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Arthroscopic lower trapezius tendon transfer provides equivalent outcomes to latissimus dorsi transfer in the treatment of massive posterosuperior rotator cuff tears

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ABSTRACT

Objectives The purpose of this study is to compare early postoperative recovery following open and arthroscopic-assisted latissimus dorsi tendon (aa-LDT) transfer to arthroscopic-assisted lower trapezius tendon (aa-LTT) transfer for patients with massive irreparable posterosuperior rotator cuff pathology.

Methods A multicentre retrospective analysis comparing the postoperative outcomes after open LDT, arthroscopic-assisted LDT (aa-LDT) or arthroscopic-assisted LTT (aa-LTT) was performed. Active range of motion and patient-reported subjective outcomes were reported preoperatively and postoperatively. Overall, there were 10 patients who underwent open LDT transfer, 16 aaLDT transfers and 8 aa-LTT transfers with mean age of 55±3, 57±6 and 53±13, respectively. Mean follow-up was 22±10 months.

Results Arthroscopic-assisted LDT had significantly improved postoperative forward flexion (85–124, p<0.003) and external rotation (29–38, p<0.005), whereas aa-LTT had significantly improved postoperative forward flexion (101–146, p<0.04). Arthroscopic-assisted LDT and aa-LTT transfers improved American Shoulder and Elbow Surgeons (ASES) Shoulder Function scores and Single Assessment Numeric Evaluation (SANE) at 2 years (p<0.03). Arthroscopic-assisted LTT compared with open LDT demonstrated significantly improved ASES Shoulder Index score (20.0 vs 12.6; 84.8 vs 55.6) and visual analogue scale (VAS) (0.66 vs 4.14; 1.17 vs 3.88) at postoperative 6 months and 2 years, respectively. Arthroscopic-assisted LDT transfer compared with open LDT had improved VAS at 6 months (0.66 vs 2.11, p<0.05). In total, 6 (17.6%) complications were noted. These included two infections with *Cutibacterium acnes*, two axillary nerve injuries, complex regional pain syndrome and a postsurgical adhesive capsulitis.

Conclusions Arthroscopic-assisted LDT and aa-LTT transfers provided improvement in pain and function at 2-year follow-up. The aa-LTT transfer provided significantly improved outcomes at 2 years compared with the open-LDT (latissimus dorsi tendon transfer) transfer. This study demonstrates superiority of arthroscopic-assisted tendon transfer techniques over traditional open techniques while establishing the aa-LTT transfer as a safe and effective alternative in the management of massive irreparable rotator cuff tears.

Level of evidence IV.

What are the new findings

- ▶ Arthroscopic techniques provide improved outcomes over traditional open tendon transfer.
- ▶ Lower trapezius transfer resulted in improved outcome when compared with open latissimus dorsi transfer.
- ▶ Arthroscopic-assisted lower trapezius tendon transfer is a safe alternative in the treatment of massive irreparable rotator cuff tears.

INTRODUCTION

The management of chronic massive (two or more tendons involved) rotator cuff tears is challenging.^{1,2} Many of these tears are considered ‘irreparable’ given that retear rates have been reported to be as high as 79%–94%.^{2,3} Factors that have been identified to increase the retear rate, and thus be associated with irreparable tears, include increased fatty infiltration, tendon retraction, muscle atrophy and decreased tendon length.^{4–6} Furthermore, if left untreated, these tears can progress to shoulder degeneration in as short as 4 years.⁷

Many salvage options exist for the treatment of massive irreparable rotator cuff tears including debridement, biceps tenotomy or tenodesis, partial rotator cuff repair, bridging repair, superior capsular reconstruction and tendon transfers.^{8–13} In the chronic setting, tendon transfers can provide dynamic functional replacement for the deficient rotator cuff.^{14–17} Open latissimus dorsi tendon (LDT) transfer has a long-standing history of success, with predictable pain relief and improved shoulder function. The open lower trapezius tendon (LTT) transfer has been introduced as an alternative to the LDT transfer, with potential advantages including it being an ‘in-phase’ and ‘in-line’ transfer with similarly good clinical outcomes.^{18–20}

In recent years, both LDT and LTT transfer techniques have been modified to include arthroscopic-assisted techniques for anchoring the tendon into the greater tuberosity, thus avoiding the need for an acromial osteotomy or deltoid take-down.^{21–25} This is particularly important given the controversy that a certain number of patients will not respond well after open LDT transfers in many series.^{17 26 27} Furthermore, the outcomes of arthroscopic-assisted LTT have not been reported. The purpose of this study is to compare the outcomes for pain and

function after open LDT, arthroscopic-assisted LDT (aa-LDT) and arthroscopic-assisted LTT (aa-LTT) transfers.

MATERIALS AND METHODS

Approval was obtained from two independent institutional review boards. A multicentre retrospective analysis was performed using data stored in the Surgical Outcomes System (SOS) database (Arthrex Inc, Naples, Florida, USA). After consented for participation, patients received seven surveys via email over the course of 2 years at select time intervals assessing patient reported outcome measures regarding pain, active range of motion and functional scores. Operative details from each surgery were entered into the patient's SOS record by the surgeon or research fellow. The operation was performed by one of two surgeons (LDH or JPW). After their preoperative survey, patients received questionnaires at 2 weeks, 6 weeks, 3 months, 6 months, 1 year and 2 years. Validated outcomes measured included the American Shoulder and Elbow score (ASES), Single Assessment Numeric Evaluation (SANE) score and visual analogue scale (VAS) for pain, on a scale of 0–10.^{28 29}

All patients selected to undergo tendon transfer demonstrated a chronic massive posterosuperior rotator cuff tear in the absence of arthritis. Inclusion required a Goutallier grade of 2, 3 or 4, a Hamada grade of 0, 1 or 2 and an inability to reduce the rotator cuff to the rotator footprint despite adequate mobilisation techniques. The subscapularis was intact or fully repairable. Patients were excluded if they did not complete a preoperative baseline survey. All patients participated in the same standardised rehabilitation protocol.

Patient demographics

A total of 34 patients were included in the study. There were 10 patients who underwent an open LDT transfer (8 men, 2 women), 16 aa-LDT transfer (13 men, 3 women) and 8 underwent aa-LTT transfer (five men, 3 women). The mean age for open LDT, aa-LDT and aa-LTT was 55 ± 3 , 57 ± 6 , and 53 ± 13 , respectively. Of aa-LDT, open LDT and aa-LTT cohorts, 81.3%, 80.0% and 50% had prior rotator cuff repairs. The three cohorts demonstrated comparable demographics including gender, smoking status, diabetes diagnosis, insurance coverage, age and body mass index. The demographic information is summarised in [table 1](#).

Surgical details

The surgical technique used for open LDT transfer and the aa-LDT and aa-LTT transfers have been previously described with slight modifications.^{13–15 30} In brief, all techniques were performed in the beach chair position with an arm holder. For the LDT transfers, an incision is made over the posterior axillary fold overlying the latissimus muscle. The tendon is released directly off the humerus ensuring maximal length. Adequate excursion is achieved with release of adhesions to the teres major (TM), the subcutaneous tissue on the chest wall and the inferior angle of the scapula while protecting the neurovascular bundle. The tendon is prepared for passage with placement of two heavy non-absorbable running sutures on either side of the tendon. The remainder of the procedure was performed either open or arthroscopic-assisted. For the open cases, an acromion osteotomy was performed allowing direct visualisation to the proximal humerus and rotator cuff. The LDT is then transferred into the shoulder between the teres minor and the deltoid. The tendon is secured to the anterolateral aspect of the greater

Table 1 Study population demographics

	aa-LDT (n=16)	Open LDT (n=10)	aa-LTT (n=8)
Gender			
Male		80.0%	62.5%
Female	18.8%	20.0%	37.5%
Tobacco use			
Non-smoker	75.0%	80.0%	100.0%
Smoker	25.0%	20.0%	0.0%
Diabetes			
Non-diabetic	81.3%	80.0%	100.0%
Diabetic	18.7%	20.0%	0.0%
Worker's compensation (WC)			
Non-WC	43.8%	60.0%	75.0%
WC	56.2%	40.0%	25.0%
Anxiety, depression, PTSD or bipolar disorders			
No	75.0%	75.0%	100.0%
Yes	25.0%	25.0%	0.0%
Rheumatoid arthritis			
No	100.0%	100.0%	100.0%
Yes	0.0%	0.0%	0.0%
Previous rotator cuff repair			
No	18.8%	20.0%	50.0%
Yes	81.3%	80.0%	50.0%
Age	57	55	53
BMI	30.0	31.1	27.8

aa-LDT, arthroscopic-assisted latissimus dorsi tendon; aa-LTT, arthroscopic-assisted lower trapezius tendon transfer; BMI, body mass index; open LDT, open latissimus dorsi tendon transfer; PTSD, post-traumatic stress disorder.

tuberosity with suture anchor fixation. A partial rotator cuff repair is performed when possible.

The LTT is harvested through an 6–8 cm incision centred over its insertion on the medial spine of the scapula. The LTT is mobilised with release from the scapular, middle trapezius and chest wall while protecting the neurovascular bundle on its under-surface. Two non-absorbable running sutures are placed down either side of an Achilles tendon allograft, which is transferred into the shoulder arthroscopic-assisted beneath the infraspinatus fascia and secured to the anterolateral aspect of the greater tuberosity. The arm is then placed in maximum external rotation and 60° abduction and the allograft and LTT are secured with a pulvertaft weave.

Statistical analysis

Descriptive statistics were used for overall outcomes and relevant comparisons between the open LDT, aa-LDT and aa-LTT transfer procedures. Using one-tailed Student's t-test with unequal variances, we compared preoperative and postoperative patient-reported outcomes measures (PROMs) and range of motion (ROM) in individual open LDT, aa-LDT and aa-LTT groups. Additionally, we made a comparison of PROMs and ROMs among all three groups using Student's t-test. P value <0.05 was considered statistically significant. Microsoft Excel programme was used to perform the statistical analysis.

RESULTS

Outcome measures

Arthroscopic-assisted LTT had the lowest overall pain scores at all time points (including preoperatively), but the improvement

Table 2 Preoperative (preop) versus postoperative (postop) patient-reported outcomes measures (PROMs) for arthroscopic-assisted latissimus dorsi tendon transfer (aa-LDT), open LDT and arthroscopic-assisted lower trapezius tendon transfer (aa-LTT)

Preoperative versus postoperative (2 years) PROMs				
		aa-LDT	Open LDT	aa-LTT
VAS	Preop	4.04	5.33	2.85
	Postop	1.65	3.88	1.17
	P value	0.19	0.21	0.089
ASES function	Preop	9.1	12.1	12.5
	Postop	19.1	15.0	24.4
	P value	0.026	0.28	0.0092
ASES index	Preop	39.0	44.0	56.6
	Postop	70.1	55.6	84.8
	P value	0.026	0.20	0.0056
SANE	Preop	21.0	36.0	34.4
	Postop	71.0	55.0	68.0
	P value	0.0078	0.34	0.0026

Shaded red indicates $p < 0.05$.

ASES, American Shoulder and Elbow score; SANE, Single Assessment Numeric Evaluation; VAS, visual analogue scale.

did not reach statistical significance ($p = 0.089$). In comparison with open LDT, aa-LDT had lower pain scores at all time points, but this was not statistically significant (table 2). However, when compared with open LDT, aa-LTT demonstrated significantly lower pain scores at 6 months and 2 years postoperatively ($p = 0.014$ and $p = 0.037$, respectively) (table 2; figure 1). At 2 years postoperatively, aa-LDT and aa-LTT provided significantly improved forward elevation ($p = 0.0027$ and $p = 0.031$; respectively) (table 3).

Table 3 Preoperative (preop) and postoperative (postop) range of motion (ROM) comparison for arthroscopic-assisted latissimus dorsi tendon transfer (aa-LDT), open LDT and arthroscopic-assisted lower trapezius tendon transfer (aa-LTT)

Preoperative versus postoperative ROMs						
	Forward flexion			External rotation		
	Preop	Postop	P value	Preop	Postop	P value
aa-LDT	85	124	0.0027	29	38	0.0044
Open LDT	126	110	0.26	51	33	0.15
aa-LTT	101	146	0.031	33	44	0.27

Shaded red indicates $p < 0.05$.

Arthroscopic-assisted treatments demonstrated significant improvements compared with preoperatively in ASES index, ASES function and SANE score at 2-year postoperatively ($p < 0.05$) (table 2; figure 1). Compared with preoperative, open LDT transfer did not demonstrate significant improvement in VAS, ASES index, ASES function or SANE at 2-year postoperatively ($p > 0.05$) (table 2; figure 1).

Comparing the three techniques, aa-LTT transfer resulted in significantly better VAS at 6 months when compared with both aa-LDT and open LDT ($p = 0.042$ and $p = 0.014$, respectively) (table 4). When compared with open LDT, aa-LTT also had improved ASES function and ASES index scores at 6 months ($p = 0.041$ and $p = 0.031$, respectively) (table 4). Significant differences between aa-LTT and open LDT persisted at 2 years for VAS and ASES index ($p = 0.037$ and $p = 0.044$, respectively) (table 4). There was no difference in outcomes between the aa-LDT and open LDT at any timepoint postoperatively (table 4).

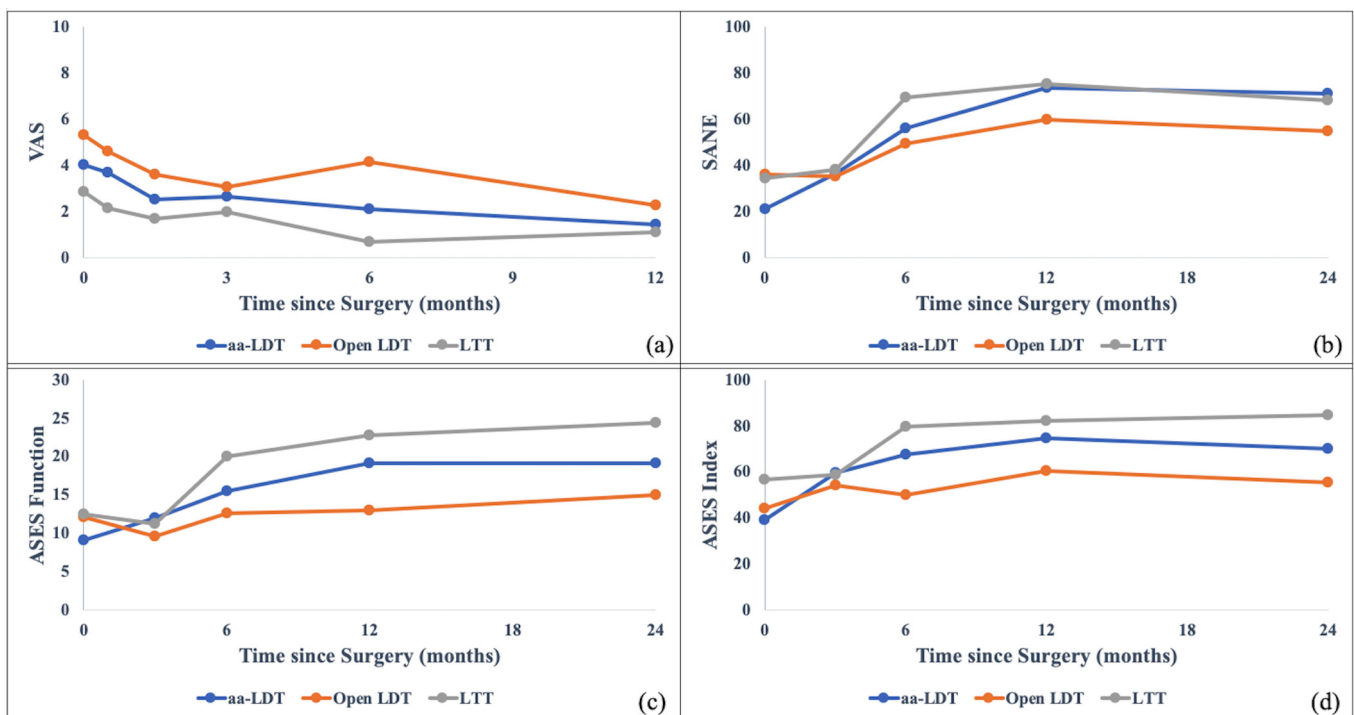


Figure 1 (A) Visual analogue scale (VAS) pain score, (B) Single Assessment Numeric Evaluation (SANE) score, (C) American Shoulder and Elbow Society (ASES) function score and (D) ASES index score for arthroscopic-assisted latissimus dorsi tendon transfer (aa-LDT), open LDT and lower trapezius tendon transfer (LTT) groups.

Table 4 Statistical comparison for arthroscopic-assisted latissimus dorsi tendon transfer (aa-LDT), open LDT and lower trapezius tendon transfer (LTT)

		Preop	3 months	6 months	1 year	2 years
aa-LDT versus open LDT						
VAS	aa-LDT	4.04	2.63	2.11	1.43	1.65
	Open LDT	5.33	3.08	4.14	2.26	3.88
	P value	0.33	0.67	0.12	0.38	0.085
ASES function	aa-LDT	9.1	12.0	15.5	19.1	19.1
	Open LDT	12.1	9.6	12.6	13.0	15.0
	P value	0.32	0.53	0.42	0.15	0.39
ASES index	aa-LDT	39.0	59.8	67.6	74.7	70.1
	Open LDT	44.0	54.0	50.0	60.4	55.6
	P value	0.54	0.57	0.17	0.10	0.29
SANE	aa-LDT	21.0	36.6	56.1	73.5	71.0
	Open LDT	36.0	35.1	49.4	60.0	55.0
	P value	0.14	0.91	0.51	0.22	0.30
aa-LDT vs aa-LTT						
VAS	aa-LDT	4.04	2.63	2.11	1.43	1.65
	LTT	2.85	1.97	0.66	1.11	1.17
	P value	0.27	0.49	0.042	0.71	0.61
ASES function	aa-LDT	9.1	12.0	15.5	19.1	19.1
	LTT	12.5	11.3	20.0	22.7	24.4
	P value	0.22	0.79	0.20	0.32	0.13
ASES index	aa-LDT	39.0	59.8	67.6	74.7	70.1
	LTT	56.6	58.9	79.6	82.3	84.8
	P value	0.015	0.92	0.17	0.41	0.14
SANE	aa-LDT	21.0	36.6	56.1	73.5	71.0
	LTT	34.4	38.3	69.3	75.1	68.0
	P value	0.13	0.86	0.23	0.82	0.79
Open LDT versus aa-LTT						
VAS	Open LDT	5.33	3.08	4.14	2.26	3.88
	LTT	2.85	1.97	0.66	1.11	1.17
	P value	0.083	0.29	0.014	0.28	0.037
ASES function	Open LDT	9.1	9.6	12.6	13.0	15.0
	LTT	12.5	11.3	20.0	22.7	24.4
	P value	0.92	0.60	0.041	0.033	0.073
ASES index	Open LDT	44.0	54.0	50.0	60.4	55.6
	LTT	56.6	58.9	79.6	82.3	84.8
	P value	0.18	0.57	0.031	0.020	0.044
SANE	Open LDT	36.0	35.1	49.4	60.0	55.0
	LTT	34.4	38.3	69.3	75.1	68.0
	P value	0.89	0.78	0.085	0.13	0.41

Shaded red indicates $p < 0.05$.

ASES, American Shoulder and Elbow score; SANE, Single Assessment Numeric Evaluation; VAS, visual analogue scale.

Complications

A total of six (17.6%) complications were identified, of which three had aa-LDT and the other three had open LDT. No complications were identified in the aa-LTT cohort. Among those who developed complications in the aa-LDT group, one patient developed an infection requiring irrigation, debridement and cultures revealing *Cutibacterium acnes* and *Finegoldia*. The patient was treated with intravenous followed by oral antibiotics. The infection was successfully eradicated, and the patient went on to achieve excellent ROM and underwent an MRI that confirmed that the graft remained intact. The second patient sustained an axillary nerve palsy with a motor and sensory deficit. Initial EMG demonstrated that the nerve had sustained a stretch injury. Sensation has since normalised, and motor power continues to improve at 1-year follow-up. The third patient

underwent a reverse shoulder arthroplasty for persistent pain. Transfer was intact during surgery. Among those who underwent open LDT, one patient was diagnosed with complex regional pain syndrome at 6 months but was lost to follow-up. Another patient was diagnosed with postsurgical adhesive capsulitis. The patient was offered surgical release, but this has been postponed for other medical work-up. Last, a patient developed an infection requiring irrigation and debridement at 4 weeks following by antibiotics. At 1-year follow-up, the infection was eradicated.

DISCUSSION

The most important finding of this study is that aa-LDT and aa-LTT transfers provided improvement in pain and function at 2-year follow-up. There was no difference in outcomes when

comparing aa-LTT and aa-LDT (table 4). Significantly improved outcomes were observed following aa-LTT when compared with the openLDT technique.

The open LDT transfer was originally described by Gerber *et al* in 1988, and subsequent reports by this group have demonstrated predictable and reliable improvements in patients pain and function over a long-term follow-up period.^{14–16 30} However, poor predictors of outcomes after the open LDT, including difficulty retraining the transfer,²⁷ teres minor or subscapularis pathology^{14 17 31} and prior failed rotator cuff repair,^{17 31 32} has led surgeons to innovate novel modifications to improve on these outcomes including avoiding the acromial osteotomy or deltoid take-down to gain exposure to the greater tuberosity, by performing an ‘arthroscopic-assisted’ approach to anchoring the tendon.^{1 13 21 23 24 33–37} Although there has been promising results for both open and arthroscopic-assisted approaches, there remains a paucity of studies comparing the various treatment options.^{1 14 15 17 18 21 24 30–32 34 38 39}

The open lower trapezius tendon transfer has been proposed as an alternative treatment option. Initially described for brachial plexus lesions by Elhassan *et al* in 2009,³⁸ the technique has been modified by using an Achilles tendon allograft to treat patients with massive irreparable posterosuperior rotator cuff tears.²² In the current study, the aa-LTT transfer demonstrated improved pain and functional outcomes at 2-year follow-up with significantly improved outcomes when compared with open LDT and no difference when compared with aa-LDT. Although this study is limited in its small numbers, these findings may be related to the inherent biomechanical advantages that the LTT has over the LDT when used in the treatment of massive irreparable rotator cuff tears. First, the LTT is an ‘in-phase’ transfer, shown to fire on electromyography (EMG) in a normal shoulder when the patient abducts and/or externally rotates their shoulder.²⁰ The LDT requires patients to retrain an ‘out of phase’ muscle to fire during shoulder abduction and external rotation, instead of internal rotation and adduction.²⁷ A second consideration when comparing the two transfers involves the line of pull. The LTT line of pull closely mimics the infraspinatus. The external rotation moment arm (ERMA) of the LDT, LTT and TM were evaluated in a cadaveric study using six fresh-frozen specimens.¹⁹ With the arm at the side, the LTT demonstrated a significantly greater ERMA than both the LDT and TM. The LDT origin is inferior to both the infraspinatus and lower trapezius. Thus, when the arm was placed in 90° of abduction, the LDT demonstrated the greatest ERMA, which can also assist with forward elevation of the upper extremity. While both of these transfers have been clinically proven to improve external rotation, there may be a role for selecting a LTT transfer when the ER lag is predominantly at 0° shoulder abduction and LDT transfer when the ER lag is predominantly at 90° of abduction. This is the first study to directly compare the outcomes of these two types of tendon transfer. The findings confirm that both arthroscopic-assisted techniques provide significant improvement in pain and function. Future research is needed to determine if more specific indications should be considered for each type of transfer, such as the predominant location of ER lag.

To avoid having to perform an acromial osteotomy or deltoid take-down, there has been recent innovations in performing these techniques arthroscopic-assisted.^{1 21 22 24 32 34 39} These techniques allow for the potential advantages of decreased soft-tissue dissection, improved intra-articular visualisation, improved anchor positioning and the ability to identify and treat concomitant pathology. The current study demonstrates significant improvements in pain, function and subjective

shoulder evaluation following arthroscopic techniques with no significant improvement observed with an open approach. Delayed recovery following open techniques has been previously observed in rotator cuff surgery when comparing arthroscopic to mini-open techniques.⁴⁰ Although rare, postoperative stiffness is significantly more common following open rotator cuff repair.³⁹ In addition to the potential for a more rapid recovery and an improved outcome, arthroscopic techniques also provide the proposed benefits of smaller skin incisions, less soft tissue dissection and the ability to easily identify and treat concomitant intra-articular pathology.⁴¹

The following limitations should be considered when interpreting the results of this study. First, this was a retrospective study with its inherent biases. Second, although this is the first comparative study to evaluate the outcomes of LDT transfer versus LTT transfer, it remains limited by its relatively small sample size. Third, long-term data are not available for these recently developed arthroscopic-assisted techniques. Thus, it is not possible to comment on the durability of each procedure over time. Additionally, when comparing the outcomes of open transfer to those performed arthroscopic-assisted, the improved outcomes with arthroscopy-assisted techniques may reflect surgeon learning curve rather than the techniques themselves as the open cases were all performed prior to the arthroscopic-assisted cases for each of the participating surgeons.³⁹ Finally, the preoperative status of the patients could not be standardised, which, as has been demonstrated by Castricini *et al*, could bias the results.³¹

CONCLUSIONS

Arthroscopic-assisted LDT and aa-LTT transfer provided improvement in pain and function at 2-year follow-up. The aa-LTT transfer provided significantly improved outcomes at 2 years compared with the o-LDT transfer. This study demonstrates superiority of arthroscopic-assisted tendon transfer techniques over traditional open techniques while establishing the aa-LTT transfer as a safe and effective alternative in the management of massive irreparable rotator cuff tears.

Contributors JMW and ERW have contributed equally in this paper as first coauthors. Design: JMW, MJC, KMW, ERW, LDH and JPW. Data acquisition: JMW, MJC, KMW, ERW and FG. Data analysis: JMW, MJC, KMW, ERW and FG. Manuscript drafting: JMW, MJC, KMW, ERW, LDH and JPW.

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Patient consent for publication Not required.

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