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Long head of biceps tendon transposition for massive and irreparable rotator cuff tears can improve superior humeral migration and reduce retear rate: A Meta-analysis and systematic review of biomechanical and clinical outcomes

Wan RW *et al*. LHBT transposition

Abstract

BACKGROUND

Superior capsular reconstruction (SCR) with long head of biceps tendon (LHBT) transposition was developed to massive and irreparable rotator cuff tears (MIRCTs); however, the outcomes of this technique remain unclear.

AIM

To perform a systematic review of biomechanical outcomes and a meta-analysis of clinical outcomes after LHBT transposition for MIRCTs.

METHODS

We performed a systematic electronic database search on PubMed, Embase and Cochrane Library. Studies of SCR with LHBT transposition were included according to the inclusion and exclusion criteria. Biomechanical studies were assessed for main results and conclusions. Included clinical studies were evaluated for quality of methodology. Data including study characteristics, cohort demographics and outcomes were extracted. A meta-analysis was conducted of the clinical outcomes.

RESULTS

According to our inclusion and exclusion criteria, a total of 6 biomechanical studies were identified and reported an overall improvement in subacromial contact pressures and prevention of superior humeral migration without limiting range of motion (ROM) after LHBT transposition for MIRCTs. A total of 5 clinical studies were included in the meta-analysis of LHBT transposition outcomes, consisting of 253 patients. The results indicated that compared to other surgical methods for MIRCTs, LHBT transposition had advantages of more significant improvement in ROM [forward flexion mean difference (MD) = 6.54, 95% confidence interval (CI): 3.07-10.01; external rotation (MD = 5.15, 95%CI: 1.59-8.17), the acromiohumeral distance (AHD) (MD = 0.90, 95%CI: 0.21-1.59)] and reducing retear rate (odds ratio = 0.27, 95%CI: 0.15-0.48). No significant

diff erence in American Shoulder and Elbow Surgeons score, visual analogue scale score and University of California at Los Angles score was demonstrated between these two groups for MIRCTs.

CONCLUSION

In general, SCR with LHBT transposition was a reliable and economical technique for treating MIRCTs, both in terms of biomechanical and clinical outcomes, with comparable clinical outcomes, improved ROM, AHD and reduced the retear rates compared to conventional SCR and other established techniques. More high-quality randomized controlled studies on the long-term outcomes of SCR with LHBT transposition are required to further assess.

Key Words: Massive and irreparable rotator cuff tears; Long head of biceps tendon transposition; Rotator cuff repair; Superior capsular reconstruction

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Core Tip: Superior capsular reconstruction (SCR) with long head of biceps tendon (LHBT) transposition was developed to massive and irreparable rotator cuff tears (MIRCTs). However, the outcomes of this technique remain unclear. SCR with LHBT transposition was a reliable and economical technique for treating MIRCTs, both in terms of biomechanical and clinical outcomes, with comparable clinical outcomes, improved range of motion, acromiohumeral distance and reduced the retear rates compared to conventional SCR and other established techniques.

INTRODUCTION

Rotator cuff tears are one of the most common musculoskeletal disorders, affecting between 15% and 50% of the population, and increasing in prevalence with age[1]. The prevalence of massive and irreparable rotator cuff tears (MIRCTs) has been reported to be as high as 40% in rotator cuff tears[2,3]. The rotator cuff works as a dynamic stabilizer of the glenohumeral joint, and MIRCTs will cause the absence of this stabilizer, with the head migrating superiorly and anteriorly, leading to abnormal wear and tear of the head and glenohumeral joint[4,5]. If left untreated, the MIRCTs may lead to permanent pain and loss of function, eventually resulting in rotator cuff arthropathy.

The repair of MIRCTs still remains a surgical challenge due to muscle fat infiltration, tendon retraction and tissue degeneration. Numerous surgical management options for MIRCTs are available, including debridement and subacromial decompression, partial rotator cuff repair, biceps tenodesis or tenotomy, an allograft or autograft (patch, fascia or dermis), tendon transfer (latissimus dorsi, pectoralis major or pectoralis minor), balloon technique, and reverse total shoulder arthroplasty have been reported[6-13]. If a complete repair cannot be accomplished, a partial repair may still improve pain and function of the shoulder. However, it has been reported the risk of retear rate after partial repair as high as 52%[14]. Compared to partial repair, the arthroscopic patch grafting has better clinical efficacy, but patch grafting has no significant benefit for patients with high-grade fatty degeneration[15,16]. Tendon transfer is a good option for young, active patients with MIRCTs, minimal glenohumeral arthritis and severe functional limitations. However, the surgical trauma of tendon transfer is relatively large and the rehabilitation process is complicated. In patients with advanced cuff tear arthropathy and/or painful pseudoparalysis, a reverse total shoulder can provide predictable pain relief and function improvement but is associated with more complications and higher failure rate[17].

Superior capsular reconstruction (SCR) is considered a possible option for treating MIRCTs and restoring superior glenohumeral stability and shoulder function, which was first described by Mihata *et al*[18] in 2013. The graft used is a tensor fasciae lata (TFL) autograft that attaches medially to the superior glenoid and laterally to the greater

tuberosity. Recently, the long head of biceps tendon (LHBT) has been proposed as an alternative to the standard SCR graft, which seems to overcome the problems of donor site morbidity, feasibility of grafting, and additional costs of allografting[19]. When performing the LHBT transposition technique, the native LHBT connection on the glenoid side was preserved. The proximal portion of the LHBT, was then transposed posteriorly and fixed on the supraspinatus tendon footprint as the SCR.

Currently, biomechanical studies have been carried out to observe the biomechanical effects of LHBT transposition for MIRCTs[20-22]. Meanwhile, few previous clinical studies have reported promising clinical outcomes after LHBT transposition for MIRCTs[23-25], however, it remains unknown about the reliability of this technique. The purpose of this study was to perform a systematic review of biomechanical outcomes and a meta-analysis of clinical outcomes after LHBT transposition for MIRCTs. We hypothesized that LHBT transposition would effectively restore joint biomechanics compared with the unrepaired state and improve overall shoulder function, the acromiohumeral distance (AHD) and decrease the retear rate of repaired rotator cuff.

MATERIALS AND METHODS

This meta-analysis and systematic review was written according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines[26].

Search strategy

Two independent authors (Wan RW and Luo ZW) performed an electronic search in 3 databases between their inception date and May 20, 2022: MEDLINE (PubMed), Embase (Ovid) and Cochrane Library. The Boolean search phrase was "(superior capsul* reconstruction OR superior capsul* repair OR superior labr* reconstruction OR superior labr* repair OR rotator cuff repair) AND (biceps)". The reference lists of correlational studies were also reviewed.

Eligibility criteria

Inclusion criteria consisted of biomechanical studies were as follows: (1) The cadaveric shoulders with massive or irreparable rotator cuff tears; (2) LHBT transposition was used in cadaveric shoulders; and (3) The articles were written in English or had an English translation.

Inclusion criteria consisted of clinical studies were as follows: (1) LHBT transposition was used to treat rotator cuff tears; (2) The rotator cuff tears were large to massive or irreparable; (3) Postoperative functional outcomes were reported; and (4) The articles were written in English or had an English translation.

The exclusion criteria were as follows: (1) Computational-based or animal studies; (2) Editorial letters or letters to the editor, case reports, technical notes, expert consensuses, systematic and narrative reviews, pilot studies, unpublished manuscripts, book chapters, lectures, meeting abstracts, conference proceedings, or dissertations; (4) Superior labrum anterior and posterior (SLAP) injury or LHBT injury; (5) SCR without using LHBT transposition; and (6) Clinical studies not reporting preoperative and postoperative outcomes or without enough information for data analysis.

Study selection

After duplicates were removed, two independent authors (Wan RW and Luo ZW) evaluated all titles and abstracts for relative articles. If these data were inadequate, full texts were assessed to judge if studies met the inclusion criteria. If there was an objection concerning the inclusion of studies, studies were judged by the senior author (Shang XL) to make the final decision.

Data extraction

After assessing full-text articles for eligibility and applying the inclusion/exclusion criteria, the following information were extracted: Study type, level of evidence, first author, publication year, country, number of patients, mean age, mean duration of follow-up, surgical technique, and postoperative clinical outcomes, postoperative retear rates. The primary outcomes of interest were American Shoulder and Elbow Surgeons

(ASES) score, visual analogue scale (VAS) score [0-10 (10 = severe pain)], University of California at Los Angles (UCLA) score, range of motion (ROM) including active external rotation at side (ER_0; degrees), active forward flexion (FF; degrees), AHD and retear rates. For studies with insufficient information, the reviewers contacted the primary authors, when possible, to acquire and verify the data.

Quality assessment

Given the abundance of nonrandomized studies in the available literature, 2 independent reviewers (Wan RW and Luo ZW) critically appraised all the eligible studies using Methodological Index for Nonrandomized Studies (MINORS) to evaluate their quality[27]. If a consensus was not achieved, a senior reviewer (Shang XL) made the final decision on the assessment. The MINORS instrument consists of 12 items: 4 for comparative studies only and 8 for noncomparative and comparative studies. A score of 0 (not reported), 1 (reported but inadequate), or 2 (reported and adequate) was suggested for each item, resulting in an ideal maximum score of 16 for noncomparative studies and 24 for comparative studies. For nonrandomized comparative studies, the methodologic quality was classified as follows: 0 to 12, low quality; 13 to 18, fair quality; and 19-24, good quality. The outcomes of the risk of bias and quality assessment offered context for the conclusions to be drawn from this review.

Statistical analysis

Statistical analyses were performed by using Review Manager, version 5.4 (Nordic Cochrane Centre, Cochrane Collaboration). The mean difference (MD) and odds ratio (OR) were used to compare continuous and dichotomous variables, respectively. All results were reported with 95% confidence intervals (CIs). A P value < 0.05 was regarded statistically significant. I^2 test was performed to assess the impact of study heterogeneity on the results of the meta-analysis. According to the Cochrane review guidelines, if severe heterogeneity was present at $I^2 > 50\%$, the random effect models were chosen. If $I^2 \leq 50\%$, multiple similar studies were considered to be homogeneous,

the fixed effects model was used to combine the statistical values. Results were summarized in forest plots.

RESULTS

Study selection

The initial literature search yielded 1675 articles (Figure 1). After removing duplicates, 1420 studies were screened for title and abstract, resulting in 34 full-text articles being assessed for eligibility. After the application of inclusion and exclusion criteria, 6 articles[21,28-32] reporting biomechanical outcomes and 5 articles[33-37] reporting clinical outcomes were identified for further analysis.

Risk of bias

The MINORS scores of two retrospective control clinical studies[33,34] were greater than or equal to 19 points, indicating good quality of evidence. The MINORS scores of three other retrospective control clinical studies[35-37] were greater than 13 points, indicating fair quality of evidence (Table 1).

Systematic review of biomechanical studies

The characteristics and main results of included biomechanical studies are shown in Table 2. Because of the heterogeneity of testing conditions and outcome reporting, no meaningful statistical analyses could be performed. Overall, LHBT transposition for MIRCTs was reported to improve subacromial contact pressures and prevent superior humeral migration without limiting ROM.

Meta-analysis of clinical outcomes

A total of 5 studies meeting inclusion criteria were included in the meta-analysis of LHBT transposition outcomes, consisting of 253 patients. The study characteristics are presented in Table 3. We considered LHBT transposition for MIRCTS as the intervention group and other surgical methods for MIRCTs, *i.e.*, (the double-row repair,

the transosseous-equivalent technique with absorbable patch reinforcement, the traditional SCR with a fascia lata autograft, arthroscopic rotator cuff repair (ARCR) alone, ARCR and tenotomy of LHBT, as the control group.

Patients were clinically assessed both preoperatively and postoperatively on a number of outcome-based scores that included ASES score, VAS score, UCLA score, rang of motion, AHD and retear rates. ASES score was measured in five studies, a total of 253 patients were included, 127 in the LHBT transposition group and 126 in the control group. The results of the heterogeneity analysis indicated that these five studies had good homogeneity (P = 0.27, I^2 = 22%). A mean difference of 0.51, 95%CI: -1.91 to 2.93 was calculated, with a P value of 0.68. No significant difference was observed between the two groups regarding the ASES score (Figure 2A).

VAS score was measured in four studies, a total of 231 patients were included, 115 in the LHBT transposition group and 116 in the control group. The results of the heterogeneity analysis indicated that these four studies had good homogeneity (P = 0.33, I^2 = 13%). A mean difference of -0.13 (95%CI: -0.33 to 0.06) was calculated, with a P value of 0.18. Implying that no significant difference was found between the two cohorts (Figure 2B).

UCLA score was measured in three studies, a total of 163 patients were included, 89 in the LHBT transposition group and 74 in the control group. The results of the heterogeneity analysis indicated that these three studies had good homogeneity (P = 0.19, I^2 = 41%). A mean difference of 0.36, 95%CI: -0.67 to 1.39 was calculated, with a P value of 0.50. This suggested that no significant difference was found between the two cohorts (Figure 2C).

ROM was evaluated in five studies, a total of 253 patients were included, 127 in the LHBT transposition group and 126 in the control group. The results of the heterogeneity analysis in FF and ER0 indicated that these five studies had good homogeneity (P = 0.61, I^2 = 0%, P = 0.32, I^2 = 14%). In terms of FF, a mean difference of 6.54, 95%CI: 3.07-10.01 was calculated, with a P value of 0.0002, indicating that the FF was significantly better in the LHBT transposition group (Figure 2D). As for ER0, a mean difference of

5.15, 95%CI: 1.59-8.17 was calculated, with a *P* value of 0.005, implying that the ER0 was significantly better in the LHBT transposition group (Figure 2E).

AHD was measured in four studies, a total of 199 patients were included, 103 in the LHBT transposition group and 96 in the control group. The results of the heterogeneity analysis indicated that these four studies had good homogeneity ($P = 0.13$, $I^2 = 48\%$). A mean difference of 0.90, 95%CI: 0.21-1.59 was calculated, with a *P* value of 0.01, implying LHBT transposition can significantly improve the AHD (Figure 2F).

Retear rate was reported in five studies, a total of 253 patients were included, 127 in the LHBT transposition group and 126 in the control group. The results of the heterogeneity analysis indicated that these five studies had good homogeneity ($P = 0.42$, $I^2 = 0\%$). An odds ratio of 0.27, 95%CI: 0.15-0.48 was measured ($P < 0.0001$), thereby indicating that the retear rate in LHBT transposition group is lower (Figure 3).

DISCUSSION

The main finding of this investigation was that LHBT transposition for MIRCTs was generally reported to reduce subacromial contact pressures and prevent superior humeral migration without limiting ROM. On clinical outcomes, compared to other surgical methods for MIRCTs, LHBT transposition resulted in significant improvement in ROM, AHD and reducing retear rate.

In the included biomechanical study, Park *et al*[22] reported that SCR with LHBT transposition significantly reduced the humeral head displacement caused by massive rotator cuff tears and decreased subacromial contact pressure. Meanwhile, El-shaar *et al*[21] found that SCR with LHBT transposition achieved equivalent and potentially even greater biomechanical stability than SCR using a TFL autograft in preventing humeral head migration. Han *et al*[30] found that SCR for LHBT transposition with or without side-to-side repair both shifted the humeral head downward and was a further reduction in the contact surface area of the acromion. Besides the results of both techniques were comparable in terms of contact pressure and total rotational ROM. A biomechanical study by Han *et al*[29] found that compared with partial repair after

MIRCTs, LHBT transposition with or without side-to-side repair both significantly reduced the humeral head migration distance at 0° and 20° of glenohumeral abduction and effectively reduced the subacromial contact pressure at 0° of glenohumeral abduction. Three different SCR with LHBT transposition techniques were compared in the study of Berthold *et al*[32]: V-shaped, box-shaped and single-stranded. Each of the techniques significantly increased maximum abduction angle while significantly decreasing glenohumeral superior translation and maximum cumulative deltoid force compared with the irreparable posterosuperior rotator cuff tear. The V-shaped technique further showed a significantly increased maximum abduction angle and decreased maximum cumulative deltoid force when compared with the box-shaped and single-stranded techniques, as well as a significantly decreased glenohumeral superior translation when compared with the box-shaped technique. Meanwhile, Denard *et al*[31] found that ROM was not impaired with box-shaped and single-limb LHBT transposition and that there was no difference in subacromial contact pressure compared to an intact rotator cuff.

In the meta-analysis of the clinical study, compared to control group, LHBT transposition group improved FF, ER0 and AHD with lower retear rate. No significant difference in ASES score, VAS score and UCLA score was demonstrated between these two groups for MIRCTs. Two articles pioneered the treatment of MIRCTs with SCR using autologous broad fascia as the repair material, and the postoperative follow-up found that the patients' function improved significantly with satisfactory clinical outcomes[18,38]. However, the autologous broad fascia retrieval requires additional incisions, which not only increases the trauma, but also makes the operation complicated and technically demanding. Besides, more anchors are used to fix the broad fascia, which leads to increased costs. Some authors have suggested replacing fascial autografts with human acellular dermal patch allografts to avoid any additional skin incisions and any donor site morbidity[39,40]. A recent study reported by Shin *et al*[41] showed satisfactory outcomes with SCR using acellular dermal allograft. However, a systematic review showed high retear rate on SCR using acellular dermal allograft

compared with fascia lata[42]. The mechanical strength of acellular dermal materials remains controversial and expensive.

SCR with LHBT transposition was proposed by Boutsiadis *et al*[19] firstly, and the LHBT without significant tears or severe degeneration was fully utilized in the operation, with the superior glenoid labral is preserved. LHBT was transferred laterally to the supraspinatus tendon footprint area for fixation. Finally, the distal LHBT is chosen to be cut or preserved according to its distal LHBT quality in order to simulate SCR, while the partially repaired rotator cuff can be bridged. The main advantage of this method is to borrow the LHBT to provide a tension-reducing scaffold to strengthen the anterior rotator cuff tissue mechanics and anterosuperior blocking effect to assist the massive rotator cuff repair and reduce the tension on the repaired rotator cuff tissue, thereby reducing the rate of postoperative rotator cuff retears and improving the AHD. This is consistent with the results of our meta-analysis.

Other advantages of SCR with LHBT transposition are that it not only avoids the trauma at the extraction site caused by taking the autologous broad fascia for SCR, but also reduces the amount of anchor nails used, thus greatly reducing the cost and time of the procedure and decrease of infection. In addition, it is technically easier and more reproducible than SCR using fascial autografts or dermal allografts, which require a long learning curve. Finally, another possible advantage is the biological aspect of using a local autograft attached to the upper glenoid so that its vasculature may be preserved.

There are several potential limitations of this technique. The main condition is the availability of a relatively good quality LHBT, and SCR with other grafts should be considered when there is LHBT severe degeneration, LHBT rupture or partial tearing involving more than 50%, SLAP lesions > II, and some rare cases of anatomic variation or absence of the tendon[43]. However, in the case of chronic MIRCTs, they are often accompanied by LHBT damage. In addition, the LHBT has been reported to be a pain generator in patients with rotator cuff tears, and the use of the LHBT as an autograft for SCR may, in theory, increase postoperative pain[37]. However, the results of clinical studies showed no difference in postoperative pain between the various compared

techniques for either tenotomy or rerouting of the LHBT, suggesting that it can be safely used as an autograft[25,37].

This study had several limitations. First, the available studies or data about LHBT transposition used for MIRCTs were limited, only 5 studies with 127 patients in LHBT transposition group and 126 patients in control group. Second, there was insufficient high-quality comparative evidence, as the five included studies were all retrospective studies with a level of evidence 3, which may create recall or selection bias. Although the MINORS scores of these studies indicate good or fair quality evidence, they still fall short of rigorous randomized controlled trial studies. Third, the surgical approaches in the control group, although all of them are commonly used to treat MIRCTs, may have influenced the comparison of outcomes. Additional comparative trials, or even randomized controlled trials, are necessary in the future to determine which treatments are more advantageous in treating MIRCTs, and which modifications of the technique provide better outcomes. Moreover, prior investigations have revealed that distinct rehabilitation modalities and durations exhibit diverse prognostic implications for individuals undergoing arthroscopic repair of rotator cuff tears[44]. In this regard, forthcoming studies could potentially prioritize the evaluation of the influence of diverse rehabilitation approaches on the utilization of LHBT transposition as a therapeutic intervention for the management of MIRCTs. In addition, high-quality studies are necessary to evaluate the long-term outcomes of SCR with LHBT transposition, including postoperative pain, function and structural integrity. High-resolution ultrasound investigation may play an important role in this regard[45]. In a word, future high-quality research of SCR using LHBT transposition for MIRCTs is necessary.

CONCLUSION

This systematic review and meta-analysis demonstrated that SCR with LHBT transposition was a reliable and economical technique for treating MIRCTs, both in terms of biomechanical and clinical outcomes, with comparable clinical outcomes,

improved ROM, AHD and reduced the retear rates compared to conventional SCR and other established techniques. To further evaluate the long-term effects of SCR with LHBT transposition, more high-quality randomized controlled studies are needed.

ARTICLE HIGHLIGHTS

Research background

Supracapsular reconstruction (SCR) combined with transposition of the biceps long head biceps tendon (LHBT) is an approach designed to meet the severe challenges posed by massive rotator cuff tears (MIRCT).

Research motivation

Although LHBT transposition has been adopted, its exact impact remains to be clearly elucidated.

Research objectives

There are gaps in our knowledge of the outcomes produced by this technique, and thus further research is needed to reveal its potential benefits and limitations.

Research methods

We conducted a methodical search of electronic databases to identify relevant literature based on inclusion and exclusion criteria. We first conducted a systematic review of the main findings and conclusions of the biomechanical studies. Subsequently, we conducted a comprehensive meta-analysis of the clinical outcomes of the included studies.

Research results

Biomechanical studies reported that after performing LHBT transposition in MIRCT, there was a comprehensive improvement in subacromial contact pressure and a prevention of proximal humeral migration, without any resultant limitation in range of

motion (ROM). The meta-analysis of LHBT transposition outcomes encompassed five clinical studies demonstrated that, compared to other surgical methods for MIRCTs, LHBT transposition exhibited significant advantages in enhancing patients' ROM [forward flexion, mean difference (MD) = 6.54, 95% confidence interval (CI): 3.00-8.08, external rotation (MD = 5.15, 95%CI: 1.59-8.17), acromiohumeral distance (AHD) (MD = 0.90, 95%CI: 0.21 to 1.59), and reducing the risk of retear (odds ratio = 0.27, 95%CI: 0.15-0.48)]. There were no discernible differences between the two groups of patients in terms of American Shoulder and Elbow Surgeons scores, visual analogue scale scores, and University of California, Los Angeles scores.

Research conclusions

In summary, the utilization of LHBT transposition in SCR proved to be a dependable and cost-effective approach for addressing MIRCTs. This technique demonstrated favorable results not only in terms of biomechanical factors but also in clinical outcomes. It exhibited comparable efficacy to conventional SCR and other established techniques, while presenting notable improvements in ROM, AHD, and a reduced incidence of retear. Nevertheless, it is essential to emphasize the necessity for additional high-quality randomized controlled trials focusing on the long-term effects of SCR with LHBT transposition to further evaluate its efficacy.

Research perspectives

Future high-quality research of SCR using LHBT transposition for MIRCTs is necessary.

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PRIMARY SOURCES

1	Allison K. Perry, Ophelie Lavoie-Gagne, Derrick M. Knapik, Bhargavi Maheshwer et al. "Examining the Efficacy of Medial Meniscus Posterior Root Repair: A Meta-analysis and Systematic Review of Biomechanical and Clinical Outcomes", The American Journal of Sports Medicine, 2022 Crossref	100 words — 2%
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