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Latissimus Dorsi Tendon transfer for treatment of irreparable posterosuperior rotator cuff tears: Long-term results at a minimum follow-up of ten years

Gerber, Christian ; Rahm, Stefan A ; Catanzaro, Sabrina ; Farshad, Mazda ; Moor, Beat K

Abstract: **BACKGROUND:** Transfer of the latissimus dorsi tendon to the greater tuberosity of the humerus for treatment of an irreparable rotator cuff tear has been reported to yield good-to-excellent short to intermediate-term results in well-selected patients. The purpose of this study was to evaluate the long-term outcome of such transfers for irreparable posterosuperior rotator cuff tears to determine the durability of the results and to identify risk factors for an unfavorable outcome. **METHODS:** Fifty-seven shoulders in fifty-five patients (seventeen women and thirty-eight men with a mean age of fifty-six years) were managed with latissimus dorsi tendon transfer. Final follow-up was performed at a mean of 147 months. Outcome measures included the Constant score and the Subjective Shoulder Value (SSV). Osteoarthritis, the acromiohumeral distance, and the so-called critical shoulder angle were assessed on standardized radiographs. **RESULTS:** Forty-six shoulders in forty-four patients were available at the time of final follow-up. The mean SSV increased from 29% preoperatively to 70% at the time of final follow-up, the relative Constant score improved from 56% to 80%, and the pain score improved from 7 to 13 points ($p < 0.0001$ for all). Mean flexion increased from 118° to 132°, abduction increased from 112° to 123°, and external rotation increased from 18° to 33°. Mean abduction strength increased from 1.2 to 2.0 kg ($p = 0.001$). There was a slight but significant increase in osteoarthritic changes. Inferior results occurred in shoulders with insufficiency of the subscapularis muscle and fatty infiltration of the teres minor muscle. Superior functional results were observed in shoulders with a small postoperative critical shoulder angle. **CONCLUSIONS:** Latissimus dorsi tendon transfer offered an effective treatment for irreparable posterosuperior rotator cuff tears, with substantial and durable improvements in shoulder function and pain relief. Shoulders with fatty infiltration of the teres minor muscle and insufficiency of the subscapularis muscle tended to have inferior results, as did those with a large critical shoulder angle. **LEVEL OF EVIDENCE:** Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

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Latissimus Dorsi Tendon Transfer for Treatment of Irreparable Posterosuperior Rotator Cuff Tears

Long-Term Results at a Minimum Follow-up of Ten Years

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Background: Transfer of the latissimus dorsi tendon to the greater tuberosity of the humerus for treatment of an irreparable rotator cuff tear has been reported to yield good-to-excellent short to intermediate-term results in well-selected patients. The purpose of this study was to evaluate the long-term outcome of such transfers for irreparable posterosuperior rotator cuff tears to determine the durability of the results and to identify risk factors for an unfavorable outcome.

Methods: Fifty-seven shoulders in fifty-five patients (seventeen women and thirty-eight men with a mean age of fifty-six years) were managed with latissimus dorsi tendon transfer. Final follow-up was performed at a mean of 147 months. Outcome measures included the Constant score and the Subjective Shoulder Value (SSV). Osteoarthritis, the acromiohumeral distance, and the so-called critical shoulder angle were assessed on standardized radiographs.

Results: Forty-six shoulders in forty-four patients were available at the time of final follow-up. The mean SSV increased from 29% preoperatively to 70% at the time of final follow-up, the relative Constant score improved from 56% to 80%, and the pain score improved from 7 to 13 points ($p < 0.0001$ for all). Mean flexion increased from 118° to 132° , abduction increased from 112° to 123° , and external rotation increased from 18° to 33° . Mean abduction strength increased from 1.2 to 2.0 kg ($p = 0.001$). There was a slight but significant increase in osteoarthritic changes. Inferior results occurred in shoulders with insufficiency of the subscapularis muscle and fatty infiltration of the teres minor muscle. Superior functional results were observed in shoulders with a small postoperative critical shoulder angle.

Conclusions: Latissimus dorsi tendon transfer offered an effective treatment for irreparable posterosuperior rotator cuff tears, with substantial and durable improvements in shoulder function and pain relief. Shoulders with fatty infiltration of the teres minor muscle and insufficiency of the subscapularis muscle tended to have inferior results, as did those with a large critical shoulder angle.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

Chronic rupture of the tendons of the rotator cuff leads to atrophy^{1,2}, fatty infiltration^{3,4}, and profound and irreversible⁵ functional changes in the respective muscles⁶. If the rupture involves the posterosuperior cuff, most patients experience weakness of external rotation and anterior elevation,

resulting in loss of control of the arm in space⁷ and pain of variable intensity. The changes in the supraspinatus, infraspinatus, and teres minor musculotendinous units are radiographically associated with cranial migration of the humeral head and progressive degenerative changes in the glenohumeral joint⁷.

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A commentary by Guido Marra, MD, is linked to the online version of this article at jbjs.org.

Treatment selection depends on the patient's subjective tolerance of pain and dysfunction, functional demands, and the potential for a treatment option to respond to the expectations of the patient⁸. Treatment options include corticosteroid injections, arthroscopic debridement with or without biceps tenotomy, partial rotator cuff repair, bridging of defects with graft material, and ultimately reverse total shoulder arthroplasty. Especially in younger patients with high functional demands and an unwillingness to accept the disability caused by posterosuperior tears, latissimus dorsi tendon transfer to the greater tuberosity of the humerus is an alternative to reverse total shoulder arthroplasty to alleviate pain and functional disability⁹. The transfer is based on anatomical⁹⁻¹¹ and biomechanical¹²⁻¹⁴ studies, and its use has yielded good-to-excellent short to intermediate-term clinical results in well-selected patients¹⁵⁻¹⁸. The purpose of this study was to assess the longer-term clinical and radiographic outcome of this transfer for the treatment of an irreparable posterosuperior rotator cuff tear and to identify risk factors for an unfavorable outcome.

Materials and Methods

Patients

A total of fifty-seven latissimus dorsi tendon transfers were performed in fifty-five patients from October 1995 to May 2001. Our investigational review board approved the long-term follow-up study of these patients. All of the transfers had been performed for an irreparable posterosuperior rotator cuff tear, defined as rupture of the supraspinatus and infraspinatus tendons that was associated with (1) at least stage-3 fatty infiltration of the supraspinatus and infraspinatus muscles and/or (2) an acromiohumeral distance of <7 mm on anteroposterior radiographs made with the arm in neutral rotation¹⁹ plus the inability to close the tendon defect intraoperatively because of excessive musculotendinous retraction. Fatty infiltration was classified according to the Goutallier modification of the system developed by Fuchs et al.^{3,4}.

Before the transfer, all patients had undergone treatment with oral nonsteroidal anti-inflammatory drugs and a supervised rehabilitation program (including restoration of free passive glenohumeral motion) for at least six months. Persisting pain and/or subjectively unacceptable dysfunction despite this treatment were indications for transfer of the latissimus dorsi tendon. Exclusion criteria for the transfer were chronic, pain-free pseudoparalysis of anterior elevation, inability to stabilize the arm at 90° of abduction even with the elbow fully flexed, and dynamic anterosuperior subluxation of the humeral head upon resisted abduction; individuals with these findings were considered to be candidates for reverse total shoulder arthroplasty. Additionally, patients with a subscapularis tear that was considered to be beyond repair (as evidenced by a positive lift-off test, increased external rotation, and stage-3 or 4 fatty infiltration of the subscapularis) were also excluded.

This series involved seventeen women and thirty-eight men with a mean age (and standard deviation) of 56.0 ± 7.1 years (range, thirty-seven to sixty-seven years). The intervention was performed bilaterally in two of the men, with the interval equaling fifteen months in one and twenty-three months in the other. Standardized preoperative magnetic resonance images (MRIs) revealed complete tears of at least the supraspinatus and infraspinatus tendons in all patients. Additionally, twelve shoulders had teres minor tendon failure with fatty infiltration that was stage 1 in eight, stage 2 in two, and stage 3 in two. The subscapularis was abnormal in seventeen shoulders, with fatty infiltration that was stage 1 in thirteen and stage 2 in four; the abnormality was limited to the upper third of the subscapularis in fourteen of the seventeen shoulders. In contrast to the supraspinatus and infraspinatus tears, these tears could be repaired directly back to their anatomical insertion on the lesser tuberosity.

Clinical and Radiographic Assessment

Preoperative, intraoperative, and postoperative clinical and imaging data were collected in a prospective fashion. Follow-up examinations were performed at regular intervals, and patients were reevaluated for the purpose of this study at a mean of 146.6 ± 19.6 months (range, 122 to 184 months). Nine of the patients (15.8% of the shoulders) had been lost to follow-up at that time. Of these, four had died from unrelated reasons, three had moved overseas, and two declined to attend the final follow-up examination. In addition, two patients had undergone revision involving reverse total shoulder arthroplasty (one because of advanced, painful cuff tear arthropathy, and the other because of humeral head osteonecrosis). However, each of these eleven patients had undergone a standardized intermediate follow-up examination that could be compared with the intermediate follow-up examinations of the forty-six shoulders available for final follow-up. This intermediate follow-up examination had been performed at a mean of 41.4 ± 13.4 months (range, twenty-four to ninety months).

The clinical assessment of the remaining forty-four patients included a structured interview and a standardized physical and radiographic examination. The shoulder function was scored according to the method of Constant and Murley²⁰, and the resulting score is presented both as the absolute Constant score in points and as the percentage relative to the score of an age and sex-matched normal population¹⁶. Insufficiency of the subscapularis muscle was assessed with the lift-off and belly-press tests²¹. Additionally, the integrity of the transferred latissimus dorsi tendon was assessed clinically by active external rotation against resistance with the arm at 90° of abduction. Visible or palpable contraction of the latissimus dorsi muscle during this maneuver was considered documentation of a functional transfer (see Appendix). Isometric strength was assessed at 90° of abduction (Isobex; Cursor, Bern, Switzerland); strength was rated as 0 if 90° of abduction could not be actively reached. The Subjective Shoulder Value (SSV) was determined by asking the patient to subjectively rate the shoulder in comparison with a completely normal shoulder, which was considered to have an SSV of 100%⁶. In addition, the patient was asked to rate the overall result as excellent, good, fair, or unsatisfactory²².

The radiographic analysis consisted of assessment of the acromiohumeral distance and the so-called critical shoulder angle²³ on true anteroposterior radiographs (Fig. 1). Glenohumeral osteoarthritis was graded as described by Samilson and Prieto²⁴, and the severity of cuff tear arthropathy was graded as described by Hamada et al.²⁵.

Assessment of Potential Risk Factors for a Poor Outcome

The patient assessment was used as the ultimate benchmark for success. We considered a latissimus dorsi tendon transfer as successful if the final SSV was at least twice the mean preoperative SSV, indicating a very substantial improvement. As the preoperative SSV averaged 29%, patients with an SSV increase of <30% between the preoperative value and the value at the time of final follow-up were classified as having an unsatisfactory result; an increase of at least 30% was classified as a satisfactory result. Fourteen shoulders had an SSV increase of <30%; although the SSV in this subgroup also increased, by a mean of 11%, these procedures were considered to have an unsatisfactory result. The remaining thirty-two shoulders had an increase of at least 30%.

The influence of the following factors was assessed in each SSV subgroup: the number of previous rotator cuff repair attempts prior to the index surgery, insufficiency of the subscapularis muscle (assessed clinically at the time of final follow-up), the degree of fatty infiltration of the teres minor muscle on preoperative MRIs, inactivity of the latissimus dorsi transfer, and the critical shoulder angle and acromiohumeral distance on the postoperative radiographs.

Surgery and Postoperative Care

The latissimus dorsi tendon transfer was performed as a primary reconstruction in forty-seven (82%) of the shoulders and as a salvage procedure, after one to four failed attempts at open or arthroscopic rotator cuff repair, in the remaining ten shoulders (18%). All interventions were performed by the senior author (C.G.) or under his direct supervision according to a previously described technique²⁶. Additional procedures included direct repair of the subscapularis (n = 17) and the teres minor tendon (n = 12). One patient who had



Fig. 1

The critical shoulder angle was measured on standardized anteroposterior radiographs. It is formed by a line connecting the inferior with the superior border of the glenoid fossa and a second line connecting the inferior border of the glenoid with the most inferolateral point of the acromion. This angle reflects not only the lateral extension of the acromion but also the inclination of the glenoid fossa; both of these parameters have previously been shown to be related to degenerative rotator cuff tears.

undergone a previous deltoid flap procedure underwent a reconstruction of the lateral aspect of the deltoid muscle. Excision of the acromioclavicular joint was performed in four shoulders. The long head of the biceps was routinely tenodesed into the bicipital groove if it was not already spontaneously ruptured.

After surgery, the arm was maintained in 45° of abduction and 30° to 45° of external rotation by an adaptable aluminum brace (Abduction Brace "Dr. Berrehail"; pharmap medical, Geneva, Switzerland). Passive range-of-motion exercises and hydrotherapy were started on the first postoperative day. After six weeks, the splint was discontinued and active external and abduction range-of-motion exercises were initiated. Strengthening exercises were not allowed until three months after surgery and were continued until six to nine months postoperatively.

Statistical Analysis

Descriptive analyses of the mean and standard deviation as well as the range of the data are reported if appropriate. Statistical comparisons between subgroups were performed with use of the two-tailed unpaired t test, and comparisons within the same individual were performed with use of the two-tailed paired t test. A p value of <0.05 was considered significant.

Results

Intermediate Follow-up

The data for the entire cohort are summarized in Table I. The mean age at the time of intermediate follow-up was 59.1 ± 7.3 years (range, forty-four to seventy-three years). The

mean SSV improved from 29% preoperatively to 69.4% at the intermediate follow-up examination ($p < 0.0001$). The mean absolute Constant score improved from 47.3 ± 15.1 (range, 18 to 73) to 63.5 ± 17.8 (range, 23 to 86), and the mean age and sex-matched relative Constant score improved from 56.1% ± 18.2% (range, 20% to 91%) to 76.7% ± 21.2% (range, 26% to 100%) ($p < 0.0001$ for both). The mean pain score improved from 6.6 to 12.1 ($p < 0.0001$); the maximum possible value of 15 points on this scale indicated no pain. Mean active external rotation increased from 18° to 33° ($p < 0.0001$). Active flexion and abduction increased from 118° to 132° ($p = 0.01$) and 112° to 128° ($p = 0.009$), respectively. Mean strength improved from 1.2 to 2.2 kg ($p = 0.001$).

No patient developed an infection, but one patient required superficial debridement and wound closure because of a wound dehiscence that healed without further sequelae. There were four reoperations in four shoulders: two shoulders with postoperative stiffness underwent arthroscopic debridement with release of adhesions, one required a reconstruction for a traumatically avulsed latissimus dorsi tendon five weeks after the index surgery, and the fourth underwent revision because of avulsion of the central portion of the deltoid muscle. Two patients had postoperative dysesthesia of the ulnar nerve, which resolved spontaneously within six months in both cases.

None of the parameters investigated at the intermediate follow-up examination differed significantly between the patients who attended the final follow-up examination and those who were lost to follow-up subsequent to the intermediate examination.

Final Follow-up

Forty-six shoulders in forty-four patients were available at the time of final follow-up (Table I). The mean age at the time of final follow-up was 68.4 ± 7.5 years (range, forty-seven to eighty-two years). The mean SSV was 70.1% ± 24% (range, 0% to 100%). The mean absolute and relative Constant scores were 63.8 ± 17.2 (range, 22 to 86) and 80.3% ± 22.5% (range, 24% to 100%), respectively (Fig. 2). The mean pain score was 13 ± 3.1 (range, 4

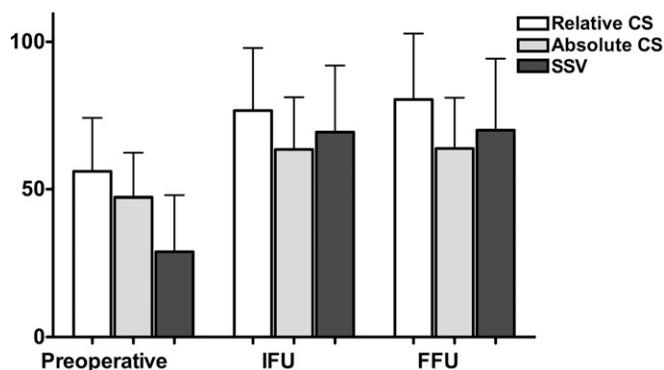


Fig. 2

Bar graph showing the Constant score (CS) in points, the CS as a percentage of an age and sex-matched normal population, and the SSV percentage at the three times. The values are given as the mean and the standard error of the mean. IFU = intermediate follow-up, and FFU = final follow-up.

TABLE I The Overall Cohort According to Time

Parameter*	Mean	Std. Dev.	Min.	Max.	P Value	
					Compared with Preop.	Compared with Intermediate Follow-up
Preop.						
Age (yr)	56.0	7.1	37	67		
SSV (%)	29.0	19.0	0	70		
Constant (%)	56.1	18.2	20	91		
Constant (points)	47.3	15.1	18	73		
Pain level	6.6	3.1	0	12		
Flexion (deg)	118.0	46.2	20	165		
Abduction (deg)	112.1	47.8	20	180		
Ext. rotation (deg)	17.9	24.0	-30	80		
Strength (kg)	1.2	1.1	0	4		
Intermediate follow-up						
Elapsed time (mo)	41.4	13.4	24	90		
Age (yr)	59.1	7.3	44	73		
SSV (%)	69.4	22.6	0	100	0.0001	
Constant (%)	76.7	21.2	26	100	0.0001	
Constant (points)	63.5	17.8	23	86	0.0001	
Pain level	12.1	3.2	5	15	0.0001	
Flexion (deg)	131.7	36.1	40	170	0.014	
Abduction (deg)	128.1	45.3	40	180	0.009	
Ext. rotation (deg)	33.2	17.1	-10	80	0.0001	
Strength (kg)	2.2	1.7	0	7	0.001	
Final follow-up						
Elapsed time (mo)	146.6	19.6	122	184		
Age (yr)	68.4	7.5	47	82		
SSV (%)	70.1	24.2	0	100	0.0001	0.387
Constant (%)	80.3	22.5	24	100	0.0001	0.037
Constant (points)	63.8	17.2	22	86	0.0001	0.580
Pain level	12.8	3.1	4	15	0.0001	0.102
Flexion (deg)	132.4	35.3	30	170	0.029	0.557
Abduction (deg)	122.6	40.1	30	170	0.089	0.193
Ext. rotation (deg)	32.5	19.3	-10	60	0.0001	0.466
Strength (kg)	2.0	1.7	0	7	0.001	0.712

*The Constant score is given as the absolute score in points and the relative score in percent compared with matched controls.

to 15). Mean external rotation was $33^\circ \pm 19.3^\circ$ (range, -10° to 60°), which was unchanged from the value at the time of intermediate follow-up. Mean active flexion and abduction were $132^\circ \pm 35.3^\circ$ (range, 30° to 170°) and $123^\circ \pm 40.1^\circ$ (range, 30° to 170°), respectively. Mean strength was 2.0 ± 1.7 kg (range, 0 to 6.9 kg). Except for the relative Constant score, which was slightly better at the final follow-up examination (80.3%) than at the intermediate examination (76.7%; $p = 0.03$), none of the parameters studied had changed significantly between the two follow-up time points, and all tested parameters remained significantly superior to the preoperative values. The patients rated twenty-three shoulders (50%) as excellent, eleven (24%) as good, nine (20%) as fair, and three (7%) as unsatisfactory.

Insufficiency of the subscapularis muscle was clinically evident, with positive belly-press and/or lift-off tests, in five shoulders, and no visible or palpable activity of the transferred latissimus dorsi tendon could be demonstrated in six shoulders. Osteoarthritic changes, as measured with the method of Samilson and Prieto, increased from a mean stage of 0.4 ± 0.6 (range, 0 to 3) preoperatively to 1.0 ± 0.9 (range 0 to 3) at the time of final follow-up. Progression was noted in twenty-two shoulders; seventeen of these progressed by one stage and the remaining five progressed by two or more stages. The Hamada osteoarthritis stage progressed from a mean of 1.2 ± 0.5 (range, 0 to 3) to 2.0 ± 1.0 (range, 1 to 4), with eighteen shoulders progressing by one stage and eight progressing by two or more stages. The mean acromiohumeral distance decreased from 7.4 ± 1.9 mm

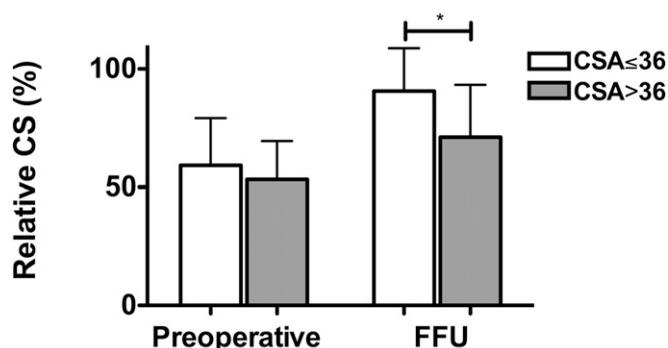


Fig. 3
The relative Constant score (CS) according to the size of the critical shoulder angle (CSA) in degrees. The values are given as the mean and the standard error of the mean. FFU = final follow-up. *P < 0.05.

(range, 4 to 13 mm) to 4.9 ± 2.0 mm (range, 1 to 10 mm). All of these radiographic changes were significant ($p < 0.0001$).

Assessment of Potential Risk Factors for a Poor Outcome

At the time of final follow-up, fourteen (30%) of forty-six shoulders had an SSV increase of <30%, considered to be an unsatisfactory result (see Appendix). The mean extent of fatty infiltration of the teres minor muscle was greater ($p = 0.03$) in these shoulders, with a mean grade of 0.9 ± 1.1 (range, 0 to 3) compared with 0.1 ± 0.3 (range, 0 to 1) in the thirty-two shoulders with a satisfactory result. The proportion of revision procedures was higher in the shoulders with an unsatisfactory result, but this difference did not reach significance ($p = 0.09$). The subscapularis muscle was clinically insufficient in 29% (four) of the shoulders with an unsatisfactory result compared with only 6% (two) of those with a satisfactory result ($p = 0.05$).

Five of the six shoulders in which activity of the transferred latissimus dorsi tendon could not be demonstrated were in the SSV subgroup with an unsatisfactory result ($p = 0.03$). Correspondingly, mean external rotation and mean abduction strength were significantly poorer in this subgroup (see Appendix).

In the radiographic analysis, the acromiohumeral distance was comparable in the two SSV subgroups. The critical shoulder angle on the final radiographs averaged $37.2^\circ \pm 3.3^\circ$ (range, 32° to 44°). The mean value of $39.5^\circ \pm 3.6^\circ$ (range, 34° to 44°) in the subgroup with an unsatisfactory result was significantly higher ($p = 0.005$) than the value of $36.1^\circ \pm 2.6^\circ$ (range, 32° to 42°) in the subgroup with a satisfactory result. Previously assessed cutoff values²³ were used to form two additional subgroups according to the size of the critical shoulder angle. The subgroup with a critical shoulder angle of $\leq 36^\circ$ included twenty-two shoulders (in twenty-one patients) with a mean critical shoulder angle of $34.4^\circ \pm 1.3^\circ$ (range, 32° to 36°), and the subgroup with an angle of $> 36^\circ$ contained the remaining twenty-four shoulders (in twenty-three patients) with a mean critical shoulder angle of $39.7^\circ \pm 2.4^\circ$ (range, 37° to 44°). The mean relative Constant score of the low-angle subgroup at the time of final follow-up was 90.6%, which was significantly higher ($p < 0.0001$) than the score of 71.1% in the high-angle subgroup (Fig. 3). Although the pain level and age

distribution did not differ between these two subgroups, functional results were significantly better in the low-angle subgroup, with mean flexion of 146° and abduction of 143° compared with 120° and 103° for the high-angle subgroup ($p = 0.01$ and $p < 0.0001$, respectively). However, mean external rotation and abduction strengths in these two subgroups were comparable.

Discussion

Latissimus dorsi tendon transfer is an effective treatment yielding reliable improvement for patients with irreparable tears of the posterosuperior rotator cuff^{9,15-18,26-29}. The present study documented that clinical results are maintained beyond ten years postoperatively, although degenerative changes progress on radiographs.

With an increase in the mean SSV from 29% to 70% and an increase of the relative Constant score by 24%, the results in this series are comparable with those reported by other authors^{18,26,27,29}. Provided the transferred latissimus dorsi tendon became functional, the clinical improvement was substantial and did not deteriorate over time. The reoperation rate was low at 12.3% (seven of fifty-seven), but two patients required conversion to a reverse total shoulder arthroplasty before the time of final follow-up. In accordance with previous reports^{15-17,27}, the results were significantly less favorable in patients with lost function of the subscapularis and fatty infiltration of the teres minor muscle.

In the experience of Warner and Parsons, latissimus dorsi tendon transfer was subjectively less satisfactory when performed as a revision procedure rather than as a primary intervention²⁹. These results have been contested by Miniaci and MacLeod, who obtained satisfactory results at a mean of fifty-one months after transfers that represented a revision of a failed rotator cuff repair¹⁸. One of us (C.G.) previously reported functional improvements and pain relief that were nearly comparable in patients with and without previous interventions¹⁵. The present series demonstrated a trend toward less favorable results after revision surgery. However, the difference did not reach significance, possibly because of the small number of patients in which the procedure represented revision surgery.

Zingg et al. followed a series of elderly patients with moderately symptomatic massive rotator cuff tears that were treated nonoperatively³⁰. Although shoulder function remained stable over time, a significant degeneration of the glenohumeral joint was observed within a period of only forty-eight months. The overall structural deterioration in our series of patients managed with latissimus dorsi tendon transfer was comparable, but the degenerative progression was considerably slower. At a mean of 147 months of follow-up, the acromiohumeral distance decreased by a mean of 2.5 mm while the mean osteoarthritis stage according to the classification of Samilson and Prieto progressed by 0.6 point.

A new finding in the present study is the association of a large critical shoulder angle with a less satisfactory result after latissimus dorsi tendon transfer. In shoulders with a small critical shoulder angle, the resulting force vector of the deltoid muscle is theoretically more centered on the glenoid surface. This may

lead to better joint stability during abduction and flexion movements since the remaining rotator cuff muscles as well as the transferred latissimus dorsi have to deal with less upward-directed deltoid power. We therefore believe that correction of a large critical shoulder angle to a value of $<36^\circ$ should be considered. We know that this can be easily achieved by an appropriate shortening of the lateral aspect of the acromion prior to reattachment of the central portion of the deltoid muscle.

As expected for a long-term follow-up study, not all initially enrolled patients could be reviewed at the time of final follow-up. The number of patients lost to follow-up was substantial, amounting to 20% of the cohort. The mean duration of long-term follow-up, however, was more than twelve years, so that $<2\%$ of the patients were lost per year. In addition, all patients lost to final follow-up had been reviewed at an intermediate follow-up appointment, and we were able to document that the intermediate follow-up results for the eleven patients lost to final follow-up did not differ from the intermediate follow-up results of the forty-six patients available at the time of final follow-up with respect to any parameter. Thus, it is unlikely that our conclusions are subject to a relevant bias due to selective loss to follow-up. Another potential limitation of the study results from the fact that the clinical evaluations at the three time points were not performed by the same examiner. The techniques of physical examination and assessment of the Constant score, however, are highly standardized at our institution, with continuous training and retraining that should keep the inevitable variations to a minimum. In addition, as the entire study population would be affected, this limitation should not compromise the validity of our findings.

In conclusion, latissimus dorsi tendon transfer offered an effective treatment for irreparable posterosuperior rotator cuff tears in either primary or revision situations. The improvements in shoulder function and pain level were substantial and durable over the course of time. Although the development of degenerative joint changes associated with the rotator cuff tear could not be inhibited, their progression appeared to be slowed compared with those associated with nonoperatively managed massive rotator cuff tears³⁰. Patients with fatty infiltration of the teres minor and insufficiency of the subscapularis muscle had inferior results after the transfer, as did patients with a large critical shoulder angle.

Appendix

 A table comparing patients with satisfactory and unsatisfactory results and photographs showing clinical assessment of the activity of the transferred muscle are available with the online version of this article as a data supplement at jbjs.org. ■

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