Latissimus Dorsi Tendon Transfer for Massive Irreparable Rotator Cuff Tears

A Systematic Review

Umile Giuseppe Longo, MD, MSc, Edoardo Franceschetti, MD,* Stefano Petrillo, MD,* Nicola Maffulli, MD, MS, PhD, FRCS(Orth),†‡ and Vincenzo Denaro, MD**

Abstract: Tendon transfers have been proposed as a possible solution to restore pain-free functions, strength, and range of motion in patients with massive and irreparable cuff tears. The aim of this review is to establish the outcomes of (1) latissimus dorsi tendon transfer (LDT-T) surgery performed as a single procedure or in combination with other muscle-tendon transfer procedures, replacement, or both; (2) LDT-T in primary and revision surgery for massive irreparable rotator cuff tears; (3) the LDT-T procedure in relation to subscapularis and teres minor integrity; (4) the LDT-T procedure in relation to the reattachment position on the humeral head of the transferred tendon; (5) the LDT-T procedure performed as a single or a double incision; (6) arthroscopic, open, or combined approach: and (7) the LDT-T procedure in patients with preoperative osteoarthritis and a nonosteoarthritic condition with the evaluation of osteoarthritis progression. A systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines. Studies of levels of evidence I-IV were included. The LDT-T surgical procedure, outcomes, and complications were evaluated. Twenty-two studies describing 493 shoulders in 487 patients were included in our study. There were no prospective randomized, controlled studies. LDT-T is a promising strategy for the management of massive and irreparable rotator cuff tears, even though no agreement was found on several aspects and options of LDT-T. Randomized prospective control studies are still awaited on this subject.

Key Words: latissimus dorsi, transfer, rotator cuff tears, sport, shoulder, arthroscopy

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Massive and irreparable rotator cuff tears represent a challenge, especially in young and active patients.[1] There is no universal agreement on either the definition or the management of "massive" tears of the rotator cuff: several different definitions have been reported in the literature. The tear is classified after minimal debridement of the nonviable tendinous tissue and extensive mobilization of the cuff including intra-articular and extra-articular lysis of adhesions, section of the coracohumeral ligament, and, if needed, an anterior, inferior, or posterior capsulotomy. A tear is small (type I) if stable reinsertion of the cuff to a bony trough immediately adjacent to the greater tuberosity (or, for the subscapularis, to the lesser tuberosity) is feasible with the arm in full adduction. If stable reinsertion of the cuff is possible only if the arm is abducted to 60 degrees or less, the tear is defined as large (ie, type II). If the remaining cuff cannot be anchored to this bony trough even though the arm is abducted 60 degrees, the tear is considered irreparable and called massive or type III.[2] Cofield used this term for any tear with a diameter of more than 5 cm.[3] Moreover, the term irreparable refers not only to the tear size and amount of tendon involvement and retraction but also to the grade of fatty infiltration and atrophy of the muscle belly.[4] The diagnostic criteria for a massive irreparable rotator cuff tear, usually confirmed by magnetic resonance imaging (MRI) or computed tomography scan findings, are stage 3 tendon retraction according to the classification system by Patte[5]; stage 3 or 4 fatty infiltration as determined with the classification system by Goutallier et al[6]; and stage 3 muscle atrophy according to the classification system by Thomazeau et al.[7]

The most frequent and consistent deficit associated with massive and irreparable lesions is the loss of supraspinatus and infraspinatus muscle-tendon-bone continuity, leading to loss of active external rotation and inability to stabilize the arm in the space. This condition can be associated with severe impairment in functional and daily life activities and also with chronic disabling pain that does not respond to a conservative or a nonoperative treatment.[8]

In addition, rotator cuff tears often evolve into progressive cuff degeneration, proximal migration of the humeral head, and sweeping cuff tear arthropathy,[9,10] worsening the patient's pain and functional condition.

Several surgical procedures have been proposed for the management of massive rotator cuff tears, including debridement, partial rotator cuff repair, subscapularis tendon transfer, transfer of the subscapularis and teres minor, transfer of the long head of the triceps, transfer of the teres major, interposition of a biceps tendon autograft, a freeze-dried rotator cuff allograft, and the use of synthetic grafts.[11–14]

Historically, in 1934, L'Episcopo first described the latissimus dorsi muscle-tendon transfer (LDT-T) for brachial plexus palsy in children. In 1988, Gerber[2] presented a preliminary report on patients who underwent LDT-T for irreparable rotator cuff tear.

Subsequently, several investigators reported the outcome of these procedures, whereas others modified the LDT-T surgical procedure or combined LDT-T with teres major transfer (TM-T), reverse shoulder prosthesis, or both.

From the *Department of Orthopaedic and Trauma Surgery, Campus Biomedico University, Trigoria Rome, Italy; †Centre for Sports and Exercise Medicine, Queen Mary University of London, Barts; and ‡London School of Medicine and Dentistry, Mile End Hospital, London, England.

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Reprints: Nicola Maffulli, MD, MS, PhD, FRCS(Orth), Centre for Sports and Exercise Medicine, Barts, and London School of Medicine and Dentistry, Mile End Hospital, 275 Bancroft Road, London E1 4DG, England (e-mail: n.maffulli@qmul.ac.uk).

LDT-T offers a promising solution in the management of patients with irreparable tears of the posterosuperior rotator cuff, and it was conceived as a method to provide containment of the humeral head with the additional benefit of an external rotation force. In this way, a fixed fulcrum of rotation would increase the efficiency of the remaining rotator cuff muscles and the deltoid to also produce improved motion, especially in anterior elevation.[15]

The results of LDT-T are variable, and large differences in outcome are reported, particularly in its indications and surgical technique. In addition, to date, the factors that predict good outcomes are poorly understood. The lack of published data and information makes the actual findings controversial and often difficult to understand. To date, no systematic reviews on LDT-T are available.

The aim of this systematic Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) review is to establish the outcomes of LDT-T procedure in relation to (1) LDT-T surgery performed as a single procedure or in combination with other muscle-tendon transfer procedures, replacement, or both; (2) LDT-T in primary and revision surgery for massive irreparable rotator cuff tears; (3) the LDT-T procedure in relation to subscapularis and teres minor integrity; (4) the LDT-T procedure in relation to the reattachment position on the humeral head of the transferred tendon; (5) the LDT-T procedure performed as a single or a double incision; (6) arthroscopic, open, or combined approach; and (7) the LDT-T procedure in patients with preoperative osteoarthritis and a nonosteoarthritic condition with the evaluation of osteoarthritis progression.

MATERIALS AND METHODS

We undertook a systematic review of the literature according to the PRISMA guidelines with a PRISMA checklist and algorithm,[16,17] and already validated in our setting.[18–35] Three independent reviewers (U.G.L., S.P., and E.F.) separately conducted the search. All journals were considered, and all relevant studies were analyzed. To qualify for the study, an article had to be published in a peer-reviewed journal. All articles were initially screened for relevance by title and abstract, excluding articles without an abstract, and obtaining the full-text article if the abstract did not allow the investigators to assess the defined inclusion and exclusion criteria. The 3 investigators (U.G.L., S.P., and E.F.) separately reviewed the abstract of each publication and then performed a close reading of all papers and extracted data, to minimize selection bias and errors. A cross-reference research of the selected articles was also performed to obtain other relevant articles for the study. All articles reporting outcomes on shoulders treated with LDT-T, performed singularly or in combination with other surgical procedures, for the management of rotator cuff massive and irreparable tear were taken into account.

The search was performed on June 1, 2011. The following databases were searched: Medline, Google Scholar, EMBASE, and Ovid.

According to the Oxford center of evidence based medicine, level I to IV articles were found in the literature and included in our study.

Given the linguistic capabilities of the authors, articles in English, French, Spanish, German, or Italian were included.

We included articles published from January 1, 1988 to June 1, 2011 that reported shoulders with a massive and irreparable rotator cuff tear; presented a sufficient description of the lesion with arthroscopy or with imaging; had an adequate description of the clinical condition of the patients; had an appropriate and clear description of the surgical procedure and follow-up period; and presented a detailed report of the complications, outcome measures, and outcome scores. In addition, we included all articles that reported a follow-up period longer than 12 months. Missing data pertinent to these parameters warranted exclusion from this systematic review.

Literature reviews, case reports, studies on animals, cadavers or in vitro, biomechanical reports, tumoral studies, technical notes, letters to editors, and instructional course were excluded.

Studies on patients with massive rotator cuff tears managed with conservative or operative management without an LDT-T were excluded.

We also excluded articles with no information on surgical intervention, diagnosis, follow-up, imaging, arthroscopic, or surgical assessment of the massive tear of the rotator cuff, clinical examination, clinical postoperative outcomes, and statistical analysis.

In addition, we excluded all articles reporting a follow-up period shorter than 12 months.

Finally, to avoid bias, the selected articles, the relative list of references, and the articles excluded from the study were reviewed, assessed, and discussed by all the authors, and if there was disagreement among investigators regarding the inclusion and exclusion criteria, the senior investigators (N.M. and V.D.) made the final decision.

The inclusion and exclusion criteria for study analysis, the check-list, and the search algorithm according to the PRISMA guidelines are, respectively, given in Table 1 (check list), Table 2 (INCL-EXL Criteria), and Figure 1 (algorithm). Finally, Table 3 lists a summary of information in the articles and all the surgical procedures and techniques associated with LDT-T.

The following data were independently extracted by all the investigators: LDT-T as a single or a combined procedure, LDT-T as the primary or the revision procedure, relationship with presurgical subscapularis and teres minor integrity, and outcomes, position of reattachment of the transferred tendon, single or double surgical incision approach, arthroscopic, open or combined surgery.

The categorical variable was reported as frequency with percentage. Continuous variable data were reported as mean ± standard deviation or range as minimum and maximum values. In all studies, P values less than 0.5 were considered statistically significant.

RESULTS

The literature search and cross-referencing resulted in a total of 678 references, of which 600 were rejected due to off topic abstract and/or failure to fulfill the inclusion criteria (Fig. 1).

After reading the remaining full-text articles, another 56 articles were excluded because of insufficient details and uncertain diagnosis and outcome measures. The remaining 22 articles,[2,4,8,11,36–53] describing a total of 493 shoulders in 487 patients, were included in the study.

Demographic Details

The total number of patients of the included studies was 487 (268 male and 162 female; for the remaining 57 patients, sex was not reported).

TABLE 1. PRISMA Check List

Section/Topic	No.	Checklist Item	Reported on Page No.#
Title			
Title	1	Identify the report as a systematic review, meta-analysis, or both	
Abstract			
Structured summary	2	Provide a structured summary including, as applicable, background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; and systematic review registration number	
Introduction			
Rationale	3	Describe the rationale for the review in the context of what is already known	
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design	
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists, if and where it can be accessed (eg, Web address), and, if available, provide registration information including registration number	
Eligibility criteria	6	Specify study characteristics (eg, PICOS, length of follow-up) and report characteristics (eg, years considered, language, publication status) used as criteria for eligibility, providing rationale	
Information sources	7	Describe all information sources (eg, databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched	
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated	
Study selection	9	State the process for selecting studies (ie, screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis)	
Data collection process	10	Describe the method of data extraction from reports (eg, piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators	
Data items	11	List and define all variables for which data were sought (eg, PICOS, funding sources) and any assumptions and simplifications made	
Risk of bias in individual studies	12	Describe the methods used for assessing the risk of bias of individual studies (including specification of whether this was done at the study or the outcome level), and how this information is to be used in any data synthesis	
Summary measures	13	State the principal summary measures (eg, risk ratio, difference in means)	
Synthesis of results	14	Describe the methods of handling data and combining the results of studies, if done, including measures of consistency (eg, I^2) for each meta-analysis	
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (eg, publication bias, selective reporting within studies)	
Additional analyses	16	Describe methods of additional analyses (eg, sensitivity or subgroup analyses, meta-regression), if done, indicating which were prespecified	
Results			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram	
Study characteristics	18	For each study, present the characteristics for which data were extracted (eg, study size, PICOS, follow-up period), and provide the citations	
Risk of bias within studies	19	Present data on the risk of bias of each study and, if available, any outcome-level assessment (see item 12)	
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot	
Synthesis of results	21	Present the results of each meta-analysis carried out, including confidence intervals and measures of consistency	
Risk of bias across studies	22	Present the results of any assessment of risk of bias across studies (see Item 15)	
Additional analysis	23	Give results of additional analyses, if done (eg, sensitivity or subgroup analyses, meta-regression [see item 16])	
Discussion			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (eg, healthcare providers, users, and policy makers)	
Limitations	25	Discuss limitations at the study and outcome levels (eg, risk of bias), and at review level (eg, incomplete retrieval of identified research, reporting bias)	
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research	
Funding			
Funding	27	Describe sources of funding for the systematic review and other support (eg, supply of data); role of funders for the systematic review	

TABLE 2. Inclusion and Exclusion Criteria

Inclusion Criteria: Latissimus dorsi tendon transfer for massive irreparable rotator cuff tears.	
Databases	Medline, Google Scholar, EMBASE, Ovid
Source date/ pubdate	June 1, 2011/1988–2011
Articles' Language	English, French, Spanish, German, Italian
Level of evidence	Oxford centre of EBM, level I, II, III, IV
Diagnosis	Massive, irreparable, rotator cuff tear
Lesion assessment	Imaging: MRI, CT Surgical: Open, Arthroscopy
Type of surgery	Latissimus dorsi tendon transfer Latissimus dorsi and Teres major tendon transfer Latissimus dorsi and teres major tendon transfer associated with reverse shoulder prosthesis
Outcomes assessment	Clinical: Clinical examination, clinical questionnaires, clinical scores. Imaging: MRI, CT evaluation
Minimum follow-up time	12 mo
Exclusion criteria: Latissimus dorsi tendon transfer for massive irreparabile rotator cuff tears	
Type of study	Literature reviews, case reports, studies on animals, cadavers, in vitro, biomechanical reports, tumoral studies, technical notes, letters to editors, instructional course
Diagnosis	No imaging, arthroscopic, or surgical assessment of the massive irreparable rotator cuff tear
Management	Conservative, non-operative management, operative management without a Latissimus dorsi muscle-tendon transfer
Outcome Measures	No information on diagnosis, follow-up, imaging assessment of the repaired rotator cuff, clinical examination, clinical post operative outcomes, clinical scores, clinical questionnaires, and statistical analysis of the relative outcomes

CT indicates computed tomography; EBM, evidence based medicine MRI, magnetic resonance imaging.

The average age of the patients included at surgery was 60.04 years, ranging from 26[51] to 85[41] years, and were assessed at an average follow-up period of 30.50 months (ranging from 6[46] to 124[8] mo). Only 1 shoulder in 1 patient[49] was excluded from follow-up. The dominant side was involved in 260 patients, the nondominant side in 84 patients, whereas for the other 143 patients,[11,40,42–44,47,52,53] these data were not reported.

Imaging Evaluation of Injured Tendons and Fatty Infiltration

The diagnosis of massive irreparable rotator cuff tear was made preoperatively by MRI in 284 shoulders,[4,37,39–41,43–45,47,52,53] by computed tomography scan in 118 shoulders,[37,38,40,41,49–51] and by arthroscopy in 18 shoulders.[11] In the rest of the shoulders, the information was not reported. In all the patients included in this systematic review, rotator cuff tears were evaluated during surgery, and the lesion was assessed and classified according to what was found at surgery.

Preoperative information on the supraspinatus condition was reported in 472 shoulders, on the infraspinatus in 454 shoulders, on the teres minor in 120, on the subscapularis in 464 shoulders, and the long head of biceps in 122 shoulders.

Supraspinatus and infraspinatus lesions were found preoperatively in 472[4,8,11,36,38–53] and 454[4,8,11,36–53] shoulders, respectively, whereas teres minor and subscapularis occurred in 79[11,37–39,45,49,51] and 56[8,36,38,42,45,46,48,50–52] shoulders, respectively.

Finally, preoperatively, the long head of the biceps was partially or completely torn in 35 shoulders,[36,38,42,50] the deltoid was injured in 13[11,46,48] shoulders, and was also detached during surgery in 5 additional[51] patients.

Radiographic Evaluation: Osteoarthritis, Migration of Humeral Head, and Acromiohumeral Distance

The diagnosis of osteoarthritis of the glenohumeral joint, and the superior migration of the humeral head, at admission and at the time of latest follow-up, was made in all studies on 441 patients with radiographs. In 1 study[11] reporting on 18 patients, the diagnosis was made by arthroscopy, and in 3 studies[2,38,52] on 31 patients, an appropriate preoperative radiographic evaluation was not carried out.

The acromiohumeral distance (ACHD), reported in centimeters, was calculated by radiographic images in 12 studies.[8,37,39–47,49,50] Gerber[42] and Aoki et al[36] graded proximal migration of the humeral head as absent, present, or severe. The presence of proximal migration of the humeral head was shown by an interrupted Shenton line; severe changes were recorded when there was obliteration of the subacromial space. The investigators used the Shenton line at the shoulder to measure proximal migration because the acromiohumeral interval that had been widened by 3 to 5 mm by anterior acromioplasty at surgery no longer indicated the correct amount of proximal migration after operation.

Outcome Measures

The activity level of the affected shoulder was assessed before and after surgery using the Constant and Murley score[54] in 17 studies[4,8,37–44,46,47,49–53] on 427 patients, the American Shoulder and Elbow Surgeon(ASES) score[55] in 2 studies[4,11] on 60 patients, the University of California, Los Angeles (UCLA) score in 3 studies[36,37,48] on 42 patients, the Penn[56] score in one study[45] on 14 patients, the Oxford Shoulder score[57] used in 1 study[52] on 16 patients, and the Quick Dash score in 1 study[40] on 26 patients.

Finally, the combination of Constast and Murley/ASES scores and Constant and Murley/UCLA scores was used in 2 studies[4,37] on 42 and 13 patients, respectively.

The range of movements (ROM) was not evaluated in 2 studies[36,47] on 38 shoulders, and was clinically detected in the remaining 20 selected studies on 455 patients, focusing on abduction, forward flexion, external, and internal rotation.

Tests to highlight shoulder's tendon and muscle integrity or function were performed in 12 articles[4,8,11,37,38,41,43,44,46,47,49,50] on 325 patients.

The preoperative /postoperative activity of daily living (ADL) score was used and completed in 2 studies[41,52] by 28 patients. A modified ADL score called ADL-ER, specific for daily activities requiring external rotation, was used and completed in another 3 studies[37–39] in 46 patients, whereas

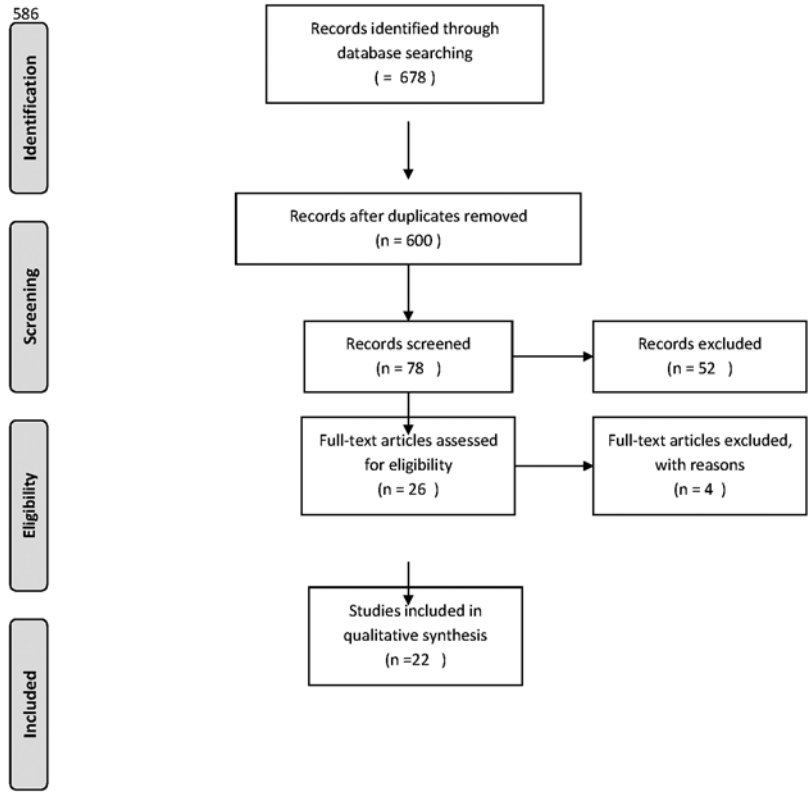

FIGURE 1. PRISMA Algorithm: PRISMA 2009 Flow Diagram.

in 13 articles[2,4,8,37–41,46,49–51,53] on 342 patients, the subjective shoulder value (SSV) score[58] was assessed and in 7 studies[4,8,11,40,41,48,51] a total of 206 patients completed a visual analog scale for pain assessment.

Finally, the postoperative electrical activity and functional status of the transferred tendon-muscle were evaluated by electromyography in 6 studies[2,36,42–45] on a total of 43 patients and by ultrasound in another 2 studies[43,47] on 43 patients, whereas in only 1 study[43] describing 17 patients, both assessments were submitted.

LDT-T Outcomes

Latissimus Dorsi Versus Combined Transfer

Regarding each surgical procedure performed in the study group, in 19 articles,[2,4,8,11,36,39,40,42–53] 457 shoulders were managed with an LDT-T single procedure, whereas in 3 articles[36–38,41] shoulders were treated with LDT-T in association with TMT-T, reverse prostheses, or both.

All the articles included in our study reported that, after the LDT-T single procedure, active external rotation was restored in the injured shoulders, whereas the investigators[37,38,41] who reported LDT-T in association with TM-T and reverse shoulder prosthesis outcomes showed that combined procedures were more efficient to restore active external rotation and also anterior elevation.

In addition, the best results were reported with LDT-T combined with TM-T and reverse shoulder prosthesis.[37,38,41]

Primary Versus Revision Surgery

To repair the massive rotator cuff lesion, an LDT-T as a single procedure, or combined with other surgical procedures, was performed as a primary surgery in 17 studies[4,8,36,38–43,45–52] on 277 shoulders, as a revision surgery in 18 studies[4,8,11,36,38–43,45–52] on 167 shoulders, whereas in the remaining 4 articles[2,37,44,53] on 49 shoulders, this information was not reported.

In 2 studies,[46,51] the investigators suggested that the LDT-T procedure is associated with the best outcomes, especially satisfaction, function, and lower percentage of rupture of the transferred tendon, if it is performed as the primary surgical intervention after massive and irreparable rotator cuff tears.

Warner et al,[51] on the basis of a modified Constant scoring system, compared the outcomes of 16 patients who underwent latissimus dorsi transfer as a salvage reconstruction for a failed prior rotator cuff repair with outcomes for 6 patients who underwent a primary reconstruction for an irreparable cuff defect. This study showed a statistically significant difference in the Constant score between groups, which measured 55% for the salvage group compared with 70% for the primary group ($P < 0.05$). Poor tendon quality, stage 4 muscle fatty degeneration, and detachment of the deltoid insertion each had a statistically significant effect on the Constant score ($P < 0.05$). Late rupture of the tendon transfer occurred in 44% of patients in the salvage group compared with 17% in the primary group at a mean of 19 months postoperatively. A rupture had a statistically significant effect on the Constant score, which declined by a mean of 14% ($P < 0.05$).

Irlenbush et al[46] analyzed the influence of LDT-T on the postoperative function in 52 patients with an irreparable tear of the rotator cuff (35 primary operations, 17 revision surgeries) and observed, in the group of patients

TABLE 3. Surgical Procedures

	Sample Size		Sex		Side Involved		Age		LDT-T vs. Combined Surgery		Follow-up	
Author, Journal, Year	Patients	Shoulders	Male	Female	Dominant	Not Dominant	Mean	Range (min; max)	LDT-T	Combined	Mean (mo)	Range (min; max)
Aoki et al[36]	10	12	9	1	9	3	64	48–82	12	0	35,6	26;42
Birminghan and Neviaser[11]	18	18	14	4	NR	NR	60	48–74	18	0	25	12;62
Bolieau et al[37]	13	13	4	9	9	4	70	60–82	0	13	22	14;41
Bolieau et al[38]	11	11	4	7	8	3	70	60–79	0	11	19,5	12;35
Coustoros et al[39]	22	22	16	6	16	6	58	40–68	22	0	34	24;57
Debeer et al[40]	25	26	8	17	NR	NR	56,5	42–66	26	0	43,3	13;124
Gerber et al2006[8]	67	69	52	15	50	17	61	49–72	67	0	53	24;126
Gerber et al[41]	11	12	1	10	NR	NR	73	59–85	0	12	18	12;33
Gerber et al[2]	4	4	4	0	4	0	59	39–75	4	0	15	14;16
Gerber et al[42]	16	16	15	1	15	1	60	39–75	16	0	33	26;41
Gerhardt et al[43]	17	17	NR	NR	NR	NR	55,8	34–71	0	17	24,7	13;39
Habermeyer et al[44]	14	14	NR	NR	NR	NR	61	47–76	0	14	32	19;42
Iannotti et al[45]	14	14	9	5	13	1	54,8	44–68	14	0	34	24;89
Irlenbusch et al[46]	52	52	30	22	42	10	60,1	42–74	47	5	11,1	6;18
Lehmann et al[47]	26	26	NR	NR	NR	NR	64	41–78	0	26	24	12;41
Miniaci et al[48]	17	17	12	5	10	7	55	32–77	17	0	50	24;72
Moursy et al[4]	42	42	31	11	30	12	58	40–75	22	20	47	24;77
Nove-josserand et al[49]	27	27	14	13	25	2	55	36–71	27	0	34	24;62
Valenti et al[50]	25	25	14	11	15	10	55,8	42–64	25	0	22	6;126
Warener and Pearson[51]	22	22	15	7	14	8	62,5	26–78	22	0	25,2	12;65
Weening and Willems[52]	16	16	11	5	NR	NR	60	49–71	16	0	26	7;73
Zafra et al[53]	18	18	5	13	NR	NR	54	37–62	18	0	28	12;58

LDT-T indicates latissimus dorsi tendon transfer; NR, not reported.

undergoing primary surgery, a continuous improvement in the Constant score from 36 to 69 points, and also in ROM, strength, relief of pain, and of different subjective parameters for the entire group in consecutive examinations at 11.1, 35.7, and 50.2 months. The investigators also found an increased rate of osteoarthritis and a decrease in the ACHD (from 5.6 to 4.7 mm). In contrast, the investigator detected a slight decrease in the above values in the revision group and in the presence of an additional subscapularis lesion.

Despite these results, several investigators[11,48,50] did not find significant differences in term of the results and outcomes between LDT-T performed as a primary or a revision surgery.

Debeer et al[40] found no significant difference between patients who underwent primary LDT-T and those who had undergone previous surgery. The authors suggest that this can be explained by the fact that most of the previous were arthroscopic procedures that did not alterates the deltoid integrity.

In 17 salvage transfers, Miniaci et al[48] found satisfactory outcomes in 82% of the patients the basis of the UCLA rating scale. There was significant pain relief and functional improvement in all patients, regardless of whether the deltoid was intact or deficient, with an average postoperative active elevation of 100 degrees (an increase of 59 degrees). They also noted that those patients with subscapularis tears also showed comparable improvement. In addition, the average postoperative UCLA score was 16.4, which they acknowledge is moderately disabled at best.

Birmingham et al[11], in their series with LDT-T as a salvage procedure for failed rotator cuff repair, showed an improvement in active forward elevation, active external rotation at the side, ASES score, and pain relief at a minimum of 12 months.

Integrity of the Subscapularis Tendon

Several authors focused their attention on the relationship with subscapularis pre-surgical condition and outcomes of the LDT-T procedure.

Relevant differences in terms of the outcomes, functional, pain and subjective result, comparing shoulders with or without a lesion of the subscapularis tendon, were found.

The integrity of the subscapularis tendon is crucial for the best outcomes and results after LDT-T. In 9 studies[8,36,38,42,45,46,50–52] that reported outcomes of the LDT-T procedure in patients with a subscapularis lesion, poor results were found after surgery in all the 59 shoulders.

Gerber et al[42], in 16 patients with irreparable, massive rotator cuff tears treated with LDT-T and reviewed after an average of 33 months, found that pain relief was satisfactory in 94% of the shoulders at rest and in 81% on exertion. Flexion was 83 degrees preoperatively and 135 degrees postoperatively. The functional value of the shoulder averaged 73% of an age- and sex-adjusted normal score. For the 12 shoulders with a functional subscapularis,

it averaged 82% and for the four shoulders without a functioning subscapularis, it averaged 48%. If the subscapularis tendon was torn and could not be adequately repaired, latissimus dorsi transfer was of no value. In patients with good subscapularis function but irreparable defects in the external rotator tendons, restoration of approximately 80% of normal shoulder function was achieved, indicating that latissimus dorsi transfer is a safe and valuable alternative for the treatment of this specific type of irreparable rotator cuff tear.

Aoki et al[36] found that the involvement of the subscapularis muscle led to unsatisfactory results as reported by Gerber et al,[42] and they agree that LDT-T should not be used for these patients.

Miniaci et al[48] reported good results in patients managed with the LDT-T procedure with subscapularis tendon tears. Therefore, the authors do not consider absence of the subscapularis a contraindication.

Integrity of the Teres Minor Muscle

Costouros at al[39] found that fatty infiltration of the teres minor less than or equal to stage 2 was associated with a better postoperative constant score ($P = 0.015$), age-adjusted Constant score ($P = 0.012$), active external rotation ($P = 0.016$), and active elevation ($P = 0.012$) relative to patients with fatty infiltration greater than stage 2. The authors also found that the presence or absence of a tear of the tendon had no significant effect on outcome. In conclusion, when performing LDTT for massive irreparable posterosuperior rotator cuff tears, fatty infiltration of the teres minor should be considered before surgery, as it is predictive of outcome.

However, Miniaci et al[48] did not consider teres minor integrity as crucial to obtain good functional results and best outcomes after LDT-T.

Position of Re-attachment of the LD

No agreement was found on the position of reattachment of the transferred tendon/s. In 6 articles,[8,37,46,50–52] the LDT was reattached on the supraspinatus and infraspinatus footprint, in 7 articles[36,40,43,45,48,49,53] it was reattached on the lateral aspect of the great tuberosity of the humeral head, in 3 articles[2,4,11] it was reattached on the superolateral aspect of the great tuberosity of the humeral head, in 4 articles[38,39,41,42] it was reattached on the posterolateral aspect of the humeral head, and in 2 studies[44,47] it was reattached on the infraspinatus footprint.

Single or Double Incisions

To perform LDT-T as a single procedure, or in combination with the other already citied surgical interventions, a single incision technique was reported in 5 articles[37,38,43,44,47] on 81 shoulders and, in the remaining 17 articles,[2,4,8,11,36,39–42,45,46,48–53] on 412 shoulders, a double incision was performed.

The studies[37,38,43,44,47] that reported a minimally invasive, or a single delto-pectoral incision to perform the LDT-T procedure, obtained very similar results in terms of ROM, satisfaction, strength, and pain relief compared with the studies that reported the "classic" double incision procedure described by Gerber et al[2] to perform the LDT-T procedure.

Arthroscopic Versus Open

In all the articles selected in this study, an open surgery was performed, and only in 2 studies[44,47] with 40 patients was operative arthroscopy performed before the open surgery. Gervasi et al[59] recently described, in technical terms, the possibility of performing LDT-T with arthroscopy, but no clinical data are available to date.

Osteoarthritis and Superior Migration of the Humeral Head

Gerber et al[42] found that in 16 shoulders managed with the LDT-T procedure, there was no increase in osteoarthritis in 14 shoulders, whereas there was progression from mild to moderate in 2 shoulders. In these series, one of four patients with a centered humeral head developed mild superior migration, and three heads remained centered. Mild superior migration was observed in four patients, all with a complete, inadequately repaired degenerative subscapularis tear. The authors found that the degree of superior migration was related to the overall functional result. Indeed, shoulders without superior migration, compared with normal shoulder scores, scored an average of 90%; those with mild superior migration scored 77%; and those with severe superior migration scored 62% of the normal value.

In 12 shoulders (10 patients) treated with the LDT-T procedure, there was no increase in the progression of osteoarthritis in seven shoulders, progression from mild to moderate or severe in three, and progression from moderate to severe in the other two.[36] Also, some increase in proximal migration of the humeral head had occurred in six shoulders: from absent to severe in one and from present to severe in five.

Debeer and De Smet,[40] in a retrospective study, found that the mean acromiohumeral head distance decreased at the time of the latest follow-up ($P = 0.05$) and that the mean degree of osteoarthritis significantly increased at the time of the latest follow-up ($P = 0.002$). The investigators also found that the outcome score of patients with severe osteoarthritis treated with the LDT-T procedure was lower than those with no or mild osteoarthritis, but the observed difference was not statistically significant ($P = 0.13$).

Costouros et al[39] found that, in patients managed with the LDT-T procedure, the degree of osteoarthritis increased at the final follow-up and that the ACHD decreased after LDT-T, but these results were not statistically significant.

Gerhardt et al[43] found that, in patients managed with a modified LDT-T procedure, the grade of cuff arthritis progressed from initially Grade 1 in 17% and Grade 2 in 28% to Grade 2 in 8%, Grade 3 in 69%, and Grade 4 in 15% at the final follow-up. The ACHD increased from 4.5 to 6 mm and decreased to 3.8 mm after 5 years. The increase in osteoarthritis was not associated with a decline in shoulder function as seen in persistently improved Constant and Murley scores.

DISCUSSION

LDT-T is a therapeutic option for the management of patients with massive irreparable rotator cuff tears, especially in young and active patients. All the authors of the selected study group demonstrated good results in terms of restoration of function and physiological ROM of the shoulder.

However, the results are variable and the factors that predict outcomes are not clearly defined and understood.

Regarding each surgical procedure performed in the study, in 19 articles,[2,4,8,11,36,39,40,42–53] 457 shoulders were managed with an LDT-T single procedure, whereas in 3 articles,[37,38,41] 36 shoulders were treated with LDT-T in association with TMT-T, or reverse prostheses, or both.

All the selected articles included in the study reported that, after an LDT-T single procedure, active external rotation was restored in the injured shoulders, whereas the authors[37,38,41] who reported LDT-T in association with TM-T and reverse shoulder prosthesis outcomes showed that combined procedures were more efficient to restore active external rotation and also anterior elevation. In addition, the best results were reported with LDT-T combined with TM-T and reverse shoulder prosthesis.[37,38,41]

Nevertheless, several studies demonstrated that LDT-T, performed in combination with TM-T and reverse shoulder prosthesis, improves both external rotation and anterior elevation. These findings are not usually obtained after an LDT-T single procedure. Thus, patients undergoing a combined surgery had better ROM, especially in external rotation and anterior elevation.

Focusing on ROM, anterior elevation is better restored with the combination of TM-T and reverse shoulder prosthesis, compared with the single LDT-T procedure results. Nevertheless, external rotation results comparing the LDT-T single procedure or in combination with TM-T and reverse shoulder prosthesis or both are very similar.

LDT-T as a primary treatment for irreparable rotator cuff tears has shown a moderate improvement in pain and function. However, the procedure as a salvage for failed rotator cuff repair has shown mixed outcomes.

Two studies[46,51] suggested that LDT-T is associated with better outcomes, especially satisfaction, function, and lower percentage of rupture of the transferred tendon, if it is performed as the primary surgical intervention after massive and irreparable rotator cuff tears.

Warner and Parson[51] and Irlenbush et al[51] conclude that salvage reconstruction of failed prior rotator cuff repairs yields more limited gains in satisfaction and function than primary latissimus dorsi transfer. In contrast, several authors[11,48,50] did not find significant differences in terms of the results and outcomes between LDT-T performed as a primary or a revision surgery.

The LDT-T procedure, when performed as a revision surgery, is a good solution for massive and irreparable rotator cuff tears, whereas a few investigators reported that, when it is performed as a primary surgery, it is associated with better results. Inferior results were found in shoulders with a subscapularis lesion relative to shoulders with subscapularis integrity, such as shoulders with teres minor fatty infiltration greater than stage 2[6] compared with shoulders with teres minor fatty infiltration lower than stage 2.

Relevant differences in terms of the outcomes, functional, pain, and subjective result, comparing shoulders with or without a lesion of the subscapularis tendon, can be found in the literature.

The integrity of the subscapularis tendon is crucial for the best outcomes and results after LDT-T. In 10 studies[8,36,38,42,45,46,48,50–52] that reported outcomes of the LDT-T procedure in patients with a subscapularis lesion, poor results were found after surgery in all the 59 shoulders. Despite these results, Miniaci et al[48] reported good results in patients managed with the LDT-T procedure with a subscapularis tendon tear. Therefore, the investigators do not consider the absence of the subscapularis a contraindication.

The presence or absence of a lesion of the teres minor tendon had no significant effect on the outcomes, whereas fatty infiltration of the muscle is predictive of outcomes.[39] In fact, fatty infiltration of the teres minor lower than or equal to stage 2[6] was associated with a better postoperative Constant score, Constant age-adjusted score, active external rotation, and anterior elevation, after LDT-T, compared with shoulders that presented teres minor fatty infiltration greater than stage 2.

No agreement was found concerning the position of reattachment of the transferred tendon/s. Gerber [42] found that the degree of superior migration was related to the overall functional result, and shoulders without superior migration, compared with normal shoulder scores, scored an average of 90%, those with mild superior migration scored 77%, and those with severe superior migration scored 62% of the normal value.

The outcome score in patients treated with the LDT-T procedure with severe osteoarthritis were worse than those with no or mild osteoarthritis, but the observed difference was not statistically significant.[40] Mild progression of osteoarthritic changes cannot be healed by the LDT-T, but this does not seem to be associated with inferior clinical results.

In various studies,[2,36,42–45] electromyography showed the presence of electrical activity of the LDT after surgery, confirming the promising outcome of the LDT-T procedure in terms of improving the ROM and functionality of the injured shoulder. Active external rotation and inability to stabilize the arm in the space were especially restored after LDT-T, providing containment of the humeral head with the additional benefit of an external rotation force. In addition, the outcomes were different when comparing primary or revision surgery, but no agreement was evident.

The lack of information found in the literature did not allow a comparison of open surgery versus arthroscopic surgery.

CONCLUSIONS

Given the limitations of the case series, especially the extensive clinical heterogeneity, it is not possible to establish clear recommendations regarding the use of LDT-T for the management of patients with massive rotator cuff tears, even though preliminary results are encouraging. Problems remain the need to understand the details of pathology,[60–69] the natural history of the disease, and the best available therapeutic options.[1,70–79] Clearly, studies with higher levels of evidence, including large randomized trials, should be conducted to help answer these questions.[80–91] Future trials should use validated functional and clinical outcomes, adequate methodology, and be sufficiently powered.

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