Augmented latissimus dorsi transfer: initial results in patients with massive irreparable posterosuperior rotator cuff tears

Claudia C. Sidler-Maier¹, Jennifer A. Mutch², Martin Sidler³,
Dimitra Leivadiotou⁴, Jubin B. Payandeh⁵ and Diane Nam⁶

Abstract

Background: The surgical treatment of irreparable massive rotator cuff tears is challenging. The purpose of the present study was to report the initial outcomes after a modified latissimus dorsi transfer (LDT) augmented by acellular dermal allograft (ADA).

Methods: This retrospective study includes 24 patients managed with LDT using ADA augmentation as a bursal-sided onlay between March 2009 and December 2015.

Results: All patients were men with a mean age of 57 years (range 48 years to 70 years). Seven patients had a previously failed rotator cuff repair and ten patients presented with a deficient subscapularis tendon. At last follow-up (mean 27 months), there was a significant improvement in active forward flexion (mean increase 31°; $p = 0.016$), and abduction by 25° ($p = 0.059$). The acromiohumeral distance remained stable and the failure rate was low (4%). Neither a history of previous rotator cuff surgery, nor the presence of a subscapularis tear had a negative impact on functional outcome.

Conclusions: In our cohort of patients, LDT augmented with ADA was a reasonable option for patients with previously failed rotator cuff repair, as well as in the subgroup of patients with a deficient subscapularis tendon.

Level of evidence: Level IV: Therapeutic study (case series)

Keywords

augmentation, GraftJacket, human dermal tissue allograft, irreparable massive rotator cuff tear, latissimus dorsi, rotator cuff, tendon transfer

Date received: 7th March 2017; revised: 23rd November 2017; accepted: 25th November 2017

Introduction

The successful treatment of massive irreparable rotator cuff tears is challenging,^{1,2} especially in the presence of a deficient subscapularis tendon. Latissimus dorsi transfer (LDT) was originally described by Gerber et al.³ in 1988 and has subsequently become an established reconstructive procedure.⁴

Transfer of the latissimus dorsi tendon to the desired recipient site on the superior leading edge of the subscapularis may result in increased tendon tension and decreased healing resulting in early re-rupture. This high failure rate following LDT (4% to 44%)^{4–6} has lead to investigations using scaffolds and other tissue augments to enhance tissue strength and protect the

¹Upper Limb Surgery, Ashford and St Peter's Hospital, NHS Foundation Trust, Chertsey, Surrey, UK

²Department of Orthopaedic Surgery, St-Mary's Hospital Center, Montreal, Canada

³Department of Paediatric and Neonatal Surgery, Great Ormond Street Hospital, London, UK

⁴Orthopaedic Department, East Surrey Hospital, Surrey, UK

⁵Department of Orthopaedic Surgery, Thunder Bay Regional Health Sciences Centre, Thunder Bay, Canada

⁶Division of Orthopaedic Surgery, Sunnybrook Health Sciences Centre, Toronto, Canada

Corresponding author:

Claudia C. Sidler-Maier Ashford and St Peter's Hospital, Upper Limb Surgery Guildford Road, Chertsey KT16 0PZ, UK.
E-mail: clamine@gmail.com

native LDT. Using an immunologically inert acellular dermal allograft (ADA) for tendon augmentation has been shown to be successful in the management of arthroscopic and open rotator cuff repair.^{1,7,8} This scaffold consists of collagen⁹ and extracellular protein matrix and provides an environment for revascularization, cellular repopulation and tissue regeneration with high tensile properties.^{7,9}

The aim of the present study was to present our initial results after application of ADA to reinforce the strength and facilitate repair of the native LDT in the surgical reconstruction of massive irreparable rotator cuff tears even in the presence of an associated subscapularis tear, a traditional contraindication for LDT.

Materials and methods

This case series, approved by our institutional review board, involves 24 patients who underwent unilateral LDT with ADA (GraftJacket®; Wright Medical, Memphis, TN, USA) augmentation between March 2009 and December 2015. Patients presented with massive rotator cuff tears according to the definition of Gerber et al.,¹⁰ as confirmed by magnetic resonance imaging (MRI). The fatty atrophy of the posterosuperior rotator cuff was graded according to the stages of Goutallier et al.¹¹ using the tangent sign method of Zanetti et al.¹² Pre-operatively, the integrity of the teres minor was tested clinically (strength in external rotation in 90° of abduction) and examined on MRI images. All patients failed a course of non-operative management for at least 3 months and were subjectively limited by pain, weakness and/or loss of overhead elevation. All of our patients who met the inclusion criteria for surgery, underwent standard physical therapy and achieved at least 50% increase in active range of motion before proceeding with surgery to facilitate compliance with the postoperative rehabilitation. All rotator cuff tears were pre-operatively classified as 'irreparable' as a result of severe tendon retraction and fatty infiltration.⁶ Radiographically, only patients with glenohumeral arthrosis of none or mild (according to the classification of Samilson and Prieto¹³) and cuff tear arthropathy of grade 2 or less (classification of Hamada et al.¹⁴) were included in the study.

Exclusion criteria were acute rotator cuff tear, a non-functional latissimus dorsi muscle, neurological injury, significant medical co-morbidity limiting the ability to undergo surgery, cuff tear arthropathy (grade 3 or higher of Hamada et al.¹⁴), infection, axillary nerve palsy or deltoid insufficiency. The following pre-operative parameters were assessed: presence of subscapularis tendon tear and lift-off test, previous surgery, extent of tendon retraction (supraspinatus) and degree

of fatty infiltration (Goutallier stage¹¹). Outcome measures included gain in active range of motion in forward flexion, abduction and external rotation (arm by the side of the body), abduction strength (measured in a standard fashion using a hand held device with the patient seated, shoulder in 90° of abduction in the scapular plane and arm angled at 30° anteriorly), as well as lift-off test, return to work status, Constant score and the Disabilities of the Arm, Shoulder and Hand (DASH) score. Superior migration of the humeral head was assessed by measuring the acromiohumeral distance (ACHD), defined as the perpendicular distance (mm) between the apex of the humeral head and the sclerotic undersurface of the acromion on standardized anteroposterior radiographs.

Surgical technique

All procedures were performed in a lateral decubitus position using a two-incision approach to the shoulder in accordance with the technique of Gerber et al.³: laterally for the cuff reconstruction and posteriorly for the LDT harvest. Our modified surgical technique using an ADA to augment the native latissimus dorsi tendon has been described previously.¹⁵ Briefly, a standard lateral open rotator cuff approach was used. The decision to proceed on with a LDT was determined if a primary repair of the posterosuperior rotator cuff tear was not possible. The integrity of the subscapularis was also checked but did not impact on the decision to perform LDT. Two fiberwire sutures were then placed in the stump of the retracted posterosuperior rotator cuff tendon and a broad bone trough was made into the greater tuberosity just lateral to the articular margin. Transosseous sutures were placed in the trough for later fixation of the transferred tendon. A posterior approach was used. The latissimus dorsi muscle was identified, the tendon isolated and released off the humeral insertion. The ADA was sized to match the host tendon dimensions and the biological surface of the graft was sutured to the bursal side of the transferred tendon as an onlay. The mobilized LDT/ADA construct was then passed and placed over the humeral head in direct contact with the superior-anterior free edge of the subscapularis tendon. The transferred tendon construct was then secured laterally to the tuberosity trough through the bone tunnels, medially to the stump of the retracted posterosuperior rotator cuff with non-absorbable sutures, and anteriorly to the superior fibers of the subscapularis tendon. In cases with a fully deficient subscapularis tendon that could not be repaired, the LDT/ADA was repaired to the lesser tuberosity. This resulted in full coverage of the articular surface of the humeral head (Fig. 1).

Figure 1. Fixation of augmented latissimus dorsi transfer (LDT).

Postoperative protocol

An abduction sling was worn for 6 weeks. Passive and active-assisted range of motion exercises started after 4 weeks, and progressed to active range of motion after 6 weeks. Careful strengthening exercises were allowed after 3 months.

Statistical analysis

Statistical analysis was performed using SPSS, version 23 (IBM Corp., Armonk, New York, NY, USA). Pre- and postoperative values were compared using paired two-sided *t*-tests, and differences between groups were tested with two-sided independent samples *t*-tests or with Welch *t*-tests where appropriate. $p \leq 0.05$ was considered statistically significant; p values between 0.05 and 0.075 were considered as borderline significant. Relationships between continuous variables are reported using Pearson's correlation.

Results

All 24 patients were male and working in manual labour jobs with a mean age at surgery of 57 years (range 47 years to 70 years) (Table 1). All cases were unilateral and the right side was affected in 20 cases. The mean time from the accident until surgery was 18 months (range 5 months to 72 months) and seven of the patients had a previously failed rotator cuff repair. Six of our study patients presented with a partial thickness subscapularis tear, and four with a full-thickness tear, confirmed on MRI. The teres minor was intact in all of our patients. All pre-operative range of motion values were measured after physical therapy.

The pre-operative active forward flexion was on average 115° (range 30° to 180°), abduction was 105° (range 30° to 180°) and mean external rotation was 43° (range 20° to 70°). The mean ACHD pre-operatively was 4.2 mm (range 2.2 mm to 8.4 mm).

Subgroup comparison between complete and partial tear patients did not show any significant difference in any of the pre-operative or postoperative collected data. Therefore, we compared them as one group with the group of intact subscapularis patients.

The mean tendon retraction was 3.9 cm (range 2 cm to 5 cm); for the subgroup of patients with deficient subscapularis, this was 3.5 cm, whereas, for the patients with intact subscapularis, it was 4.2 cm ($p=0.07$) and the fatty atrophy of the posterosuperior rotator cuff was graded as Goutallier¹¹ 3 or higher in all cases. There were no intra-operative complications. The average hospital stay was 1.4 days (range 1 day to 3 days) and one patient was lost to follow-up after 5 months. At last follow-up (mean 27 months, range 5 months to 7 years), all patients but one were satisfied with their postoperative function and pain reduction. This one patient, with previous ipsilateral anterior shoulder stabilization and failed prior rotator cuff repair, suffered a failure 3 months postoperatively. This occurred immediately following the start of strengthening exercises in physiotherapy and was confirmed on ultrasound and MRI as a massive retear. One other patient had residual pain 9 months postoperatively, although he nevertheless reported a significant reduction in pain compared to his pre-operative levels. Clinical examination demonstrated an intact latissimus dorsi tendon confirmed on MRI (for an example of intact allograft on MRI, see Fig. 2). No other complications were noted.

The LDT augmented with ADA significantly improved active forward flexion ($p=0.016$) with a mean increase of 31° (from 113° to 145°). The abduction tended to improve by 25° (from 102° to 127° , $p=0.059$) (Fig. 3). The following pre-operative criteria had no effect on postoperative gains in motion: subscapularis tear, previous surgery, tendon retraction and fatty atrophy of the posterosuperior rotator cuff. The external rotation and ACHD remained stable (Fig. 4).

At last follow-up, the mean abduction strength of the affected side was 3.7 pounds (range 0 pounds to 14 pounds) and the unaffected side was 11.4 pounds (4 pounds to 33 pounds). The average postoperative Constant score was 57.8 (range 18 to 78) and the mean DASH score was 37.7 (range 2.3 to 88.6).

Our patients returned to work at an average of 20.4 weeks after the LDT (range 2 weeks to 50 weeks). Five patients did not return to work (mean age 58.4 years; range 54 years to 62 years) and the reasons were unrelated to shoulder function.

Table 1. Patients.

Patient	Age at surgery (years)	Subscapularis tear	Extend	Previous surgery	Tendon retraction (cm)	Fatty degeneration (Goutallier) ¹¹
1	52.9	Yes	Partial	No	3.2	Grade 3
2	58.6	Yes	Complete	No	2.5	NA
3	67.9	Yes	Partial	Yes	3	Grade 4
4	61.9	Yes	Complete	No	3	Grade 3
5	63.6	No	NA	No	NA	NA
6	58.2	No	NA	No	4.5	Grade 3
7	55.9	Yes	Partial	No	3	Grade 3
8	70.3	No	NA	No	5	Grade 4
9	63.0	No	NA	Yes	5	Grade 3
10	61.7	No	NA	Yes	3.4	Grade 4
11	69.8	Yes	Complete	No	3.2	Grade 3
12	50.0	No	NA	Yes	3.2	Grade 3
13	59.3	Yes	Partial	No	4	Grade 4
14	48.8	No	NA	No	4.7	Grade 4
15	54.4	No	NA	Yes	5	Grade 3
16	48.0	No	NA	No	3.5	Grade 4
17	58.7	Yes	Partial	No	4.3	Grade 3
18	51.6	Yes	Partial	Yes	2	Grade 3
19	56.9	Yes	Complete	No	5	Grade 4
20	51.2	No	NA	No	5	Grade 4
21	62.3	No	NA	No	4.3	Grade 4
22	51.7	No	NA	No	5	NA
23	57.5	No	NA	Yes	NA	NA
24	51.9	No	NA	No	4	Grade 3

NA, not applicable.

We found that the pre-operative grade of fatty infiltration negatively affected postoperative Constant scores. Patients with pre-operative subscapularis tears had better postoperative Constant scores and tended to have greater gains in abduction (on average 43°; range 102° to 145°) than patients without subscapularis tear (range 102° to 115°; $p=0.075$). Neither the extent of

tendon retraction, nor previous surgery influenced the outcome after LDT (Table 2).

Discussion

The transferred latissimus dorsi tendon can be very thin and tenuous, contributing to impaired tendon–bone

Figure 2. (a) Latissimus dorsi tendon augmented by acellular dermal allograft (arrow 1) shown on coronal shoulder magnetic resonance imaging (MRI) (in supine position). Medial tenodesis to postero-superior rotator cuff (arrow 2), lateral fixation into bone trough (arrow 3). (b) Augmented LDT (arrow 1) shown on sagittal shoulder MRI. Native latissimus tendon (arrow 2). (c) Augmented LDT (arrow 1) shown on sagittal shoulder MRI. Native latissimus tendon (arrow 2) and anterior tenodesis to subscapularis tendon (arrow 3).

Figure 3. Pre- and postoperative range of motion.

healing and poor outcomes. Acellular dermal allografts can be used to cover and reinforce soft tissue repairs.¹⁶ We report the outcomes of LDT augmented with an ADA as a bursal-sided onlay. The purpose of the modification of the LDT procedure in the present study was not only to augment the native latissimus tendon and improve its tensile properties during the healing process, but also to act as a denervated barrier to reduce subacromial impingement pain.

Our patient cohort was comparable with previous studies with regard to sample size, age, sex, previous rotator cuff surgery and pre-operative fatty infiltration.^{4,17–27}

Previous studies^{20,25,27} have reported difficulty suturing the retracted posterosuperior rotator cuff to the transferred latissimus dorsi tendon, although this was possible for all of our patients. This may be a result of the ADA reinforcement of the latissimus dorsi tendon

Figure 4. Pre- and postoperative acromio-humeral distance (ACHD).

allowing for more manipulation and mobilization with successful attachment to the humeral head and retracted rotator cuff. Similarly, humeral head coverage has not consistently been achieved but was possible in all of our patients. Possibly, this is important for latissimus dorsi tendon healing and postoperative function through force couple restoration,²⁸ dynamic depression²⁹ and humeral head re-centering³⁰ within the glenoid.

Our mean follow-up was 27 months and this is similar to other studies.^{20,24,25} Maximal recovery following

Table 2. Influence of pre-operative factors on outcome.

Pre-operative factor	Outcome			p-value
Fatty infiltration		Goutallier ¹¹ 3	Goutallier ¹¹ 4	
	Mean Constant score (range)	66.3 (55 to 78)	46.2 (18 to 70)	0.063
Subscapularis		Torn	Intact	
	Mean Constant score (range)	64 (37 to 78)	44 (18 to 60)	0.010
	Mean abduction gain (range) (°)	43° (–20° to 70°)	13° (–60° to 110°)	0.075

LDT typically occurs within the first 6 months to 12 months postoperatively and does not appear to improve or deteriorate with longer follow-up.²⁹ All of our patients but one showed substantial pain relief, were satisfied with their outcomes and stated that they would have undergone surgery again. Although not an ideal method for evaluating improvement, this approach has been used in prior publications.^{31–33}

Although Pearsall et al.²⁸ did not find a statistically significant gain in abduction or forward flexion using a fascia lata augmented LDT, these parameters both improved in the current cohort (flexion gain 31°, $p=0.016$; abduction gain 25°, $p=0.059$). Other studies have shown similar gains in forward flexion, including those of Zafra et al.²⁰ (40°; $p=0.025$) and El-Azab et al.³⁴ (47.5°; $p<0.0001$). The gain in abduction is best explained by reduction of subacromial impingement pain. The lack of active external rotation improvement after surgery may be explained by the intact teres minor tendon in all our patients or the placement of the latissimus dorsi tendon end directly anterior to the superior subscapularis tendon. The goal of the augmented LDT in the present study was not primarily to increase external rotation but, instead, to act as a humeral head depressor stabilizing and centering the humeral head to improve the biomechanics³⁵ and the effective mobility and strength of the shoulder. The influence of the teres minor tendon on LDT outcomes is unclear. Costouros et al.¹⁷ found that fatty infiltration of the teres minor negatively influenced the results of LDT but the presence of a tendon tear did not. Additionally, most studies about LDT do not mention the integrity of the teres minor.^{19,21,23–29,36–39}

The degree of superior migration of the humeral head after LDT may be related to functional outcome and progression of tendon failure, which was a common finding in the studies of Moursy et al.,⁴ El-Azab et al.³⁴ and Irlenbusch et al.²⁹ In the present study, the ACHD remained stable and, although the follow-up was relatively short, there was no

progression of rotator cuff arthropathy according to Hamada grades.¹⁴ A longer follow-up would be required to evaluate for clear progression of rotator cuff arthropathy.

Abduction strength generally improves following LDT but not always in a statistically significant manner.⁵ At last follow-up, our patients showed a mean strength in abduction of 3.3 pounds (compared to 11.4 pounds for the unaffected side). This is comparable to values reported in literature.^{6,17,24,27,34} The post-operative Constant scores in the present study (mean 56.3) were also similar to other studies.^{24,25,27,34} Unfortunately, pre-operative Constant scores were not available.

Failure of LDT is a common problem.⁵ Failure rates following primary LDT range from 4% to 18%^{4,6,24} and an increase to 44% for revision LDT. In the present study, one patient (4%) had a retear 3 months after surgery when he started strengthening exercises. Reoperation following LDT was also common in previous studies and occurred for a variety of indications including hematoma,^{5,28,29} seroma, infection,^{5,20,29} subscapularis tear,²⁷ persistent acromioclavicular joint pain, shoulder stiffness,^{6,29} deltoid avulsion^{5,27,36} and failed LDT requiring conversion to reverse total shoulder arthroplasty.^{21,22,26} None of the patients in the present study required reoperation.

Pre-operative factors influencing the outcome after LDT showed that the degree of fatty infiltration negatively affected the Constant score of our patients. This is compatible with the findings in the study of Warner et al.,¹⁸ whereas Costouros et al.¹⁷ and Pearsall et al.²⁸ showed no association between pre-operative fatty infiltration and postoperative outcomes. The association between fatty degeneration and worse outcome likely relates to the inability of the severely degenerated muscle to regenerate despite tendon repair and rehabilitation.¹⁸

The use of LDT as a salvage option in patients with previously failed and irreparable rotator cuff tears has important clinical implications because there are

limited surgical options for this cohort of patients.¹⁸ A previous history of surgery in the operative shoulder has been reported to negatively affect outcomes in several studies.^{4-6,18,19,29,36} However, neither Pearsall et al.,²⁸ Costouros et al.,¹⁷ Gerber et al.⁶ or Valenti et al.,²⁵ nor the present study, found any effect of prior surgery on patient outcomes. We can therefore offer LDT augmented with ADA to our patients with massive irreparable rotator cuff tears as a primary or salvage procedure.

Simultaneous tear of the subscapularis tendon was not considered a contraindication for LDT augmented with allograft in the present study, although it is generally reported as a contraindication for LDT^{28,40} because of inferior results.^{6,21,27} A primary repair would generally be attempted if possible¹ and, in the case of a nonreconstructable isolated subscapularis tendon tear, it has been suggested that an anterior tendon transfer is performed.^{21,35,41} In our cases, the tear configuration and the associated fatty atrophy of the musculature did not permit a repair. As a result of the rare evidence of reproducible results of a combined LDT with pectoralis major transfer in patients with massive posterosuperior and anterior rotator cuff tears⁴² and also because the focus of the present study was the application of ADA as an augment for the transferred latissimus dorsi tendon, we did not perform a concomitant anterior tendon transfer.

Even though partial tears may not have been detected in earlier series of LDT as MRI or ultrasound examination was not available, there have been several studies distinguishing and treating partial, as well as complete subscapularis tears.^{6,25,29,36,39} In the present study, ten patients presented with additional deficient subscapularis tendon of which six were partial and four were complete. A subgroup analysis comparing partial and complete subscapularis tears did not show any significant difference in any of the pre-operative or post-operative findings, neither clinically, nor radiologically. Therefore, we analyzed them as a single group for the purposes of the present study, as reported previously in the literature.^{6,25,29,36,39}

As far as the outcome is concerned, Iannotti et al.³⁶ and Valenti et al.²⁵ both reported no significant influence of a subscapularis tear on outcome, and Irlenbusch et al.²⁹ reported significant improvements in forward flexion, abduction and external rotation irrespective of subscapularis deficiency. In the present study, ten patients had subscapularis tears (six partial tears and four full-thickness tears) and did as well as patients without subscapularis tears, with similar DASH and Constant scores and a trend towards greater gains in abduction (average of 43°, from 102° to 145°). This was an encouraging finding in the present study because patients with massive irreparable

posterosuperior rotator cuff tears in conjunction with subscapularis tears historically have had no joint preserving reconstruction options available to them. We consider that these positive results may be a result of the secure placement of the ADA construct anteriorly to the superior subscapularis or directly to the humeral head acting as a counter force vector to the anterosuperior escape moment arm during shoulder motion, allowing better leverage of the deltoid and the surrounding periscapular muscles. There are techniques described in the literature using allograft as a bridging construct in the case of massive and irreparable rotator cuff tears.^{1,2,8} However, in the case of LDT, although a case report exists,¹⁶ no long-term follow-up results have been reported.¹⁶

There are limitations to the present study, including its retrospective nature with incomplete data, lacking randomization and comparison with a control group. Although important for the selection of surgical candidates with regard to their postoperative rehabilitation compliance, the pre-operative increase in range of motion by performing standard physiotherapy may be a source of selection bias. The aim of the present study was to present a modified technique of LDT in a case series and its initial results, using an ADA augment to achieve full humeral head coverage. The patient cohort consisted entirely of men working in manual labour, and so the findings obtained may not be generalizable to women or sedentary employment. However, massive and symptomatic irreparable rotator cuff tears are typically reported and treated in male labourers and so the current cohort is likely representative of the typical candidate for LDT. Also, nerve conduction studies and MRI were not regularly performed postoperatively. Thus, the integrity and function of the transferred latissimus dorsi tendon objectively could not be reported for all cases.

In conclusion, LDT augmented with ADA has shown similar improvements in function and pain compared to the standard LDT reported in the literature. Important advantages found in this series include a low failure rate (4%), a low complication rate, and significant improvements in function and pain, regardless of a history of prior failed rotator cuff repairs or the presence of a subscapularis tear.

Acknowledgements

This work was presented orally at the '2016 City-wide Fellow Research Day' in Toronto, Canada on 11 May 2016.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Ethical Review and Patient Consent

The Research Ethics Board of Sunnybrook Health Sciences Centre approved this study (Project Identification Number 306-2015).

References

- Pandey R, Tafazal S, Shyamsundar S, et al. Outcome of partial repair of massive rotator cuff tears with and without human tissue allograft bridging repair. *Shoulder Elbow* 2017; 9: 23–30.
- Modi A, Singh HP, Pandey R, et al. Management of irreparable rotator cuff tears with the GraftJacket allograft as an interpositional graft. *Shoulder Elbow* 2013; 5: 188–194.
- Gerber C, Vinh TS, Hertel R, et al. Latissimus dorsi transfer for the treatment of massive tears of the rotator cuff. A preliminary report. *Clin Orthop Relat Res* 1988; 232: 51–61.
- Moursy M, Forstner R, Koller H, et al. Latissimus dorsi tendon transfer for irreparable rotator cuff tears: a modified technique to improve tendon transfer integrity. *J Bone Joint Surg Am* 2009; 91: 1924–1931.
- Grimberg J and Kany J. Latissimus dorsi tendon transfer for irreparable postero-superior cuff tears: current concepts, indications, and recent advances. *Curr Rev Musculoskelet Med* 2014; 7: 22–32.
- Gerber C, Rahm SA, Catanzaro S, et al. Latissimus dorsi tendon transfer for treatment of irreparable posterosuperior rotator cuff tears. *J Bone Joint Surg Am* 2013; 95: 1920.
- Barber FA, Burns JP, Deutsch A, et al. A prospective, randomized evaluation of acellular human dermal matrix augmentation for arthroscopic rotator cuff repair. *Arthroscopy* 2012; 28: 8–15.
- Gupta AK, Hug K, Berkoff DJ, et al. Dermal tissue allograft for the repair of massive irreparable rotator cuff tears. *Am J Sports Med* 2012; 40: 141–147.
- Barber FA, Herbert MA and Coons DA. Tendon augmentation grafts: biomechanical failure loads and failure patterns. *Arthroscopy* 2006; 22: 534–538.
- Gerber C, Fuchs B and Hodler J. The results of repair of massive tears of the rotator cuff. *J Bone Joint Surg Am* 2000; 82: 505–515.
- Goutallier D, Postel J-M, Gleyze P, et al. Influence of cuff muscle fatty degeneration on anatomic and functional outcomes after simple suture of full-thickness tears. *J Shoulder Elbow Surg* 2003; 12: 550–554.
- Zanetti M, Gerber C and Hodler J. Quantitative assessment of the muscles of the rotator cuff with magnetic resonance imaging. *Invest Radiol* 1998; 33: 163–170.
- Samilson RL and Prieto V. Dislocation arthropathy of the shoulder. *J Bone Joint Surg Am* 1983; 65: 456–160.
- Hamada K, Fukuda H, Mikasa M, et al. Roentgenographic findings in massive rotator cuff tears. A long-term observation. *Clin Orthop Relat Res* 1990; 92–96.
- Sidler-Maier CC, Leivadiotou D, Payandeh JB, et al. Latissimus dorsi tendon transfer augmented by human dermal tissue allograft – surgical technique. *Tech Should El Surg* 2017; 18: e1–e5.
- Skedros J and Henrie T. Latissimus dorsi tendon transfer with GraftJacket® augmentation to increase tendon length for an irreparable rotator cuff tear. *Case Rep Orthop* 2017; 2017: 8086065.
- Costouros JG, Espinosa N, Schmid MR, et al. Teres minor integrity predicts outcome of latissimus dorsi tendon transfer for irreparable rotator cuff tears. *J Shoulder Elbow Surg* 2007; 16: 727–734.
- Warner JJP and Parsons IM IV. Latissimus dorsi tendon transfer: a comparative analysis of primary and salvage reconstruction of massive, irreparable rotator cuff tears. *J Shoulder Elbow Surg* 2001; 10: 514–521.
- Birmingham PM and Neviaser RJ. Outcome of latissimus dorsi transfer as a salvage procedure for failed rotator cuff repair with loss of elevation. *J Shoulder Elbow Surg* 2008; 17: 871–874.
- Zafra M, Carpintero P and Carrasco C. Latissimus dorsi transfer for the treatment of massive tears of the rotator cuff. *Int Orthop* 2008; 33: 457–462.
- Weening AA and Willems WJ. Latissimus dorsi transfer for treatment of irreparable rotator cuff tears. *Int Orthop* 2010; 34: 1239–44.
- Nové-Josserand L, Costa P, Liotard JP, et al. Results of latissimus dorsi tendon transfer for irreparable cuff tears. *Orthop Traumatol Surg Res* 2009; 95: 108–113.
- Lichtenberg S, Magosch P and Habermeyer P. Are there advantages of the combined latissimus-dorsi transfer according to L'Episcopo compared to the isolated latissimus-dorsi transfer according to Herzberg after a mean follow-up of 6 years? A matched-pair analysis. *J Shoulder Elbow Surg* 2012; 21: 1499–1507.
- Lehmann LJ, Mauerman E, Strube T, et al. Modified minimally invasive latissimus dorsi transfer in the treatment of massive rotator cuff tears: a two-year follow-up of 26 consecutive patients. *Int Orthop* 2009; 34: 377–383.
- Valenti P, Kalouche I, Diaz LC, et al. Results of latissimus dorsi tendon transfer in primary or salvage reconstruction of irreparable rotator cuff tears. *Orthop Traumatol Surg Res* 2010; 96: 133–138.
- Debeer P and De Smet L. Outcome of latissimus dorsi transfer for irreparable rotator cuff tears. *Acta Orthop Belg* 2010; 76: 449–455.
- Gerber C, Maquieira G and Espinosa N. Latissimus dorsi transfer for the treatment of irreparable rotator cuff tears. *J Bone Joint Surg Am* 2006; 88: 113–120.
- Pearsall AW, Madanagopal SG and Karas SG. Transfer of the latissimus dorsi as a salvage procedure for failed debridement and attempted repair of massive rotator cuff tears. *Orthopedics* 2007; 30: 943–949.
- Irlenbusch U, Bracht M, Gansen H-K, et al. Latissimus dorsi transfer for irreparable rotator cuff tears: A longitudinal study. *J Shoulder Elbow Surg* 2008; 17: 527–534.
- Werner CML, Zingg PO, Lie D, et al. The biomechanical role of the subscapularis in latissimus dorsi transfer for

- the treatment of irreparable rotator cuff tears. *J Shoulder Elbow Surg* 2006; 15: 736–742.
31. Razmjou H, Lincoln S, Axelrod T, et al. Factors contributing to failure of rotator cuff surgery in persons with work-related injuries. *Physiother Can* 2008; 60: 125–133.
32. Meeks BD, Meeks NM, Froehle AW, et al. Patient satisfaction after biceps tenotomy. *Orthop J Sports Med* 2017; 25: 2325967117707737.
33. Beck CE, Jacobson S and Thomasson E. A retrospective outcomes study of 20 sacroiliac joint fusion patients. *Cureus* 2015; 7: e260. DOI: 10.7759/cureus.260.
34. El-Azab HM, Rott O and Irlenbusch U. Long-term follow-up after latissimus dorsi transfer for irreparable posterosuperior rotator cuff tears. *J Bone Joint Surg Am* 2015; 97: 462–469.
35. Greenspoon JA, Millett PJ, Moulton SG, et al. Irreparable rotator cuff tears: restoring joint kinematics by tendon transfers. *Open Orthop J* 2016; 10: 266–276.
36. Iannotti JP, Hennigan S, Herzog R, et al. Latissimus dorsi tendon transfer for irreparable posterosuperior rotator cuff tears. *J Bone Joint Surg Am* 2006; 88: 342–348.
37. Aoki M, Okamura K, Fukushima S, et al. Transfer of latissimus dorsi for irreparable rotator-cuff tears. *J Bone Joint Surg Br* 1996; 78: 761–766.
38. Miniaci A and MacLeod M. Transfer of the latissimus dorsi muscle after failed repair of a massive tear of the rotator cuff. A two to five-year review. *J Bone Joint Surg Am* 1999; 81: 1120–1127.
39. Gerber C. Latissimus dorsi transfer for the treatment of irreparable tears of the rotator cuff. *Clin Orthop Relat Res* 1992; 275: 152–160.
40. Petriccioli D, Bertone C and Marchi G. Recovery of active external rotation and elevation in young active men with irreparable posterosuperior rotator cuff tear using arthroscopically assisted latissimus dorsi transfer. *J Shoulder Elbow Surg* 2016; 25: e265–e275.
41. Elhassan B, Christensen TJ and Wagner ER. Feasibility of latissimus and teres major transfer to reconstruct irreparable subscapularis tendon tear: an anatomic study. *J Shoulder Elbow Surg* 2014; 23: 492–499.
42. Aldridge JM III, Atkinson TS and Mallon WJ. Combined pectoralis major and latissimus dorsi tendon transfer for massive rotator cuff deficiency. *J Shoulder Elbow Surg* 2004; 13: 621–629.