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Outcome of arthroscopically assisted lower trapezius transfer to reconstruct massive irreparable posterior-superior rotator cuff tears

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Background: The purpose of this study is to report the outcome of arthroscopically assisted lower trapezius transfer to reconstruct irreparable posterior-superior rotator cuff tear.
Methods: Forty-one consecutive patients with irreparable posterior-superior rotator cuff tears who underwent an arthroscopically assisted transfer of the lower trapezius transfer were included in this study. The patients' average age was 52 years (range 37-71), and average follow-up was 14 months (range 6-19 months). Nineteen patients had true pseudoparalysis preoperatively, whereas 66% had a prior failed rotator cuff repair. Outcome measures included visual analog scale (VAS) pain score, range of motion, Subjective Shoulder Value (SSV), and Disabilities of the Arm, Shoulder, and Hand (DASH) score.
Results: Thirty-seven (90%) patients had significant improvement of all outcome scores: VAS, SSV, and DASH. The presence of a subscapularis tear did not affect the outcome. However, 3 patients who had preoperative rotator cuff arthropathy changes of the shoulder had persistent pain and limited range of motion of the shoulder after surgery, and 2 of them underwent reverse shoulder arthroplasty. Two additional patients had a traumatic rupture of the transfer as a result of fall (at 5 and 8 months postop). One underwent revision arthroscopic repair and did well after surgery, and the other had good pain relief but recurrent weakness and limited range of motion, and elected not to have a revision surgery.
Conclusions: Arthroscopic-assisted lower trapezius transfer may lead to a good outcome in patients with massive irreparable posterior-superior rotator cuff tears, including patients with pseudoparalysis. The presence of an associated reparable subscapularis tear did not affect the outcome.
Level of evidence: Level IV; Case Series; Treatment Study

Keywords: Irreparable rotator cuff tear; massive rotator cuff tear; arthroscopic lower trapezius transfer; shoulder tendon transfer; arthroscopic-assisted tendon transfer; rotator cuff reconstruction; shoulder reconstruction; supraspinatus and infraspinatus tear

Patients with massive irreparable rotator cuff tears are often markedly limited in their shoulder function,[37] with pain often representing their chief complaint. Massive tears involving 2 or more tendons degenerate rapidly without treatment; within as short of a time as 4 years, 50% become irreparable, with tear progression, muscular fatty infiltration, humeral head elevation, and progression of arthritis.[47] Furthermore, up to 94% of the cases[12] reportedly

Each author certifies that his or her institution approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.

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Table I Patient characteristics

Variable	Value, n (%)
Age, yr, mean (range)	52 (37-71)
Female sex	11 (27)
Prior surgeries	
Any prior shoulder surgery	33 (80)
Rotator cuff repair	27 (66)
Biceps tenodesis	14 (34)
Biceps tenotomy	10 (24)
Glenohumeral arthritis	
Mild	10 (24)
Moderate to severe	0 (0)
Repairable subscapularis tear	
Upper 1/3 of tendon	20 (49)
Upper 2/3 of tendon	5 (12)
Grade 1-4 fatty infiltration	0 (0)
Hamada grade	
Grade 1	29 (71)
Grade 2	2 (5)
Grade 3	2 (5)
Grade 4 or 5	0 (0)
Supraspinatus fatty infiltration grade	
Grade 0 or 1	0 (0)
Grade 2	0 (0)
Grade 3 or 4	41 (100)
Infraspinatus fatty infiltration grade	
Grade 0 or 1	0 (0)
Grade 2	4 (10)
Grade 3 or 4	37 (90)
Teres minor fatty infiltration grade 3 or 4	8 (20)

Unless otherwise noted, values are n (%).

demonstrate failure to heal primary repair of massive rotator cuff tears.

Initially described for the paralytic shoulder,[6] the lower trapezius transfer (LTT) is particularly appealing for massive irreparable posterosuperior cuff tears. A recent biomechanical study demonstrated that the LTT has a better moment arm for external rotation compared with latissimus dorsi transfer (LDT).[22] Furthermore, a series of 33 patients who underwent open LTTs to manage posterosuperior cuff tears achieved improvements in shoulder function and pain at 47 months of follow-up.[10]

In recent years, surgeons have modified the open technique, opting for a minimally invasive arthroscopy-assisted approach, thereby avoiding the need to perform an acromial osteotomy or to take down the deltoid to perform the transfer.[9] However, there is a paucity of clinical studies examining this minimally invasive technique. Therefore, the purpose of this study was to assess the outcomes of arthroscopy-assisted lower trapezius transfer (aaLTT) to reconstruct patients' shoulders with massive irreparable rotator cuff tears. We hypothesized that this technique would produce reliable pain relief and improvements in function while having a low risk of infection or deltoid complications.

Methods

After institutional review board approval, we performed a retrospective case series of 41 patients with irreparable massive posterosuperior rotator cuff tears who had undergone an aaLTT. The indications for the aaLTT included (1) pain and limitations in shoulder function that interfered with a patient's daily life; (2) magnetic resonance imaging (MRI) evidence of a combined supraspinatus-infraspinatus tear considered to be irreparable (retraction to glenoid along with tendon length <1 cm, fatty infiltration grade >2, and/or poor tendon quality); and (3) normal function of the lower trapezius. We also included patients undergoing revision rotator cuff repair surgery in the study.

Patient population

Table I summarizes the demographics and patient characteristics. Of note, there were 27 patients (66%) with previous failed rotator cuff surgery (open or arthroscopic); 9 had failed 2 previous repairs and 3 had more than 2 failed repairs. There were 6 other patients who had undergone prior shoulder surgeries not involving a rotator cuff repair. Other relevant pathologies included concomitant carpal tunnel syndrome in 4 patients and mild glenohumeral osteoarthritis (joint space narrowing) in 10 patients evident on radiographs and MRI.

Every patient within this cohort was considered to be "physiologically young" and active, all with a desire to return to an active level of shoulder use involving repetitive and shoulder-level or overhead activities. The majority of these patients were also potential candidates for reverse shoulder arthroplasty, but they were referred to our practice for consideration of tendon transfer surgery.

Physical examination and imaging

The physical examination findings for patients varied, despite many having similar pathology severities. Table II summarizes preoperative shoulder function. On a specific examination for posterosuperior rotator cuff findings, all patients had positive empty can test[27] and external rotation weakness with the arm to the side (muscle strength average M3, range, 2-4). External rotation lag signs were present in 31 shoulders, with a mean lag of 22° (range 20°-50°) when present. There was a Hornblower's sign in 8 (20%) patients. Sixteen patients had normal subscapularis provocative maneuvers, whereas 25 patients had positive subscapularis findings, including belly-press test and lift-off test. We defined true pseudoparalysis present for at least 6 months as active shoulder flexion $<60°$ and active shoulder abduction $<60°$, with no improvement in motion once pain was eliminated with a lidocaine injection; according to this definition, we considered 19 shoulders to have pseudoparalysis. Of note, they also all had external rotation lag signs.

Each patient underwent standard imaging protocols, including 3-view (Grashey, scapular Y, and axillary) shoulder radiographs and shoulder MRI. Radiographs showed proximal migration of the

Table II Clinical outcomes

Variable	Value, mean (range)	*P* value
Pain VAS score		<.001
Preoperative	6 (4-10)	
Postoperative	2 (1-5)	
Forward flexion		<.001
Preoperative	67° (30°-120°)	
Postoperative	133° (90°-150°)	
Abduction		<.001
Preoperative	50° (20°-80°)	
Postoperative	95° (65°-140°)	
External rotation		<.001
Preoperative	25° (−50° to 45°)	
Postoperative	47° (10°-70°)	
Disabilities of the Arm, Shoulder, and Hand score		<.001
Preoperative	49 (27-71)	
Postoperative	18 (5-26)	
Subjective Shoulder Value, %		<.001
Preoperative	55 (25-70)	
Postoperative	80 (55-100)	

VAS, visual analog scale.

humerus in 33 patients, classified according to the Hamada classification (Table I).[21] We measured the Goutallier classification of fatty infiltration on the sagittal T1 view of the MRI,[11,19] and we measured the tendon length and extent of retraction on the coronal views.

All patients had a massive posterosuperior rotator cuff tear (full-thickness tear involving the supraspinatus and infraspinatus) that we deemed irreparable because of Goutallier grade >2 fatty infiltration,[11,19] tendon length <1 cm,[32] torn tendon retracted to the level medial to the glenoid,[32] or Patte stage 2+.[29]

Surgical technique

We slightly modified the technique used from its original description.[9] In the beach chair position, they harvested the tendon before the arthroscopic portion. We first marked out surface landmarks, including the scapular spine and body, lower trapezius (LT) (origin from midthoracic to T12; insertion on medial 3-4 cm of scapular spine), and acromion. We then placed a horizontal incision just inferior to the scapular spine, from 4 cm lateral to the medial edge to 1 cm medial to the medial edge (Fig. 1). The fat triangle near the tendon insertion and the inferior muscle belly traveling diagonally up to the scapular spine helped us identify the insertion of the LT, which they then detached, mobilizing the trapezius muscle body from the underlying infraspinatus fascia. We then separated the lower and middle trapezius muscle bellies by following the horizontal part of the triangular tendinous insertion of the lower trapezius horizontally toward the midthoracic spine, protecting the spinal accessory nerve in the deep fascia of the muscle. We then prepared the tendon in a Krakow fashion with a no. 2 nonabsorbable suture to assist with mobilization (Fig. 2).

In the arthroscopic portion, the lateral portal primarily served as the main visualization portal, whereas the anterolateral and anterior portals served as working portals for the first part of the procedure. After performing a subacromial decompression, we débrided the irreparable portions of the rotator cuff, preparing the footprint of the supraspinatus to the bleeding subchondral bone. Although the muscles had advanced fatty infiltration, if surgeons could mobilize any rotator cuff to the tuberosity, they prepared it for a repair back to the tuberosity or to the transferred tendon before performing the transfer. We identified the interval for the transfer and developed such between the infraspinatus and deltoid muscle bellies. We incised the infraspinatus fascia through the medial incision to create adequate room for the transferred tendon.

We prepared the Achilles tendon allograft with 2 Krakow sutures into the portion of the tendon previously attached to the calcaneus (Fig. 3). A traction suture on the opposite end controlled tension during the transfer. We placed a large grasping clamp through the anterolateral portal, aimed at the medial incision, to grab the sutures attached to the tendon allograft and pull them out the anterolateral portal (Fig. 4).

We anchored the allograft into the tuberosity with multiple suture anchors in the anterior aspect of the supraspinatus footprint medially and laterally (Fig. 5, A and B). After fixing the allograft, the shoulder requires multiple cycles of internal and external rotation to increase the final tension of the allograft. We could then perform a partial rotator cuff repair to the graft if possible (n = 22). We also performed a tenotomy (n = 4) or tenodesis (n = 13) if biceps tendinitis and/or partial tear were present.

Prior to anchoring the allograft into the trapezius, the arm underwent maximal external rotation in 60°-90° of abduction. We split the allograft tendon (Fig. 6), and then secured it to the lower trapezius using a Pulvertaft weave technique in maximal tension (Fig. 7). Table III summarizes the postoperative therapy protocol.

Outcome measures

We used standard shoulder outcome measures to evaluate these patients, including pain level, range of motion, Subjective Shoulder Value (SSV), and Disabilities of the Arm, Shoulder, and Hand (DASH) score. We quantified pain using a visual analog scale (VAS), and measured the range of motion using a goniometer and internal rotation by determining the highest spinous process level the patient's thumb could reach. The SSV[21] and the DASH[6,7,24] score served the purposes previously described. We quantified external rotation muscle strength using the modified version of the British Medical Research Council scale.[34]

Statistical analysis

Statistical analysis involved descriptive and univariate analysis, including comparisons between preoperative and postoperative data using the Fisher exact test for categorical variables or Student *t* test of unequal variance for continuous and categorical variables. We were not able to use multivariate analysis, given the low number of patients in this study. We considered a *P* value <.05 statistically significant.

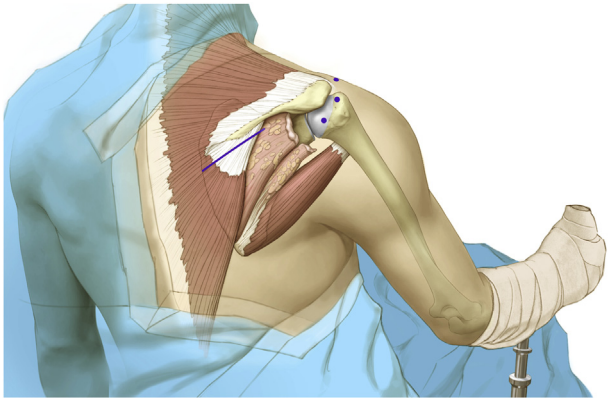

Figure 1 Lower trapezius transfer incisions. Surface landmarks include the scapular spine and body, lower trapezius (origin from midthoracic to T12; insertion on medial 3-4 cm of scapular spine), and acromion. A surgeon performs the harvest through a horizontal incision just inferior to the scapular spine, from 4 cm lateral to the medial edge to 1 cm medial to the medial edge.

Results

Clinical outcomes

At a mean follow-up of 14 months (range, 6-19 months), 37 of 41 patients had a marked improvement in all outcome measures, including pain, shoulder motion, DASH, and SSV (Table II). Of note, mean internal rotation did not significantly change from pre- to postoperative follow-up. Thirty-eight of the 41 shoulders exhibited palpable contraction of the transferred trapezius muscle at the most recent follow-up. Thirty-six patients had significant improvement of shoulder external rotation strength.

Four patients did not improve their clinical outcomes: 3 of them with arthritic changes of the shoulder and 1 with profound weakness and pseudoparalysis preoperatively.

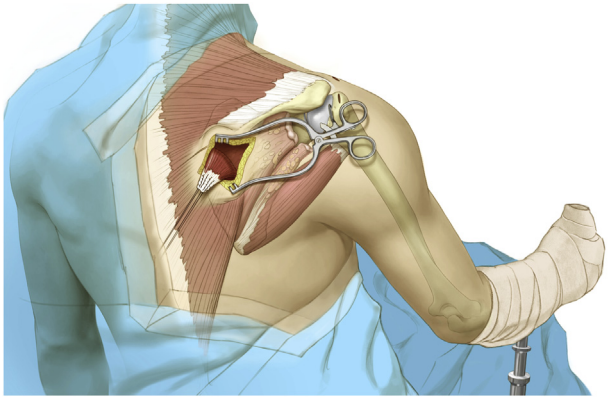

Figure 2 Lower trapezius tendon harvest. The surgeon detaches the lower trapezius from its insertion on the scapular spine, then mobilizes it away from the middle trapezius. After adequate mobilization, the surgeon then prepares the tendon in a Krakow fashion with a no. 2 nonabsorbable suture to assist with mobilization.

Figure 3 Achilles tendon allograft preparation. The surgeon prepares the allograft with 2 Krakow sutures into the portion of the tendon previously attached to the calcaneus, with a traction suture on the opposite end.

Two of these patient underwent reverse shoulder arthroplasty, both with advanced Hamada arthritic changes. Worth noting, of the 4 patients that had Hamada Grade 2 or 3 preoperatively, 2 failed to improve clinically and underwent reverse shoulder arthroplasty. The remaining 37 shoulders had near-complete pain relief (none/mild). Nine patients experienced pain relief but had minimal motion gains; these patients felt subjectively satisfied.

Factors that we found to predict a negative clinical outcomes (visual analog scale ± SSV and DASH) included long-term symptoms (>2 years), associated advanced rotator cuff arthropathy changes of the shoulder (Hamada grade 3), and true shoulder pseudoparalysis ($P < .05$). No other variables had a significant impact on clinical outcomes, including subscapularis pathology, prior surgery, teres minor fatty atrophy, mild glenohumeral arthritis (joint space narrowing), partial rotator cuff repair, preoperative pain, clinical outcomes, or age.

Radiographic evaluation

Evaluators obtained standard radiographs (Grashey, Axial, Scapular Y) at 3 months, and then every year. Of the 33 shoulders with preoperative proximal humerus migration (acromiohumeral interval, AHI), 28 showed improvement

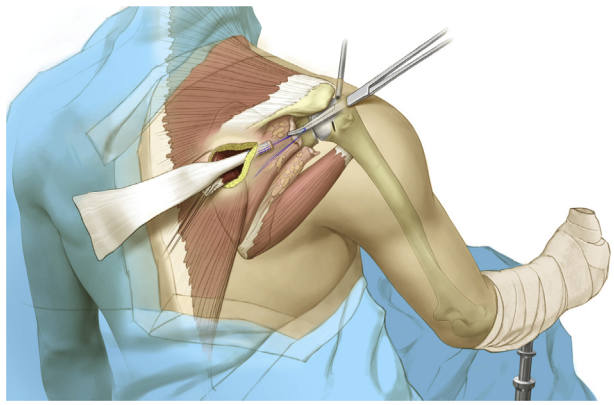

Figure 4 Tendon transfer. Using a large grasping clamp through the anterolateral portal, the surgeon grasps the sutures attached to the achilles tendon and pulls them out through the anterolateral portal to bring the tendon in proximity to the greater tuberosity.

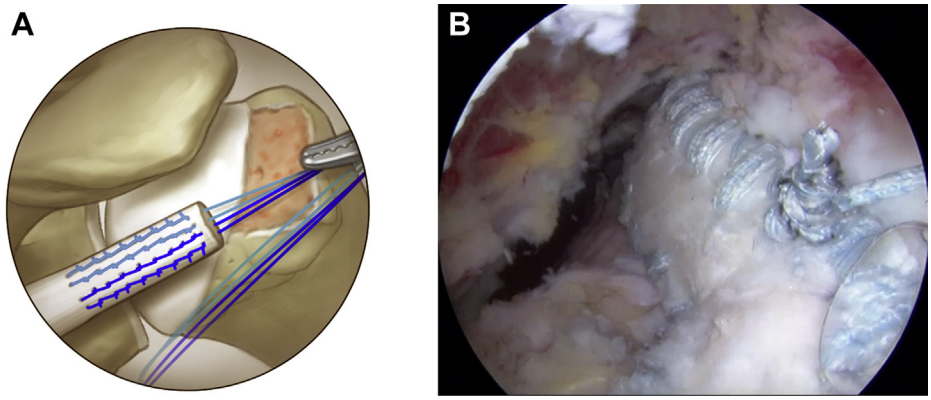

Figure 5 Graft anchored into tuberosity. (**A**) The surgeon anchors the allograft tendon into the anterior and superior aspect of the greater tuberosity, just lateral to the bicipital groove. The graft anchors with multiple self-punching anchors. (**B**) The graft is anchored to the anterior and superior aspect of the greater tuberosity and secured to any remnant rotator cuff tissue available for extra fixation.

of migration on postoperative radiographs—with complete restoration of joint congruity in 21—and persistent but improved superior subluxation in 7 shoulders. None of the shoulders with absence of proximal humeral head migration before surgery had developed proximal humeral head migration at follow-up. Joint narrowing did progress in shoulders with persistent humeral head migration; however, proximal humeral head migration did not correlate with the clinical outcome of the procedure.

Complications

There were 8 early postoperative complications, including seroma (3 shoulders) that resolved spontaneously over a 2-3-week period, a superficial infection (1 shoulder) that resolved with oral antibiotics, and hand numbness either along the thumb or in the ulnar nerve distribution (4 shoulders). We attributed peripheral nerve symptoms to use of the postoperative brace, and they resolved spontaneously over a 1-3-month period after removing the brace and starting therapy. Two shoulders sustained a traumatic rupture of the transferred tendon, which physical examination, ultrasonography, and MRI confirmed. One of these 2 shoulders underwent a successful revision aaLTT. The other patient declined a second operation, as she had achieved satisfactory pain relief despite the retear.

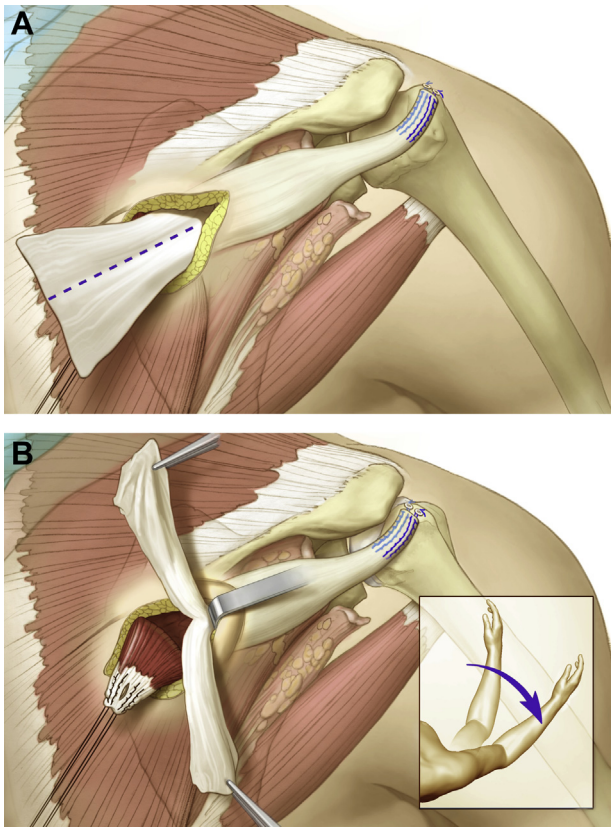

Figure 6 Preparation for lower trapezius fixation. The surgeon (**A**) splits the allograft in the midline, and (**B**) maximally externally rotates the arm in 60°-90° of abduction.

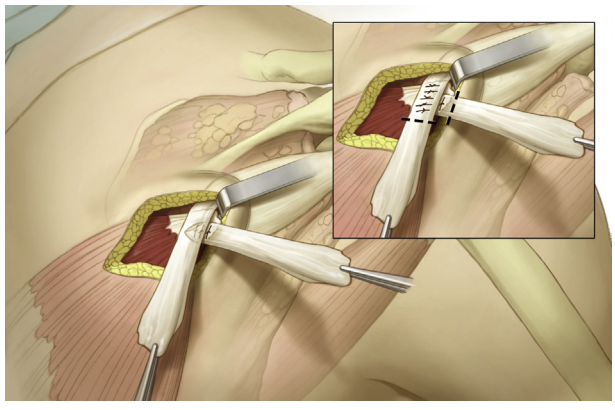

Figure 7 Fixation of graft to lower trapezius. The surgeon weaves the allograft tendon into the lower trapezius tendon via the Pulvertaft technique in maximal tension.

Table III Postoperative therapy protocol

Postoperative time point	Activity
0 to 6-8 wk	Immobilization in custom external rotation brace, with shoulder maintained in 40°-60° of external rotation
6-8 to 12 wk	Passive, active-assisted and eventually active shoulder motion with an internal rotation limit to 0°; pool-based exercises are encouraged
12-16 wk	Gradual removal of passive and active internal rotation limit; return to most activities of daily living
16 wk to 6 mo	Gradual progression of strengthening without motion limits in internal and external rotation, and abduction are permitted
6 mo	Return to full unrestricted activities

Discussion

Surgically managing massive irreparable posterosuperior rotator cuff tears is controversial. A number of factors may contribute to tear irreparability, including muscular fatty infiltration,[16,19,25,32,42] tendon retraction,[29] and chronicity.[4,12,25,29,37] In the absence of advanced arthritis, joint-preserving treatment options include arthroscopic débridement,[30,41] partial repair,[1,38] patch or interposition grafting,[31,36] superior capsular reconstruction,[33] and tendon transfers including the latissimus dorsi[2,14,17,18,28,43] and LTT.[9,10] The results of arthroscopic débridement[30,41] and partial repair[38] deteriorate with time, whereas the reported outcomes of graft augmentation and superior capsular reconstruction are limited to small case series with short-term follow-up. Some tendon transfers evidently maintain clinical and radiographic improvements over a long-term follow-up period,[15,35] likely because of their dynamic restoration force couple balances.

The results of this study indicate that aaLTT yields reliable improvements in pain level, shoulder motion, and overall shoulder function. Factors that predicted improved outcomes included shoulder flexion more than 60°, minimal to no rotator cuff arthropathy (Hamada grade 2 or less) of the shoulder, and <2 years' time interval between symptoms and presentation for treatment. Worth noting, preoperative fatty infiltration, subscapularis integrity, and humeral head elevation did not have a significant impact on functional outcomes.

Traditionally, the main tendon transfer for irreparable posterosuperior rotator cuff tears has been the LDT. Since Gerber et al initially described it in 1998,[17] the open technique[7,13,17,34,44] and, more recently, the arthroscopy-assisted technique[2,3,20,26,40,46] have achieved good shoulder pain relief and functional improvements. Several factors lead to worse outcomes after this transfer, including prior rotator cuff repair,[2,14,35,43] pseudoparalysis,[2,24] poor subscapularis function,[14,15,35] and critical shoulder angle >35°.[15] Furthermore, a biomechanical study demonstrated that the external rotation and abduction forces after the LDT are dependent on the counterbalancing forces of the subscapularis.[45]

The LT has emerged as a very good alternative when tendon transfers are considered for irreparable posterosuperior cuff tears. Since Elhassan et al[6] originally described it in 2009, it has proven to successfully restore external rotation in the paralytic shoulder.[5,7,8] This may be partly due to its "in-phase" contraction with the native shoulder external rotators and abductors,[39] a similar excursion when compared to the infraspinatus,[23] and "in-line" pull that simulates the infraspinatus line of pull. These potentially overcome some of the limitations of the LDT, including the humeral head depression and anterior translation and potential lack of synchronous contraction. These are also why the LTT does not have poor outcomes in the setting of a subscapularis tear, unlike the LDT. In a recent study on open LTT for massive irreparable rotator cuff tears, 33 patients followed for a mean 47 months experienced good pain relief and improvements in external rotation and abduction, as well as other patient-reported outcome measures.[10] Outcomes were better in patients with preoperative elevation >60°.

In spite of the lack of clinical comparative studies, the aaLTT remains our preferred tendon transfer for massive irreparable posterosuperior rotator cuff tears for multiple reasons: (1) the biomechanical advantage of the lower trapezius over the latissimus in part because of its cranial origin location and line of pull that better mimics the infraspinatus; (2) similar tension and excursion to the infraspinatus; (3) "in-phase" contraction of the LT during shoulder external rotation and abduction; (4) cranial origin of the LT potentially leads to less humeral head depression and anterior translation in the setting of subscapularis insufficiency. By restoring the anterior-posterior force couple of the rotator cuff, the deltoid, along with a contribution of the LT, is able to power shoulder elevation. In this study, in comparison to the LDT, prior rotator cuff repair,[2,14,35,43] pseudoparalysis,[2,24] or poor subscapularis function[14,15,35] did not have an adverse effect on clinical outcomes after the aaLTT. Given that most of the patients in this series had a prior rotator cuff repair, we feel this exemplifies the role for the aaLTT as a promising option for patients with failed prior rotator cuff repairs.

Readers should take the findings of this study in light of certain limitations. This is a small series with short-term follow-up. This limits our ability to comment on the sustainability of this transfer over a long-term follow-up period. The small number of patients also prevents us from being able to perform a multivariate analysis as well as an in-depth analysis of factors that influence the postoperative outcomes after this transfer. Finally, a fellowship-trained shoulder surgeon performed the transfers at a large academic referral center, opening it up to all the potential limitations of these studies, including referral bias and questionable generalizability. Nonetheless, this is the first and largest analysis of the aaLTT. It demonstrates the potential for this minimally invasive transfer and highlights the importance for future comparative studies between various reconstructive techniques for massive irreparable posterosuperior rotator cuff tears.

Conclusion

The results of this study seem to indicate that the minimally invasive aaLTT, prolonged with an Achilles tendon allograft, leads to improved pain levels and functional outcomes in patients with massive irreparable posterosuperior rotator cuff tears. We particularly see improved outcomes in patients with shoulder flexion $>60^{\circ}$, minimal to no arthritis of the shoulder, and <2 years' time interval between symptoms and presentation for treatment. Potential advantages for this tendon transfer include a similar excursion and line of pull to the infraspinatus tendon, ''in-phase'' contraction with external rotation and abduction, less humeral head depression in the setting of subscapularis insufficiency, and minimally invasive approach avoiding an acromial osteotomy. Furthermore, most patients had a prior failed rotator cuff repair, demonstrating the role for the aaLTT in treating failed rotator cuff repairs.

Disclaimer

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