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The lower trapezius transfer: a systematic review of biomechanical data, techniques, and clinical outcomes

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Background: Lower trapezius (LT) transfers were originally described to restore external rotation (ER) in the management of brachial plexus palsy; however, there is recent interest in the role of this transfer to restore shoulder function, specifically ER, in patients with a massive irreparable rotator cuff tear (RCT). The purpose of this systematic review is to summarize the current literature pertaining to LT transfers, including biomechanics, techniques, and clinical outcomes for patients with brachial plexus palsy and massive RCTs.
Methods: MEDLINE, EMBASE, and PubMed were searched for biomechanical and clinical studies, as well as technique articles. Four biomechanical studies reported on moment arms, range of motion (ROM), and force vectors. Seven clinical studies reported postoperative ROM and functional outcomes, and weighted mean improvements in ROM were calculated.
Results: Overall, 18 studies were included, and then subdivided into 3 themes: biomechanical, technique, and clinical. Biomechanical studies comparing LT and latissimus dorsi (LD) transfers observed an overall larger moment arm in abduction and ER in adduction for the LT transfer, with similar results in forward elevation. Clinical studies noted significant improvement in shoulder function following the LT transfer, including ROM and functional outcome scores. There were several described techniques for performing the LT transfer, including arthroscopically assisted and open approaches, and the use of both allograft and autograft augmentation.
Conclusion: This study suggests that the LT transfer is generally safe, and the clinical and biomechanical data to date support the use of the LT transfer for restoration of function in these challenging patient populations.
Level of evidence: Level IV; Systematic Review

Keywords: Rotator cuff tear; brachial plexus palsy; lower trapezius; tendon transfer; shoulder surgery; lower trapezius transfer

Tendon transfers are a powerful reconstructive tool in the restoration of shoulder function. In particular, paralytic conditions such as acquired or congenital brachial plexus palsy and massive irreparable rotator cuff tears (RCTs) may lead to significant limitations with respect to range of motion (ROM), strength, as well as quality of

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life. Although nonsurgical strategies are often the initial treatment of choice, persistent dysfunction may prompt surgical intervention. For the paralytic shoulder, nerve release or reconstruction may be possible with variable results reported in the literature.[5,30,32,37] In the setting of a massive RCT, attempted repair—in part or full—remains the standard of care, although outcomes are variable, retear rates high, and durability questionable.[10,22,33]

When nerve reconstruction or rotator cuff repair is unsuccessful or not possible, tendon transfers may be used to improve function while potentially avoiding salvage procedures such as glenohumeral arthrodesis or reverse total shoulder arthroplasty.[1,6,20,35] In particular, when treating young active patients, tendon transfer may be preferred considering the potential functional limitations and longevity following joint replacement.[2,14,18,31]

Historically, the latissimus dorsi (LD) has been the most commonly described tendon transfer for irreparable posterosuperior RCTs, generally in adults without other shoulder pathology. On the other hand, the lower trapezius (LT) has been used mainly in the treatment of obstetrical or traumatic brachial plexus palsy, which are associated with underlying anatomic abnormalities, resulting in significant stiffness and contracture.[11,12,21,26,27,29] More recently, studies have demonstrated encouraging results with the use of the LT tendon to restore shoulder function in the setting of irreparable RCT.[15,17,38] The initial rationale for using the LT instead of the LD includes the synergistic function of the LT (scapular retraction and shoulder external rotation), having a line of pull parallel to that of the infraspinatus tendon, and being exogenous to the glenohumeral joint. Thus, the LT transfer is more anatomic, which reduces the need for intensive retraining during the recovery process.[8,27,29,35] Drawbacks include the fact that the LT is relatively weak and has a short excursion, which introduces the need for a graft when the LT transfer is being performed to manage massive, irreparable RCTs.[23] Despite this, the potential benefits have garnered attention from both researchers and clinicians, with increased interest in the feasibility and effectiveness of this tendon transfer technique.

The purpose of this systematic review is to assess the state of the current literature exploring LT transfers in both brachial plexus palsy and massive irreparable RCTs. A review of the biomechanical literature will allow comparison of LT and LD transfers and the potential advantages and disadvantages of each. A summary of the most commonly used techniques will highlight the broad principles and help surgeons choose an appropriate procedure based on individual patient, resource, and practice patterns. Lastly, a review of the available clinical outcomes will help frame expectations as LT transfer becomes an increasingly more common procedure in orthopedics.

Methods

This study was conducted according to the methodology described in the Cochrane Handbook for Systematic Reviews of Interventions and is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.

Search

EMBASE , MEDLINE, and PubMed were searched from inception to May 29, 2019. A title, abstract, and full-text screen was performed to identify relevant articles. The reference lists of eligible articles were reviewed to find other potential articles. The following search terms were used: *lower trapezius transfer*, *rotator cuff*, *brachial plexus*, *tear*, *palsy*, *dysfunction* (Supplementary Material S1). This search was limited to the English language and humans. References of included studies were reviewed for additional relevant references that met the inclusion criteria.

Eligibility criteria

Studies were included if they assessed LT transfer in cases of brachial plexus palsy or RCTs and were published in English. A restriction for year of publication was not deemed necessary. Studies were excluded if they discussed tendon transfers in general without specifically addressing LT transfers. Further exclusion criteria included contralateral or whole trapezius transfer, case studies, review articles, and expert opinion. Studies with samples smaller than 10 participants were included to increase the pool of studies to review.

Screening and assessment of eligibility

Two reviewers (J.C. and A.S.) independently screened the titles and abstracts of all studies for eligibility using piloted screening forms. Duplicate articles were manually excluded. Both reviewers evaluated the full text of all potentially eligible studies identified by title and abstract screening to determine final eligibility. All discrepancies were resolved by a consensus decision requiring rationale with the senior author.

Data extraction and assessment of risk of bias

Data were extracted independently and in duplicate by both reviewers. The selected articles were divided into the 3 relevant categories: clinical, biomechanical, and surgical technique. Data were then extracted from the clinical and biomechanical articles. In clinical studies, ROM and pain received the most attention, whereas biomechanical studies focused mainly on moment arms, ROM, and force vectors.

Two reviewers performed an independent assessment of the methodological quality using the Methodological Index for Non-Randomized Studies (MINORS)[34] tool for all nonrandomized studies and the Cochrane risk of bias tool for all randomized control trials (Supplementary Table S2).[24] We graded the level of evidence for all studies according to the criteria of Wright and Swiontkowski.[41]

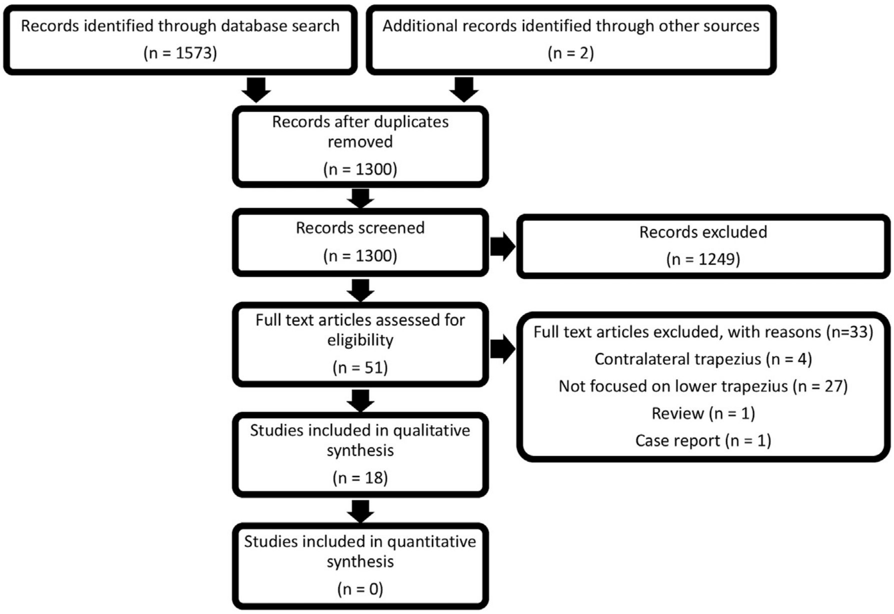

Figure 1 PRISMA flow diagram.

Statistical analysis

Interobserver agreement for reviewer's assessments of study eligibility was calculated with the Cohen κ (kappa) statistic. On the basis of the guidelines of Landis and Koch,[25] a κ of 0-0.2 represents slight agreement, 0.21-0.40 fair agreement, 0.41-0.60 moderate agreement, and 0.61-0.80 substantial agreement. A value above 0.80 is considered almost perfect agreement. Interobserver agreement for methodologic quality assessment was calculated using the intraclass correlation coefficient (ICC). Both the κ and ICC were calculated using SPSS statistical analysis software (IBM SPSS Statistics for Macintosh, Version 25.0, IBM, Armonk, NY, USA). Descriptive statistics were used and results were pooled where possible.

Results

Study selection

The initial search yielded 1573 articles, of which 273 were duplicates. Following application of inclusion and exclusion criteria, 18 articles were included in this systematic review (Figure 1). These were divided into 3 themes: clinical,[3,4,9,13,16,17,38] biomechanical,[20,21,27,29] and surgical technique [1,8,11,14,35,39,40] (Table I). The degree of agreement between reviewers, represented by Cohen *κ*, was 0.347.

Quality assessment

A MINORS quality assessment was conducted for each study included in the review. No randomized study was included. No study was blinded, but most of the outcomes measured were objective (ROM, moment arm), reducing the risk of bias (Supplementary Table S1).

Biomechanical results

Four biomechanical articles were included in the review. Three of them were cadaveric studies,[20,21,27] whereas 1 of them used simulated shoulder models.[29] Overall, the studies observed that during external rotation (ER) in adduction, the LT transfer produced larger moment arms compared with the LD transfer; in fact, the LT transfer generally produced values similar to an intact cuff during ER in abduction.

Gracitelli et al[20] assessed the feasibility of different trapezius transfers to the greater tuberosity and the viability of the repair with passive ROM in a cadaveric model. Three different biomechanical assessments were performed: (1) transfer of lower and middle trapezius together, (2) direct transfer of lower trapezius insertion (without tendon augmentation), and (3) bipolar transfer of both origin and insertion of the lower trapezius to the medial aspect of the scapula, and the infraspinatus insertion site, respectively. Each transfer was tested with the shoulder adducted and internally rotated (hand on abdomen position) with scapula fully retracted and then fully protracted. The transfer was considered successful if the tendon reached the insertion site. Success rates and incidence of accessory nerve injuries were reported. None of the direct transfers of the lower trapezius (group 2) were considered successful. Bipolar trapezius transfer had better success (7/12 with scapula retracted and 5/12 with scapula protracted); however, they report a high rate of accessory nerve injury (11/12).

Table I Summary of studies

Authors	Category	Sample size	Age, yr, mean (minimum)	Primary outcome	Follow-up, mo, mean (minimum)
Gracitelli et al[20]	Biomechanical	12	63	Transfer feasibility/suture viability	—
Hartzler et al[21]	Biomechanical	6	—	Moment arm	—
Omid et al[27]	Biomechanical	8	72.4 (52)	Range of motion	—
Reddy et al[29]	Biomechanical	12	63	Moment arm/muscle strain	—
Aibinder and Elhassan[2]	Technique	—	—	Achilles allograft	—
Clark and Elhassan[8]	Technique	—	—	Achilles allograft	—
Elhassan[11]	Technique	—	—	No graft	—
Elhassan et al[14]	Technique	—	—	Achilles allograft	—
Stoll and Codding[35]	Technique	—	—	Achilles allograft	—
Wagner and Elhassan[38]	Technique	—	—	Achilles allograft	—
Wagner et al[39]	Technique	—	—	Achilles allograft	—
Bertelli[4]	Clinical	7	28 (21)	Range of motion	48 (48)
Bertelli[3]	Clinical	7	7 (4)	Range of motion	11.7 (6)
Crepaldi et al[9]	Clinical	10	24.3	Range of motion	6 (6)
Elhassan et al[16]	Clinical	21	12 (9)	Range of motion	12 (12)
Elhassan et al[17]	Clinical	33	53 (31)	Range of motion	47 (24)
Elhassan et al[13]	Clinical	52	27 (20)	Shoulder function/range of motion	19 (12)
Valenti and Werthel[38]	Clinical/technique	15	62 (50)	Shoulder function/range of motion Semitendinosus autograft	24 (12)

Hartzler et al[21] performed a cadaveric assessment evaluating the moment arm of the LT transfer, the LD transfer, and the teres major (TM) transfer when attached to different positions around the shoulder. Assessed transfers included LT to infraspinatus insertion, LT to teres minor insertion, LD to superolateral humeral head, LD to lateral humeral diaphysis, TM to superolateral humeral head, and TM to lateral humeral diaphysis. Following transfer, the moment arm of the muscle in ER with the arm in adduction and at 90° abduction was measured. The higher the moment arm value, the more effective the muscle was at pulling on the bone during ER. The LT to infraspinatus insertion transfer demonstrated the most effective ER moment arm with the arm fully adducted and had the highest overall value. The LD to superolateral humeral head transfer demonstrated the most effective ER moment arm with the arm abducted at 90° but the difference was not statistically significant (Table II).

Omid et al[27] measured maximum internal rotation, resting humeral internal rotation, changes in anterior-posterior force at neutral humeral position, changes in compressive forces at neutral humeral rotation, superior-inferior shifts of humeral head apex, and medial lateral shifts of humeral head apex. Assessments were performed in several models: (1) an intact rotator cuff model, (2) a massive rotator cuff tear model, (3) after an LT tendon transfer tensioned at 12, 24, and 36 N, and (4) after an LD tendon transfer. Variables were measured at 0°, 30°, and 60° of abduction. The tear systematically caused an increase in internal rotation as well as an anterosuperolateral shift of the humeral head apex. None of the tendon transfers caused significant changes in maximum internal rotation or significant increases in ER, but compressive forces and shifts of the humeral head were always at least partially restored by the transfers. The LT transfer loaded both at 12 and 24 N were the most effective, and restored values closest to that of the intact cuff. The LD transfer, in some of the categories tested, applied insufficient force, thus failing to restore the initial values, whereas the LT loaded at 36 N tended to overcorrect the changes produced by the tear.

Reddy et al[29] measured moment arms and muscle strain following a variety of tendon transfers. They did not use cadavers for their study, and instead employed CT scans of healthy patients to develop a digitalized shoulder model that they manipulated to assess the tendon transfer results. They simulated 6 types of transfers: LT transfer to the site of insertion of (1) the supraspinatus, (2) the infraspinatus, or (3) the teres minor and LD transfer to the same 3 points. They measured the moment arm in abduction, forward elevation (FE), ER with the arm at 20° of abduction, and ER with the arm at 90° of abduction. Muscle strain was also measured by computing the ratio of muscle elongation over the anatomic length of the muscle. However, authors did not report exact values for all the measurements. For the sake of precision, the graphs provided in the article were not used to estimate numerical values, and only the data explicitly reported in the study are included here. For abduction, the LT transfer showed significantly higher moment arms than the LD at all 3 insertion sites, with the biggest difference demonstrated at the infraspinatus insertion (encompassing 0°-150° of abduction) (Table III). For FE, the LD transfer offered larger moment arms at all 3 insertion sites, except for the first 40° of forward flexion at the supraspinatus insertion. In general, the magnitude of the difference between LT and LD moment arms in flexion was

Table II Assessment of external rotation moment arm (Hartzler et al[21])

External rotation moment arm, mm	Lower trapezius		Latissimus dorsi		Teres major	
	Infraspinatus insertion	Teres minor insertion	Superolateral humeral head	Lateral humeral diaphysis	Superolateral humeral head	Lateral humeral diaphysis
ER in adduction	28.1	22.3	10.6	6.5	20.9	10.4
ER in 90° abduction	14.6	14.2	24.9	9.6	20.4	7.1

ER, external rotation.

smaller than the difference observed in abduction. For ER in adduction, the LT transfer provided larger moment arms at 20° adduction at both the infraspinatus and teres minor insertion sites. For ER in 90° abduction, the LD provided slightly larger moment arms at the end range. When attached to the supraspinatus insertion, the LT moment arms decreased significantly, becoming smaller than that of the LD on average. Muscle strains for the LT transfer were also significantly higher than the LD transfer (Table III).

Given the heterogeneity among variables reported in the included biomechanical studies, results could not be pooled.

Techniques

There are currently 3 general categories of techniques being used in LT transfers, and the choice made usually depends on the indication. Techniques include open direct transfer to the infraspinatus, and open or arthroscopic-assisted transfer to the greater tuberosity using graft extension (allograft or autograft). In the paralytic shoulder, the use of a graft is not necessary because the LT can be transferred to the intact but paralyzed infraspinatus without extension.[11] In cases of irreparable RCTs, the LT needs to be elongated, and this is commonly accomplished with an Achilles tendon allograft[1,8,14,35,39,40] or an autograft semitendinosus.[38] Both techniques have their own advantages and disadvantages, with autografts generally thought to incorporate faster and have a lower risk of inflammatory response at the cost of increased donor site morbidity.

The type of incision varies between open and arthroscopic technique. With the open technique, a vertical incision is placed approximately 1-2 cm medial to the medial border of the scapula, whereas in arthroscopic techniques, a horizontal incision is made just below the spine of the scapula.[1,11,14,35] In patients with brachial plexus injury, the open technique may be more extensive to allow full exposure of the lower trapezius and posterior shoulder muscles as needed. Alternatively, 2 vertical incisions may be used, one medially over the LT harvest site and a second overlying the infraspinatus tendon to allow for exposure and fixation to the infraspinatus.[11] The goal is to detach the LT from its anatomic insertion on the scapular spine and to separate it from the rest of the trapezius. When performing this separation, the accessory nerve (generally found >1.5 cm medial to the scapular border) should be protected to avoid injury or impingement. Once the LT is elevated and mobilized, the surgeon either attaches it directly to the infraspinatus tendon[11] or to a chosen tendon graft.[1,8,14,35,38-40] In the case of direct transfer to the infraspinatus, release of the posterior origin of the deltoid from the scapular spine is necessary to facilitate exposure and can be repaired once the surgery is complete.

If an Achilles allograft is chosen, no donor site procedure is necessary.[1,8,14,35,39,40] Conversely, if a semitendinosus autograft is used, 20 cm of tendon is harvested from the leg using small incision(s) and/or a tendon stripper.[38] Grafts are shuttled into the shoulder between the deltoid and native infraspinatus and attached to the chosen site on the humeral head (ie, infraspinatus insertion).[1] This can be achieved via an open approach (deltoid split or acromial osteotomy) or by more recently described arthroscopic techniques.[1,35,39] The medial infraspinatus fascia that extends between the medial edge of the posterior deltoid and medial scapula body is partially excised to allow easy passage of the tendon allograft. In the open technique described by Elhassan et al,[17] the allograft was first fixed to the LT and then shuttled into the joint to be fixed to the greater tuberosity (GT). After development of arthroscopy-assisted techniques, grafts are more commonly fixed to the GT first and then attached to the LT.[8,14,35] Either technique may be performed depending on surgeon preference, with the latter being easier to tension. Fixation at the GT is most commonly achieved by suture anchor repair, re-creating a broad footprint, or via transosseous tunnel and EndoButton fixation.[8] Medially, the tendon grafts are attached to the LT via direct suture or Pulvertaft weave.[39] Graft tensioning is performed before final fixation and is completed with the shoulder placed in full ER and 45°-90° of abduction.[1,14,40]

Clinical outcomes—pediatric brachial plexus

Two different studies assessed the effectiveness of LT transfer to restore shoulder function in pediatric brachial

Table III Assessment of moment arm and muscle strain (Reddy et al[29])

Maximum moment arm and muscle strain	Lower trapezius			Latissimus dorsi		
	Supraspinatus insertion	Infraspinatus insertion	Teres minor insertion	Supraspinatus insertion	Infraspinatus insertion	Teres minor insertion
Maximum moment arm, mm						
ER at 20° abduction	—	25.3	20.7	—	16.9	13.9
Abduction	14.5	18.0	10.6	8.6	13.6	10.6
Forward elevation	16.4	—	—	17.6	—	—
Muscle strain, elongation/resting length	0.70	0.61	0.58	0.21	0.12	0.06

ER, external rotation.

plexus palsy, resulting in a total sample of 28 patients with a mean age of 10.75 years (minimum 4) and a mean follow-up of 30 months (minimum 12).[3,16] At final follow-up, these studies had a pooled weighted mean increase of 86° in ER postoperatively. Elhassan et al[16] also measured FE in a sample of 21 patients and observed an increase of 50° postoperatively. In abduction, results are mixed, with Elhassan et al[16] reporting a 50° increase whereas Bertelli et al[3] found a 10° decrease in ROM.

Clinical outcomes—adult brachial plexus

Three studies (N = 69) evaluated the impact of LT transfer in adults with shoulder paralysis caused by brachial plexus palsy. The mean age was 26.7 years and mean follow-up was 16.4 months (6-36).[4,9,13] All outcomes were measured at final follow-up. All 3 studies assessed the increase in ER and abduction postoperatively, with a pooled weighted mean increase of 79.2° and 43.4°, respectively. Two studies (N = 62) measured FE, with a pooled weighted mean increase of 35.3° in ROM postoperatively.[9,13] One study (N = 52) measured Subjective Shoulder Value and visual analog scale scores, for which they observed a change from 5% to 40%, and 6 to 2, respectively.[13] Two studies (N = 59) assessed changes in Disabilities of the Arm, Shoulder, and Hand scores with a pooled weighted mean improvement of 48.2 points.[4,13]

Clinical outcomes—rotator cuff tear

Two studies (N = 48) assessed the effectiveness of an LT transfer in treating massive irreparable RCTs. The mean age was 55.8 years (31-70), and the mean follow-up was 39.8 months (12-73).[17,38] At final follow-up, both studies measured improvement in FE and ER, for which they observed a pooled weighted mean increase of 37.5° and 34.3°, respectively. Elhassan et al[17] also noted a 50° increase in abduction and a 34-point improvement in Disabilities of the Arm, Shoulder, and Hand score postoperatively. Both studies looked at Subjective Shoulder Value, and noted a pooled weighted mean increase of 25.8%. Lastly, Valenti and Werthel[38] reported a 5-point decrease (from 7 to 2) in pain according to the visual analog scale scores.

Discussion

Overall, the studies included in this review provide strong rationale and encouraging early clinical outcomes for the use of LT transfer in the setting of brachial plexus palsy or massive RCTs. The biomechanical evidence supports the assertion that the LT is a more anatomic transfer than the LD and provides better moment arms for abduction and ER in adduction.[29] Although the primary disadvantage of the LT transfer when compared with LD is increased muscle strain, techniques that incorporate graft augmentation have addressed this issue. In support of the anatomic and biomechanical studies, the clinical studies have consistently demonstrated significant improvements in ROM and functional outcomes among patients with both brachial plexus and massive RCTs who undergo LT transfer.

The biomechanical studies demonstrated a number of potential differences and considerations when performing LT transfer compared with LD. First, for RCTs, there is evidence of increased muscle/tendon strain when performing LT transfer and likely a higher risk of failure when a direct transfer is performed.[20,29] As such, the use of either an allograft or autograft to extend and augment the transferred tendon is imperative for a successful surgery. In the brachial plexus population, this function may be performed by the native infraspinatus. The length and the tensioning of the transfer also play a role in the ability to restore native biomechanics.[27] Omid et al[27] observed a tension of 24 N to be the most effective at restoring initial vectors on the humeral head and the scapula, whereas 12 N was often insufficient and 36 N overcorrected the changes caused by a massive RCT. Certainly, this is difficult to assess clinically, and we may develop better methods to assess appropriate tensioning as the procedure becomes more commonly performed. Finally, the biomechanical studies explored different tendon insertions, and found that the LT attached to the infraspinatus insertion creates the largest moment arm in abduction and ER in adduction.[21,29] In contrast, fixation of the LD was found to be best at the supraspinatus footprint, and there was some trend toward superiority with regard to moment arm in FE and ER in abduction (although the magnitude of this difference was not significant).[21,29] Given the potential difference in outcomes in restoring ER in adduction vs. abduction between techniques, this must be considered when assessing clinical results going forward, particularly given that ER in abduction is a critical component of restoring function in an overhead position. In addition, alternative procedures such as double transfer of the LD and TM should be considered in future biomechanical studies.[28]

As previously discussed, the specific procedure chosen for LT transfer often depends on the indications for surgery, the equipment and resources available, and individual surgeon and patient preferences. When the infraspinatus is torn, a tendon graft is required to prevent undue strain on the transferred LT.[20] Although the general belief is that an autograft incorporates quicker and reduces the risk of inflammatory response, there is insufficient evidence to find a difference in functional or clinical outcomes between techniques.[19,36] In fact, the use of Achilles allograft is by far the most well-established technique, with only 1 clinical study reporting the results of autograft to date. As such, Achilles allograft should be considered the standard of care, at least until further evidence regarding the results of autograft is available.

The clinical studies included in this review all showed improvement in ROM, strength, and functional outcome scores following the LT transfer in both brachial plexus palsy and massive, irreparable RCTs. However, the improvement in ER ROM was considerably larger for brachial plexus palsy patients than for RCTs. It still remains unclear exactly why such a difference exists; however, brachial plexus palsy patients are often younger and likely have a greater initial deficit in ER with less significant degenerative change. This may contribute to a more dramatic observed clinical increase in ROM postoperatively.

Based on the available literature, LT transfers provide similar functional benefits as LD transfers in clinical studies, but also result in improved restoration of abduction and ER in adduction moment arms in biomechanical studies. In addition, the LT transfer has been described as a simpler procedure than alternatives (such as LD and TM) because of the small incision required and relative ease of isolating the muscle and tendon.[7] Given this, although evidence is still limited, there are certainly a number of potential benefits that justify the increased utilization of LT transfer. One potential disadvantage is the necessity of using an interposition graft in the setting of rotator cuff deficiency, which adds time required to harvest or affix at each end, plus additional cost with the use of allograft. Moreover, although it is technically demanding, the LD transfer can be performed entirely arthroscopically,[40] and although arthroscopy can be used to assist the LT transfer, the LT transfer still requires an open approach to harvest the LT tendon from the scapular spine.

Although this systematic review provides a broad overview of LT transfer and its potential benefits, it should be viewed within the context of certain limitations. Because the procedure is still at an early stage, the number of studies to review and overall sample is relatively low. Furthermore, the mid- to long-term outcomes and potential complications are not established, nor has there been a prospective study comparing outcomes of different transfers. Additionally, the studies included are produced from a small number of specialist surgeons and centers that may limit the generalizability to the greater population of orthopedic surgeons. Certainly, further experience is needed to establish the effectiveness and reproducibility of these techniques.

Conclusion

LT transfer is a promising technique for the management of poor function in the setting of a brachial plexus palsy or a massive, irreparable RCT. The biomechanical rationale and early clinical results are encouraging, providing strong support for its continued use in these challenging patient populations. Long-term results and comparative data are needed to optimize outcomes and establish clear clinical indications going forward.

Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jse.2019.12.019.

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