomized clinical trials (RCTs) and controlled clinical trials (Level I to Level III evidence) are conflicted as to whether DR fixation affects structural healing or clinical outcomes.[8,9,19,21,23-30] To attempt to resolve this conflict, numerous authors have systematically reviewed the existing RCTs and controlled clinical trials with or without meta-analysis.[30-37] Although some of these studies have concluded that DR RCR provides superior structural healing to SR RCR,[31,33,37-39] others have concluded that no difference exists and SR is thus superior because it is less expensive and less technically demanding intraoperatively.[32,34,35] Similarly, whereas some of these systematic reviews have concluded that DR RCR provides superior clinical outcomes to RCR,[37] others have concluded that no difference exists[30-36] except in the setting of large to massive tears (>3 cm).[31,37] Meta-analysis of Level I RCTs theoretically provides the highest available level of evidence for clinical decision making,[40] but how shall we proceed when the highest available evidence conflicts?

The purpose of this study was (1) to conduct a systematic review of meta-analyses comparing SR and DR RCR, (2) to propose a guide through the currently discordant best available evidence to provide treatment recommendations, and (3) to highlight gaps in the literature that require future research.

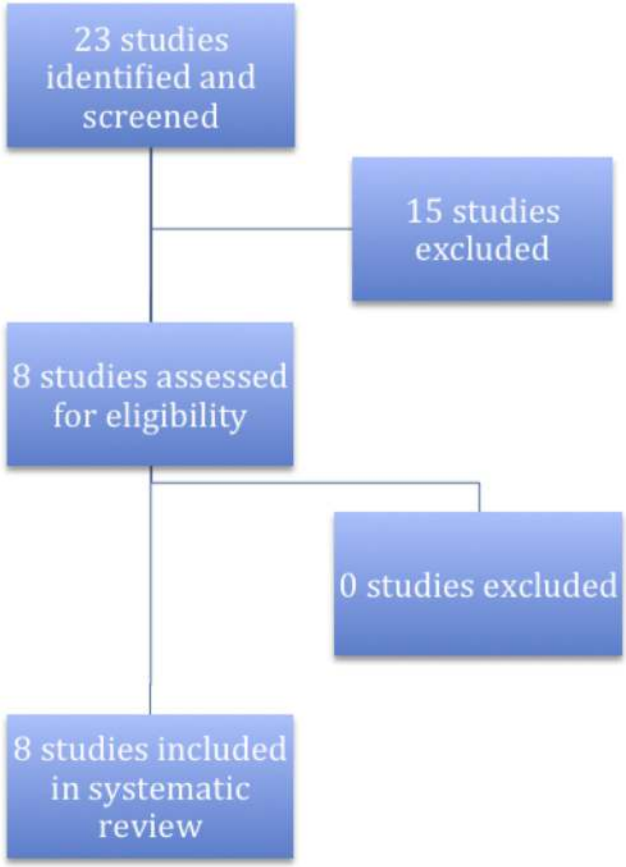

Fig 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) diagram showing the results of application of the study algorithm to the number of studies included, with the number of studies removed after application of each exclusion criterion.

Methods

A systematic review of the literature was performed using the PubMed database, Cochrane Database of Systematic Reviews, Scopus database, and Embase database. The following search terms were used: single-row, double-row, rotator cuff, meta-analysis. The search was performed on January 20, 2014, and was limited to articles written in English. Broad search query terms were used to include all possibly applicable studies. All reviewed articles were then manually cross referenced to ensure that all potential studies were included.

The abstracts that resulted from these searches were reviewed by 2 of the authors. The inclusion criteria were meta-analyses that compared arthroscopic SR and DR RCR techniques and English-language literature. Cadaveric studies were excluded. The exclusion criteria included narrative reviews or those without an organized and reported search algorithm, reviews of open procedures, and studies without clinical outcomes data. We also excluded systematic reviews that did not pool data or perform a meta-analysis. We then obtained full articles for those studies that met both the inclusion and exclusion criteria. The references for each of these citations were then manually screened to ensure that no studies were missed. The table of contents for the past 2 years of the *Journal of Bone and Joint Surgery*, the *American Journal of Sports Medicine*, *Clinical Orthopaedics and Related Research*, *Arthroscopy*, and the *Journal of Shoulder and Elbow Surgery* were manually searched as well for any additional studies. A PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) diagram shows our study selection algorithm (Fig 1).

From those studies that met the inclusion criteria, the following data were extracted: author; journal of publication; year of publication; conflicts of interest; levels of evidence included; number of studies included; dates of studies included; inclusion criteria; exclusion criteria; whether heterogeneity analytics were performed; sample size; patient demographic data; length of follow-up; tear size; blinding protocols; strength in all tested planes; range of motion; patient satisfaction; and time to return to work, as well as rate of return to work. The following standardized outcome scores were collected: Constant scores, American Shoulder and Elbow Surgeons (ASES) scores; University of California, Los

Table 1. Number of Systematic Reviews or Meta-Analyses Actually Cited Compared With Maximum Number That Could Possibly Have Been Cited

Author	Date of Publication	Date of Last Literature Search	No. of Systematic Reviews or Meta-Analyses Possible to Cite	No. of Systematic Reviews or Meta-Analyses Cited
Millett et al.[45]	January 8, 2014	September 2013	14	6
Xu et al.[44]	October 31, 2013	NA	14	0
Chen et al.[31]	August 2013	September 30, 2012	12	4
Zhang et al.[37]	July 2013	November 1, 2012	12	0
Sheibani-Rad et al.[30]	February 2013	August 2012	12	4
DeHaan et al.[32]	November 2011	April 2011	7	0
Prasathaporn et al.[39]	July 2011	September 2009	0	0
Perser et al.[34]	May 2011	April 2010	3	2

NA, not available.

Angeles (UCLA) scores; Western Ontario Rotator Cuff index scores; Disabilities of the Arm, Shoulder and Hand scores; and Single Assessment Numeric Evaluation (SANE) scores. Where available, radiographic outcomes including magnetic resonance imaging, magnetic resonance arthrogram, computed tomography arthrogram, and ultrasound were recorded to determine rates of complete and/or partial retears. Reported complication rates were also recorded. From each systematic review, we also recorded the following characteristics of the review itself: the rationale for repeating the systematic review, the number of "possible" previous systematic reviews cited as compared with the number "actually" cited, the databases used for the review, and the conclusions of the review regarding whether DR provided superior structural integrity and/or clinical outcomes.

Meta-analysis quality was scored using the Quality of Reporting of Meta-analyses (QUOROM) system.[41] This system provides a method for evaluating meta-analyses based on the quality of their reporting and methodology in 18 categories. Each meta-analysis was awarded a point in each category if it met over half of the criteria given in that category, for a total of 18 points possible. Meta-analysis quality was also graded using the Oxman-Guyatt quality appraisal tool.[42] The modified Coleman score was extracted from individual studies when available. In addition, when known biases within

Table 2. Authors' Rationale for Repeating Systematic Review

Author	Cited Meta-Analyses	Rationale for Repeating Meta-Analysis as Abstracted From Article
Millett et al.[45]	DeHaan,[32] Duquin,[38] Nho, Prasathaporn,[39] Sheibani-Rad,[30] Wall[36]	"Several systematic reviews and meta-analyses have compared the two techniques. However, the inclusion of Level II and III studies inhibits the interpretation of these studies."
Xu et al.[44]	Prasathaporn,[39] Wall[36]	NA
Chen et al.[31]	DeHaan,[32] Perser,[34] Prasathaporn,[39] Saridakis[55]	"The previous reviews were performed mainly with a focus on studies providing Level I and Level II evidence. We included 6 Level I randomized controlled trials in the first meta-analysis, and each of these studies ensured homogeneity between the 2 comparison groups, thus dramatically limiting the potential selection bias. In addition, we conducted a sensitivity analysis and a subgroup analysis in which Level I, Level II, and Level III studies were included to check the stability and reliability of our first meta-analysis."
Zhang et al.[37]	NA	NA
Sheibani-Rad et al.[30]	DeHaan,[32] Nho,[33] Saridakis,[55] Wall[36]	"There have been several systematic reviews comparing the techniques. The weakness of these studies is the inclusion of several Levels of evidence, thereby compromising the ability to make significant conclusions. The purpose of this meta-analysis was to critically assess whether there are differences in clinical outcomes between single-row and double-row rotator cuff repair in prospective randomized Level I studies."
DeHaan et al.[32]	NA	NA
Prasathaporn et al.[39]	NA	NA
Perser et al.[34]	Nho,[33] Wall[36]	"There have been 2 recent systematic reviews published comparing clinical outcomes of DR versus SR rotator cuff repair. This study differs in that the results from each Level I and II study were combined and analyzed to detect differences in clinical outcomes between SR and DR rotator cuff repairs with larger numbers. In addition, rather than highlight biases, the methodology was analyzed using Coleman scores."

NA, not available.

Table 3. Outcomes Reported by Each Included Study

	Millett et al.[45]	Xu et al.[44]	Chen et al.[31]	Zhang et al.[37]	Sheibani-Rad et al.[30]	DeHaan et al.[32]	Prasathaporn et al.[39]	Perser et al.[34]
Clinical indices								
Constant	+	+	+	+	+	+	+	+
ASES	+	+	+	+	+	+	+	+
UCLA	+	+	+	+	+	+	+	+
WORC	−	−	−	−	−	−	+	+
DASH	−	−	−	−	−	−	+	+
SANE	−	−	−	−	−	−	−	+
Objective function								
Strength	+	+	−	−	−	−	+	+
Range of motion	+	+	−	−	−	−	+	+
Subjective measures								
Pain	−	−	−	−	−	−	−	+
Return to activity	−	−	−	−	−	−	+	+
Patient satisfaction	−	−	−	−	−	−	+	+
Structural integrity								
Complete retears	+	−	+	+	−	−	+	+
Partial retears	+	−	−	+	−	−	−	+
Overall retears	+	+	−	−	−	+	−	−
Intact tendon healing	−	−	+	+	−	−	+	+
Operative factors								
Operative time	−	−	−	−	−	−	+	−
Intraoperative complications	+	−	−	−	−	−	+	−
Postoperative complications	+	−	−	+	−	+	+	−

DASH, Disabilities of the Arm, Shoulder and Hand; SANE, Single Assessment Numeric Evaluation; WORC, Western Ontario Rotator Cuff.

the literature reviewed were reported by individual trials, these were recorded.

The Jadad decision algorithm[43] was used to guide interpretation of discordant reviews. Sources of discordance among meta-analyses as described by Jadad et al.[43] include differences in the clinical question, inclusion/exclusion criteria, data extraction, quality assessment, data pooling, and statistical analysis. Scoring was performed based on assessment of randomization, randomization methodology, double blinding, withdrawals/dropouts, and allocation concealment. It was independently applied by the 3 lead authors, and their results were compared to most robustly determine which of the included systematic reviews provided the best evidence possible for recommendations. All statistical analyses were performed with Excel X (Microsoft, Redmond, WA).

Results

The initial search found 23 abstracts, and after application of our study selection algorithm, 8 studies fulfilled our inclusion and exclusion criteria and were included (Fig 1).[30-32,34,37,39,44,45] These studies were published between 2011 and 2014, with all 8 performing a meta-analysis.[30-32,34,37,39,44,45] Only 1 study reported a conflict of interest.[45] Three of the studies included Level I evidence only[30,37,45]; 4 included evidence of Levels I and II[32,34,39,44]; and 1 study performed 2 analyses, 1 with only Level I evidence and 1 with evidence Levels I to III.[31] The included studies included from 236 patients[34] to 651 patients,[44] with mean follow-up periods of 12 months[30,34,39] to 44 months.[30]

Authors' Assessment of Prior Systematic Review Literature

Authors generally cited few of the available previous meta-analyses or systematic reviews (Table 1), with many authors citing no prior systematic reviews or meta-analyses[32,37] and only 1 study citing more than 4 of the possible meta-analyses or systematic reviews.[45] No study cited all of the available systematic reviews. The rationale for repeating the systematic review was provided in 4 of the 8 studies, with the remaining 4 studies providing no rationale for repeating the review (Table 2). Three studies cited inclusion of multiple levels of evidence in prior systematic reviews or meta-analyses as the reason for repeating the review,[30,31,45] and 1 study cited the lack of inclusion of Level II evidence in prior reviews.[34]

Outcome Measures

The included studies were heterogeneous with respect to both the standardized and non-standardized patient outcome measures they reported (Table 3). Although each meta-analysis theoretically reported on a similar population of patients, high variance was seen in standard mean differences in Constant scores, from −3.7[45] to 2.24[34]; in ASES scores, from −2.1[30] to 3.27[39]; and in UCLA scores, from 0.21[31] to 1.1.[45] In addition, the included studies were heterogeneous with respect to their method of analysis of postoperative

Table 4. Search Methodology Used by Each Included Study

Author	PubMed	Medline	Embase	Cochrane Library	CINAHL	Other	No. of Primary Studies	Primary Studies Included Only RCTs
Millett et al.[45]	+	+	−	−	−	−	7	+
Xu et al.[44]	−	+	+	−	−	+	9	+
Chen et al.[31]	+	−	+	+	−	−	12	+
Zhang et al.[37]	+	−	+	+	−	−	8	+
Sheibani-Rad et al.[30]	+	+	−	−	−	+	5	+
DeHaan et al.[32]	+	+	−	−	−	−	7	−
Prasathaporn et al.[39]	−	+	−	+	+	+	5	−
Perser et al.[34]	+	+	−	+	−	+	5	−

CINAHL, Cumulative Index to Nursing and Allied Health Literature; Embase, Excerpta Medica Database; Medline, Medical Literature Analysis and Retrieval System Online; RCT, randomized controlled trial.

rotator cuff structural healing, with some studies reporting rates of complete retears, some reporting rates of partial retears, some reporting rates of overall retears, and some reporting rates of tendon healing (Table 3).

Search Methodology

Although all of the included studies searched either PubMed or Medline, there was heterogeneity as to whether studies also included searches of Embase, the Cochrane Database of Systematic Reviews, the Cumulative Index to Nursing and Allied Health Literature, and other databases. Two studies searched 4 databases,[34,39] 3 studies searched 3 databases,[30,31,37] and 2 studies searched 2 databases[32,45] (Table 4).

The total number of unique primary studies cited by the included systematic reviews was 15. The number of primary studies varied widely from 5 in those reviews performed in 2011[34,39] to 12 for a study published in 2013,[31] with a median of 7 studies cited (Table 5).

Study Results

Six reviews found no differences between SR and DR RCR for patient outcomes (ASES; Constant; Western Ontario Rotator Cuff Index; Disabilities of the Arm, Shoulder and Hand; and/or UCLA scores depending on the study),[30-32,34,39,45] and 2 reviews favored DR RCR for tears greater than 3 cm.[37,44] Two reviews found no differences between SR and DR RCR for structural healing,[32,34] 2 reviews found DR repair to provide superior structural healing for tears larger than 3 cm,[31,37] 3 reviews found DR repair to provide superior structural healing for all tears,[39,44,45] and 1 review did not assess structural healing[30] (Table 3).

Study Quality and Validity

QUOROM scores were assessed for each study and varied from 12[39] to 17,[37] with a median of 14, with a maximum possible score being 18. Oxman-Guyatt scores varied from 2[32] to 7[31] on a scale from 1 to 7, with a median score of 3.5 (Table 6). Oxman-Guyatt scores of 1 and 2 are generally considered to indicate that the study has "major flaws."[42,46]

Heterogeneity Assessment

Several methods were used to assess study heterogeneity. Of the 8 studies, 7 performed a statistical heterogeneity analysis.[30-32,37,39,44,45] Several performed sensitivity analyses assessing parameters such as primary study quality, gender, age, and tear size (Table 7). Additional sources of study heterogeneity discussed but

Table 5. Primary Studies Included in Meta-Analyses

Primary Study	Millett et al.[45]	Xu et al.[44]	Chen et al.[31]	Zhang et al.[37]	Sheibani-Rad et al.[30]	DeHaan et al.[32]	Prasathaporn et al.[39]	Perser et al.[34]
Sugaya et al., 2005[54]	−	−	+	−	−	−	−	−
Charousset et al., 2007[56]	−	+	+	+	−	+	+	+
Franceschi et al., 2007[9]	+	+	+	+	+	+	+	+
Park et al., 2008[57]	−	+	+	+	−	+	+	+
Grasso et al., 2009[26]	+	+	+	+	+	+	+	+
Burks et al., 2009[29]	+	+	+	−	+	+	+	+
Aydin et al., 2010[23]	−	+	+	−	−	+	−	−
Pennington et al., 2010[58]	−	−	+	−	−	−	−	−
Koh et al., 2011[27]	+	+	+	+	+	+	−	−
Mihata et al., 2011[19]	−	−	+	−	−	−	−	−
Carbonel et al., 2012[29]	+	+	+	+	−	−	−	−
Denard et al., 2012[59]	−	−	+	−	−	−	−	−
Lapner et al., 2012[21]	+	−	+	+	+	−	−	−
Ma et al., 2012[60]	−	+	+	+	−	−	−	−
Gartsman et al., 2013[25]	+	−	−	−	−	−	−	−

Table 6. Comparisons Performed by Each Meta-Analysis and Quality Scores for Each Meta-Analysis

Author	Heterogeneity Analysis	Constant (MD or SMD)	ASES (MD or SMD)	UCLA (MD or SMD)	Muscle Strength* (MD or SMD)	Complete Retears		Partial Retears (RR)	Overall Retears (RR)	Intact Tendon Healing		Postoperative Complications (SMD)	No. of Primary Studies	Primary Studies Included Only RCTs	QUOROM Score	Oxman-Guyatt Score
						MD or SMD	RR			RR	OR or Logarithm of OR					
Millett et al.[45]	+	+	+	+	–	–	+	+	+	–	–	–	7	+	15	4
Xu et al.[44]	+	+	+	+	+	–	–	–	+	–	–	–	–	+	14	3
Chen et al.[31]	+	+	+	+	–	–	–	–	–	–	+	–	12	+	16	7
Zhang et al.[37]	+	+	+	+	–	–	+	+	–	+	–	–	8	+	17	5
Sheibani-Rad et al.[30]	+	+	+	+	–	–	–	–	–	–	–	–	5	+	13	2
DeHaan et al.[32]	+	+	+	+	–	+	–	–	+	–	–	+	7	–	14	2
Prasathaporn et al.[39]	+	+	+	+	+	–	+	–	–	+	–	–†	5	–	12	6
Perser et al.[34]	–	+	+	+	–	–†	–	–†	–	–	+	–	5	–	14	3

NOTE. All 8 studies performed data pooling.

MD, mean difference; OR, odds ratio; RCT, randomized controlled trial; RR, relative risk; SMD, standardized mean difference.

*Category includes strength of abduction, internal rotation, and external rotation.

†Data were pooled for the listed outcome but not statistically compared.

not analyzed included surgical technique in 5 studies, number of suture anchors in 6 studies, concomitant procedures in 2 studies, rate of patient follow-up in 2 studies, and rehabilitation protocol in 4 studies (Table 7).

Application of Jadad Decision Algorithm

The Jadad decision algorithm was applied to determine which of the 8 included meta-analyses provided the best available evidence to provide treatment recommendations. Three authors independently selected the same route through the algorithm. Because (1) all reviews addressed the same study question, (2) our reviews did not include the same primary trials (Table 4), and (3) our reviews did not have the same selection criteria, the Jadad algorithm suggests that the highest-quality review can be selected based on the publication characteristics of the primary trials, the methodology of the primary trials, the language restrictions, and whether analysis of data on individual patients was included. The latter 2 criteria do not apply in this case. With respect to publication status, several newer meta-analyses included multiple newly available trials, which may explain the discordance in results and conclusions. With respect to methodology of primary trials, those reviews that include only Level I evidence include trials of superior methodology. By use of these criteria, we were thus able to select 3 high-quality reviews with concordant results that represent the current best available evidence: those by Chen et al.,[31] Zhang et al.,[37] and Millett et al.[45] These studies all concluded that RCR provided statistically significantly improved patient outcomes and structural healing after DR repair, although the differences in patient outcomes were not clinically significant.

Discussion

This study was based on a systematic review of the literature and critical inspection and quality assessment of 8 meta-analyses using the QUOROM and Oxman-Guyatt guidelines. The impetus for this study was to reconcile the disparate conclusions of these meta-analyses and, in doing so, to highlight underlying methodologic differences. The available meta-analyses used a variety of levels of evidence, with some reporting on only Level I evidence,[30] some reporting on all comparative trials,[31,36,39,47] and some performing dual analyses on both Level I evidence and Level I to Level III evidence.[31] It was determined that, according to the current best available evidence, DR RCR provides superior patient outcomes and structural healing when compared with SR RCR. Surgeons caring for patients with rotator cuff tears must consider whether the clinical benefits of DR RCR, as conveyed by the effect sizes reported in these high-quality meta-analyses, sufficiently justify the increased operative time and cost of this technique.

Table 7. Heterogeneity or Subgroup Analysis of Primary Studies

	Millett et al.[45]	Xu et al.[44]	Chen et al.[31]	Zhang et al.[37]	Sheibani-Rad et al.[30]	DeHaan et al.[32]	Prasathaporn et al.[39]	Perser et al.[34]
Statistical heterogeneity analysis	+	+	+	+	+	+	+	−
Subgroup or sensitivity analysis								
Primary study quality	+	−	+	+	−	−	−	+
Gender	+	0	0	−	−	+	−	−
Age	+	0	−	−	0	+	0	−
Dominant arm	−	−	0	−	−	+	−	−
Tear size	+	−	0	0	−	+	0	0
Tear shape	+	−	−	−	−	−	−	−
Chronicity of injury	−	−	−	−	−	+	−	−
Multiple-tendon injury	−	−	−	−	−	+	−	−
Surgical technique	0	−	0	−	0	0	0	−
No. of suture anchors	0	0	0	−	0	0	0	−
Concomitant procedures	−	−	−	0	−	−	−	0
Time to postoperative follow-up	+	0	−	0	+	+	0	+
Rate of patient follow-up	+	−	0	−	−	−	−	−
Rehabilitation protocol	0	−	0	−	0*	0	−	−
Constant (tears >3 cm v <3 cm)	−	+	+	+	−	−	−	−
ASES (tears >3 cm v <3 cm)	−	+	+	+	−	−	−	−
UCLA (tears >3 cm v <3 cm)	−	+	+	+	−	−	−	−
Intact tendon healing (tears >3 cm v <3 cm)	−	−	+	−	−	−	−	−

NOTE. A plus sign indicates formal sensitivity or subgroup analysis was performed, a minus sign indicates formal sensitivity or subgroup analysis was not performed, and a zero indicates descriptive data were provided or discussed but no analysis was performed.

*All included studies had identical rehabilitation protocols.

The debate regarding the optimal repair technique for RCR is critical because DR fixation is not without added cost, is technically demanding, and increases operative time.[39] In addition, although the cost-effectiveness of RCR has been shown to be superior to other common health care interventions (e.g., coronary artery bypass grafting) and on par with other orthopaedic interventions (e.g., total hip arthroplasty), the additional cost of DR fixation could change these relations.[48] Sensitivity analyses have estimated that a nationwide switch from SR to DR fixation would cost $80 to $260 million annually. Therefore, to attain cost neutrality, DR fixation must have a significant effect on the number of quality-adjusted life-years or the revision/reoperation rate after arthroscopic RCR. DR fixation also introduces an additional failure mechanism by medial retear due to the proximity of medial-row fixation to the musculotendinous junction. Revision repair in the setting of medial retear may be difficult to impossible.[11,36,49,50] In addition, the implications of both DR and TOE fixation on healing are unknown because the biological consequences of tissue compression remain incompletely understood.[51]

Limitations

The strengths of our review lie in the duplication of independent quality assessment by 3 authors with consensus agreement. In addition, validated quality assessment tools[41-43] were used to identify the studies of highest quality from which to extract clinical recommendations. Numerous limitations also exist for our study. Meta-analyses rely on data provided by the primary included studies and are thus hindered by limitations within these studies, which included failure to stratify by tear size,[24] small sample size,[24] loss of follow-up,[26] and failure to obtain radiographic confirmation of healing.[34] Furthermore, these studies may be underpowered[11,24] and may be susceptible to detection bias[33] because of currently used outcome variables being relatively insensitive to strength.[11] Heterogeneity may be difficult to quantify with respect to tear severity,[7] tendon and bone quality,[51] and muscular atrophy[52] and thus may bias results. The relatively short-term follow-up provided by much of the literature to date[23-26,33,36] is particularly limiting because patients may have excellent outcomes early with late deterioration of results after early structural failure.[5] One limitation that hinders much of the literature surrounding RCR is the lack of a consistently defined association between structural healing and patient outcomes. Although function is linked to cuff healing,[3,4,7,8,53] in particular strength,[4,11] patients can have a satisfactory outcome in the setting of recurrence.[3-6,8] One additional limitation lies in the heterogeneity seen in the surgical techniques themselves. Variations in technique, such as the number of anchors placed in each row,[9,11] the use of simple versus mattress versus modified Mason-Allen sutures,[13,17,20] and the use of suture versus suture tape,[49] may have important implications for repair strength. Recent evidence suggests that suture configuration may play a more critical role than the number of anchors or rows.[13,17,20] Indeed, much of the existing literature compares non-bridging DR repairs and thus may not apply to the newer TOE repairs that have been shown to have higher healing rates.[25,38,54] Ultimately, meta-analyses, which were originally used to synthesize RCTs comparing medications,[16,41,43] may be less reliable for surgical comparisons.[46]

Conclusions

The results of this systematic review of overlapping meta-analyses comparing SR and DR RCR suggest that DR RCR results in higher rates of structural healing when considering the systematic reviews with the highest level of evidence. Further cost-effectiveness research is needed examining whether these differences are still significant when accounting for the increased implant cost and operative time seen with DR RCR. In addition, the effect of tissue compression on rotator cuff healing and clinical outcomes after DR or TOE RCR must be more clearly delineated to confirm the advantages of DR repair suggested by the current best available evidence.

References

1. Lehman C, Cuomo F, Kummer FJ, Zuckerman JD. The incidence of full thickness rotator cuff tears in a large cadaveric population. *Bull Hosp Jt Dis* 1995;54:30-31.
2. Bisson L, Zivaljevic N, Sanders S, Pula D. A cost analysis of single-row versus double-row and suture bridge rotator cuff repair methods. *Knee Surg Sports Traumatol Arthrosc* in press, available online 12 December, 2012. http://dx.doi.org/10.1007/s00167-012-2338-2.
3. Anderson K, Boothby M, Aschenbrener D, van Holsbeeck M. Outcome and structural integrity after arthroscopic rotator cuff repair using 2 rows of fixation: Minimum 2-year follow-up. *Am J Sports Med* 2006;34:1899-1905.
4. Boileau P, Brassart N, Watkinson DJ, Carles M, Hatzidakis AM, Krishnan SG. Arthroscopic repair of full-thickness tears of the supraspinatus: Does the tendon really heal? *J Bone Joint Surg Am* 2005;87:1229-1240.
5. Galatz LM, Ball CM, Teefey SA, Middleton WD, Yamaguchi K. The outcome and repair integrity of completely arthroscopically repaired large and massive rotator cuff tears. *J Bone Joint Surg Am* 2004;86:219-224.
6. Lafosse L, Brozska R, Toussaint B, Gobezie R. The outcome and structural integrity of arthroscopic rotator cuff repair with use of the double-row suture anchor technique. *J Bone Joint Surg Am* 2007;89:1533-1541.
7. Sugaya H, Maeda K, Matsuki K, Moriishi J. Repair integrity and functional outcome after arthroscopic double-row rotator cuff repair. A prospective outcome study. *J Bone Joint Surg Am* 2007;89:953-960.
8. Bishop J, Klepps S, Lo IK, Bird J, Gladstone JN, Flatow EL. Cuff integrity after arthroscopic versus open rotator cuff repair: A prospective study. *J Shoulder Elbow Surg* 2006;15:290-299.
9. Franceschi F, Ruzzini L, Longo UG, et al. Equivalent clinical results of arthroscopic single-row and double-row suture anchor repair for rotator cuff tears: A randomized controlled trial. *Am J Sports Med* 2007;35:1254-1260.
10. Codman EA. Complete rupture of the supraspinatus tendon. Operative treatment with report of two successful cases. 1911. *J Shoulder Elbow Surg* 2011;20:347-349.
11. Burkhart SS, Cole BJ. Bridging self-reinforcing double-row rotator cuff repair: We really are doing better. *Arthroscopy* 2010;26:677-680.
12. Kim DH, Elattrache NS, Tibone JE, et al. Biomechanical comparison of a single-row versus double-row suture anchor technique for rotator cuff repair. *Am J Sports Med* 2006;34:407-414.
13. Lorbach O, Kieb M, Raber F, Busch LC, Kohn D, Pape D. Comparable biomechanical results for a modified single-row rotator cuff reconstruction using triple-loaded suture anchors versus a suture-bridging double-row repair. *Arthroscopy* 2012;28:178-187.
14. Mazzocca AD, Millett PJ, Guanche CA, Santangelo SA, Arciero RA. Arthroscopic single-row versus double-row suture anchor rotator cuff repair. *Am J Sports Med* 2005;33:1861-1868.
15. Lo IKY, Burkhart SS. Double-row arthroscopic rotator cuff repair: Re-establishing the footprint of the rotator cuff. *Arthroscopy* 2003;19:1035-1042.
16. Apreleva M, Ozbaydar M, Fitzgibbons PG, Warner JJP. Rotator cuff tears: The effect of the reconstruction method on three-dimensional repair site area. *Arthroscopy* 2002;18:519-526.
17. Lorbach O, Kieb M, Raber F, Busch LC, Kohn DM, Pape D. Three-dimensional evaluation of cyclic displacement in single-row and double-row rotator cuff reconstructions under static external rotation. *Am J Sports Med* 2013;41:153-162.
18. Lubowitz JH, Provencher MT, Poehling GG. Single-row versus double-row rotator cuff repair: The controversy continues. *Arthroscopy* 2011;27:880-882.
19. Mihata T, Watanabe C, Fukunishi K, et al. Functional and structural outcomes of single-row versus double-row versus combined double-row and suture-bridge repair for rotator cuff tears. *Am J Sports Med* 2011;39:2091-2098.
20. Lorbach O, Bachelier F, Vees J, Kohn D, Pape D. Cyclic loading of rotator cuff reconstructions: Single-row repair with modified suture configurations versus double-row repair. *Am J Sports Med* 2008;36:1504-1510.
21. Lapner PLC, Sabri E, Rakhra K, et al. A multicenter randomized controlled trial comparing single-row with double-row fixation in arthroscopic rotator cuff repair. *J Bone Joint Surg Am* 2012;94:1249-1257.
22. Mazzocca AD. Arthroscopic anterior shoulder stabilization of collision and contact athletes. *Am J Sports Med* 2005;33:52-60.
23. Aydin N, Kocaoglu B, Guven O. Single-row versus double-row arthroscopic rotator cuff repair in small- to medium-sized tears. *J Shoulder Elbow Surg* 2010;19:722-725.
24. Burks RT, Crim J, Brown N, Fink B, Greis PE. A prospective randomized clinical trial comparing arthroscopic single- and double-row rotator cuff repair: Magnetic resonance imaging and early clinical evaluation. *Am J Sports Med* 2009;37:674-682.

25. Gartsman GM, Drake G, Edwards TB, et al. Ultrasound evaluation of arthroscopic full-thickness supraspinatus rotator cuff repair: Single-row versus double-row suture bridge (transosseous equivalent) fixation. Results of a prospective, randomized study. *J Shoulder Elbow Surg* 2013;22:1480-1487.
26. Grasso A, Milano G, Salvatore M, Falcone G, Deriu L, Fabbriciani C. Single-row versus double-row arthroscopic rotator cuff repair: A prospective randomized clinical study. *Arthroscopy* 2009;25:4-12.
27. Koh KH, Kang KC, Lim TK, Shon MS, Yoo JC. Prospective randomized clinical trial of single- versus double-row suture anchor repair in 2- to 4-cm rotator cuff tears: Clinical and magnetic resonance imaging results. *Arthroscopy* 2011;27:453-462.
28. Sugaya H. Arthroscopic osseous Bankart repair for chronic recurrent traumatic anterior glenohumeral instability. *J Bone Joint Surg Am* 2005;87:1752-1760.
29. Carbonel I, Martinez AA, Calvo A, Ripalda J, Herrera A. Single-row versus double-row arthroscopic repair in the treatment of rotator cuff tears: A prospective randomized clinical study. *Int Orthop* 2012;36:1877-1883.
30. Sheibani-Rad S, Giveans MR, Arnoczky SP, Bedi A. Arthroscopic single-row versus double-row rotator cuff repair: A meta-analysis of the randomized clinical trials. *Arthroscopy* 2013;29:343-348.
31. Chen M, Xu W, Dong Q, Huang Q, Xie Z, Mao Y. Outcomes of single-row versus double-row arthroscopic rotator cuff repair: A systematic review and meta-analysis of current evidence. *Arthroscopy* 2013;29:1437-1449.
32. DeHaan AM, Axelrad TW, Kaye E, Silvestri L, Puskas B, Foster TE. Does double-row rotator cuff repair improve functional outcome of patients compared with single-row technique? A systematic review. *Am J Sports Med* 2012;40:1176-1185.
33. Nho SJ, Slabaugh MA, Seroyer ST, et al. Does the literature support double-row suture anchor fixation for arthroscopic rotator cuff repair? A systematic review comparing double-row and single-row suture anchor configuration. *Arthroscopy* 2009;25:1319-1328.
34. Perser K, Godfrey D, Bisson L. Meta-analysis of clinical and radiographic outcomes after arthroscopic single-row versus double-row rotator cuff repair. *Sports Health* 2011;3:268-274.
35. Seida JC, LeBlanc C, Schouten JR, et al. Systematic review: Nonoperative and operative treatments for rotator cuff tears. *Ann Intern Med* 2010;153:246-255.
36. Wall LB, Keener JD, Brophy RH. Clinical outcomes of double-row versus single-row rotator cuff repairs. *Arthroscopy* 2009;25:1312-1318.
37. Zhang Q, Zhou J, Yuan C, Chen K, Cheng B. Single-row or double-row fixation technique for full-thickness rotator cuff tears: A meta-analysis. *PLoS One* 2013;8:e68515.
38. Duquin TR, Buyea C, Bisson LJ. Which method of rotator cuff repair leads to the highest rate of structural healing? A systematic review. *Am J Sports Med* 2010;38:835-841.
39. Prasathaporn N, Kuptniratsaikul S, Kongrukgreatiyos K. Single-row repair versus double-row repair of full-thickness rotator cuff tears. *Arthroscopy* 2011;27:978-985.
40. Petrisor BA, Keating J, Schemitsch E. Grading the evidence: Levels of evidence and grades of recommendation. *Injury* 2006;37:321-327.
41. Moher D, Cook DJ, Eastwood S, Olkin I, Rennie D, Stroup DF. Improving the quality of reports of meta-analyses of randomised controlled trials: The QUOROM statement. Quality of reporting of meta-analyses. *Lancet* 1999;354:1896-1900.
42. Oxman AD, Guyatt GH. Validation of an index of the quality of review articles. *J Clin Epidemiol* 1991;44:1271-1278.
43. Jadad AR, Cook DJ, Browman GP. A guide to interpreting discordant systematic reviews. *CMAJ* 1997;156:1411-1416.
44. Xu C, Zhao J, Li D. Meta-analysis comparing single-row and double-row repair techniques in the arthroscopic treatment of rotator cuff tears. *J Shoulder Elbow Surg* 2014;23:182-188.
45. Millett PJ, Warth RJ, Dornan GJ, Lee JT, Spiegl UJ. Clinical and structural outcomes after arthroscopic single-row versus double-row rotator cuff repair: A systematic review and meta-analysis of level I randomized clinical trials. *J Shoulder Elbow Surg* 2014;23:586-597.
46. Poolman RW, Abouali JAK, Conter HJ, Bhandari M. Overlapping systematic reviews of anterior cruciate ligament reconstruction comparing hamstring autograft with bone-patellar tendon-bone autograft: Why are they different? *J Bone Joint Surg Am* 2007;89:1542-1552.
47. Zhang Q, Zhang S, Li R, Liu Y, Cao X. Comparison of two methods of femoral tunnel preparation in single-bundle anterior cruciate ligament reconstruction: A prospective randomized study. *Acta Cir Bras* 2012;27:572-576.
48. Vitale MA, Vitale MG, Zivin JG, Braman JP, Bigliani LU, Flatow EL. Rotator cuff repair: An analysis of utility scores and cost-effectiveness. *J Shoulder Elbow Surg* 2007;16:181-187.
49. Lubowitz JH, Provencher MT, Poehling GG. Single- versus double-row arthroscopic rotator cuff repair: The complexity grows. *Arthroscopy* 2012;28:1189-1192.
50. Trantalis JN, Boorman RS, Pletsch K, Lo IKY. Medial rotator cuff failure after arthroscopic double-row rotator cuff repair. *Arthroscopy* 2008;24:727-731.
51. Nho SJ, Yadav H, Shindle MK, MacGillivray JD. Rotator cuff degeneration: Etiology and pathogenesis. *Am J Sports Med* 2008;36:987-993.
52. Goutallier D, Postel JM, Bernageau J, Lavau L, Voisin MC. Fatty muscle degeneration in cuff ruptures. Pre- and postoperative evaluation by CT scan. *Clin Orthop Relat Res* 1994:78-83.
53. Lafosse L, Reiland Y, Baier GP, Toussaint B, Jost B. Anterior and posterior instability of the long head of the biceps tendon in rotator cuff tears: A new classification based on arthroscopic observations. *Arthroscopy* 2007;23:73-80.
54. Sugaya H, Maeda K, Matsuki K, Moriishi J. Functional and structural outcome after arthroscopic full-thickness rotator cuff repair: Single-row versus dual-row fixation. *Arthroscopy* 2005;21:1307-1316.
55. Saridakis P, Jones G. Outcomes of single-row and double-row arthroscopic rotator cuff repair: A systematic review. *J Bone Joint Surg Am* 2010;92:732-742.

56. Charousset C, Grimberg J, Duranthon LD, Bellaiche L, Petrover D. Can a double-row anchorage technique improve tendon healing in arthroscopic rotator cuff repair? A prospective, nonrandomized, comparative study of double-row and single-row anchorage techniques with computed tomographic arthrography tendon healing assessment. *Am J Sports Med* 2007;35:1247-1253.
57. Park JY, Lhee SH, Choi JH, Park HK, Yu JW, Seo JB. Comparison of the clinical outcomes of single- and double-row repairs in rotator cuff tears. *Am J Sports Med* 2008;36:1310-1316.
58. Pennington WT, Gibbons DJ, Bartz BA, et al. Comparative analysis of single-row versus double-row repair of rotator cuff tears. *Arthroscopy* 2010;26:1419-1426.
59. Denard PJ, Jiwani AZ, Ladermann A, Burkhart SS. Long-term outcome of arthroscopic massive rotator cuff repair: The importance of double-row fixation. *Arthroscopy* 2012; 28:909-915.
60. Ma HL, Chiang ER, Wu HT, et al. Clinical outcome and imaging of arthroscopic single-row and double-row rotator cuff repair: A prospective randomized trial. *Arthroscopy* 2012;28:16-24.