

Upper Extremity

Tendon transfers about the shoulder

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ABSTRACT

Tendon transfers have been effective in treating complex motor deficiencies around the shoulder, especially in young patients. Although they do not make up a large part of most orthopaedic surgical practices, physicians should be aware of the current state of the art in tendon transfers. This review summarizes the newest literature on latissimus transfers, latissimus with teres major transfers, pectoralis major tendon transfers, and deltoid or trapezial procedures.

Keywords

latissimus dorsi, L'Episcopo procedure, rotator cuff deficiency, teres major

INTRODUCTION

Complex motor deficiencies around the shoulder are challenging problems, particularly in younger patients. Tendon transfers have been effective techniques for decades. This review summarizes the peer-reviewed literature on tendon transfers from 2007 to March 2010. The paper is divided into basic science, latissimus transfers, latissimus with teres major transfers, pectoralis major tendon transfers, and other interesting tendon transfers. In the past 3 years, the modification of the L'Episcopo procedure, originally described for management of brachial plexus palsy, has been revisited, and results through a single deltopectoral incision appear to rival the previously published results for isolated latissimus dorsi transfer. Although tendon transfers are not a large part of most orthopaedic surgical practices, one should be familiar with the current state of the art after reading this review.

BASIC SCIENCE

Takahashi *et al.*¹ recently evaluated New Zealand white rabbits to assess adaptation after tendon transfer procedures of both muscle and tendon units. To understand the natural changes that occur after stretching a muscle past its physiological resting point in a transfer, sarcomere length was measured with laser diffraction, and the changes in serial sarcomere

number and tendon length were assessed before and after transfer. After the tendon transfer, a rapid increase in serial sarcomere number was observed immediately after surgery; however, during the first 8 weeks after surgery, it decreased and the tendon lengthened. The authors noted that this asynchronous adaptation to tensioning of the muscle and tendon after a tendon transfer can be the source of unwanted tendon lengthening. Involvement of matrix metalloproteinase in the tendon degradation after the transfer is indicated as a source of future study to prevent unwanted tendon elongation after tendon transfer.

Morelli *et al.*² evaluated 18 embalmed shoulders from nine cadavers to assess the anatomic landmarks and the relationship of these anatomic landmarks to important neurovascular and soft-tissue structures as they relate to latissimus dorsi tendon transfer surgery from a posterior approach. The authors identified a structure that they termed the *dense fibrous band*. The dense fibrous band is located where the teres major and latissimus dorsi contact each other near the myotendinous junction. Identifying this dense fibrous band may facilitate the recognition of the radial nerve, which was 22 mm deep to the dense fibrous band. In addition, the teres major muscle fibers appeared to attach onto the latissimus dorsi tendon at times. The latissimus dorsi tendon length appeared to be significantly longer than the teres major length.

Werner *et al.*³ reported the biomechanical role of the subscapularis on latissimus dorsi transfer for the treatment of irreparable rotator cuff tears. Previous researchers indicated that the absence of a subscapularis negatively affects the results of an isolated latissimus dorsi transfer.^{4,5,6,7} The authors developed a biomechanical model to explain why a latissimus dorsi transfer in the presence of a subscapularis tear can provide inferior functional results compared with latissimus dorsi transfers in the presence of a functionally intact subscapularis. To achieve this, they created a biomechanical model using cadaver humeri in 10 fresh-frozen cadaver shoulders and performed a latissimus tendon transfer. They created a massive rotator cuff tear and accomplished mechanisms to load the subscapularis, the transfer, and the ability to change the position of the humerus and space. The scapula was maintained rigidly fixed to a mounting device. Translation and rotation of the center of the humeral head were registered using a computerized motion analysis system. The humerus was placed through a range of motion with and without loading of the subscapularis. The arm was in the neutral position, and co-contraction of the latissimus and the subscapularis resulted in a 13-mm posterior translation of the humeral

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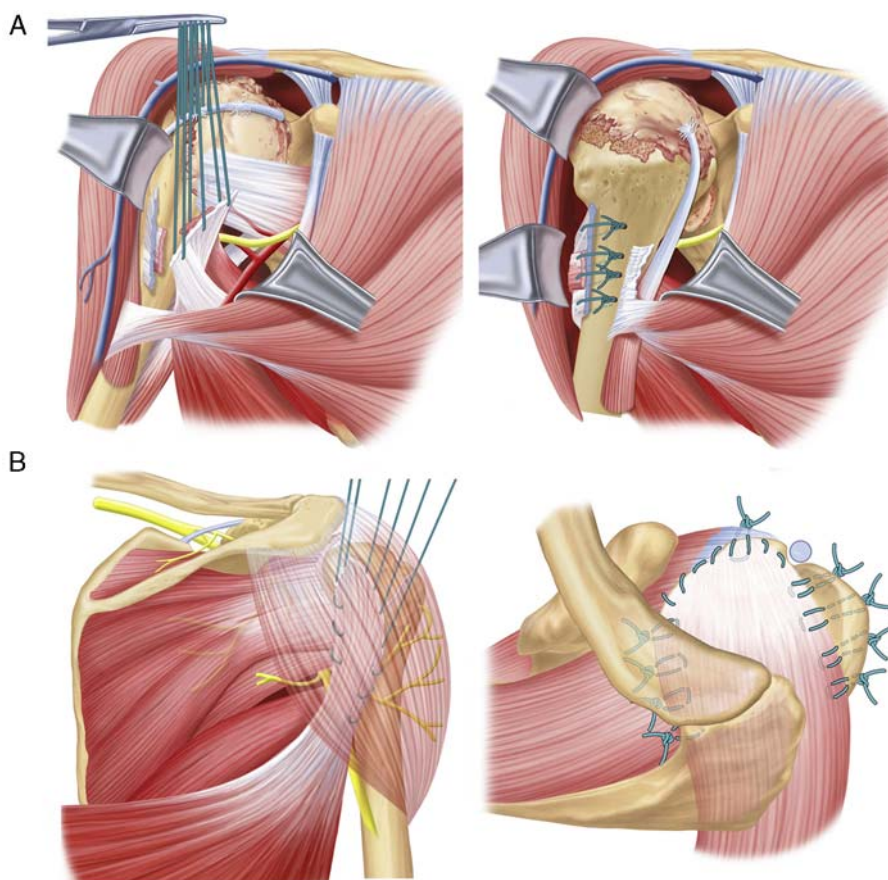


FIGURE 1. (A) Deltopectoral approach for teres and latissimus transfer as described by Boileu. (B) Latissimus transfer from posterior approach as described by Gerber.

head; however, contraction of the latissimus without the subscapularis resulted in a 19-mm anterior translation of the humeral head. In the abducted and externally rotated position, a posterior translation of 10.2 mm occurred when the subscapularis and latissimus transfer were loaded simultaneously; however, without subscapularis loading, anterior translation was 32 mm. Loading of the latissimus transfer without loading the subscapularis resulted in anterior-inferior dislocation of the humerus. The article provided the first biomechanical explanation for previously observed postoperative findings. The action of the subscapularis in this biomechanical model improved stability of the glenohumeral joint with a simulated latissimus transfer.

Favre *et al.*⁸ tried to identify the ideal insertion site to maximize the mechanical advantage for a latissimus dorsi transfer (without teres major transfer) during a reverse shoulder arthroplasty to restore external rotation strength. The three locations for insertion of the latissimus transfer were anterior, just adjacent to the bicipital groove on the greater tuberosity; posterior on the lower posterior portion of the greater tuberosity; and inferior at the metadiaphyseal junction between the anterior and posterior locations. They found that the posterior location of the transfer had the greatest external rotation moment.

Steenbrink *et al.*⁹ performed an isolated teres major transfer and transferred the teres major to the supraspinatus

footprint. A preoperative out-of-phase activity was documented, and a postoperative in-phase activity was documented for the teres major muscle, indicating that the teres major adapted to its new role as an external rotator and contributed to elevation of the humerus instead of to adduction of the humerus preoperatively.

Goldberg *et al.*¹⁰ evaluated the surgical anatomy of the latissimus dorsi muscle and found three insertion patterns of the latissimus dorsi onto the humerus with respect to the tendon of the teres major. Separate tendon attachments, loosely bound tendon attachment, and joined tendon attachments were noted. The authors described the location of the peripheral nerves relative to the surgical area.

Ling *et al.*¹¹ evaluated the ideal location of attachment of the latissimus dorsi tendon for treatment of a posterior superior rotator cuff tear. Attachment to the subscapularis, supraspinatus, infraspinatus, or teres minor insertion were tested. They reported that the preferred location was the infraspinatus location and did not recommend transfer to the teres minor.

Buijze *et al.*¹² reported the musculotendinous transfer of the teres major or latissimus dorsi as a treatment option for irreparable posterior-superior rotator cuff tears. They used cadaver dissection to evaluate the length of muscle and the length of tendon and the location of neurovascular structures for latissimus dorsi and teres major. The latissimus

dorsi was considered more likely to have neurovascular bundle problems on tendon transfer, and the teres major was more likely to have problems with suture reattachment because of a short tendon.

Pearle *et al.*¹³ familiarized surgeons with the relevant neurologic anatomy from a posterior approach to the humerus through the exposure of the latissimus dorsi and teres major tendons. They reported that the average distance from the humeral insertion of the latissimus dorsi to the thoracodorsal nerve was 13.1 cm and from the humeral insertion of the teres major to the lower subscapular nerve was 7.4 cm. They identified that tendon release, mobilization, and tunneling place neurologic structures at risk during the combined latissimus and teres major transfer.

LATISSIMUS DORSI

Weening and Willems¹⁴ reported their series of 16 latissimus dorsi transfers with an average follow-up of 26 months. They used an isolated latissimus transfer to the top of the humerus, which was sewn into the greater tuberosity at the footprint of the supraspinatus and infraspinatus as far anterior as possible. Some patients had concomitant subscapularis ruptures and had poor results. Overall, most patients did well, with the average Constant score improving from 39 before surgery to 63 after surgery ($P=0.001$). The authors cautioned that, despite the improvement in motion, an improvement in strength was not to be expected in this procedure; however, simple activities of daily living typically improved. They found that improvement was best when the patient had not had a previous rotator cuff procedure. Improvements in acromial-humeral interval were identified as position-related, as the authors obtained radiographs both in neutral internal and external rotation and found that internal rotation resulted in the most improved acromial-humeral interval in most patients. Tensioning of the transfer might be ideal in the internally rotated position, which Nové-Josserand *et al.*¹⁵ had discussed. Subscapularis insufficiency was considered a contraindication.

Zafra *et al.*¹⁶ reported 18 latissimus transfers done through a two-incision technique. The Constant score improved by 21 points from before to after surgery. The transfer was attached to the anterior-superior portion of the humeral head, suturing the repair directly into the subscapularis and superior cuff footprint in all cases. Postoperative complications included two infections and a spontaneous rupture of the long head of the biceps 4 weeks after surgery. All patients had never had shoulder surgery. No progression of degenerative change occurred during the follow-up period. The authors recommended considering this procedure particularly in young, active patients who were good candidates for the extensive postoperative rehabilitation program.

Werner *et al.*¹⁷ reported the influence of psychomotor skills and innervation patterns on the results of the latissimus dorsi tendon transfers for irreparable rotator cuff tears. They tried to identify if factors other than understood anatomic issues could explain a poor result after latissimus dorsi transfer. Factors, such as subscapularis insufficiency, fatty infiltration of the remaining cuff, insufficiency of the

deltoid and an acromiohumeral distance of less than 5 mm, frozen shoulder, or degenerative issues of the glenohumeral joint were excluded as variables in this group. From a consecutive series of patients who had the same technique without modification and had a minimum 2-year follow-up, the 10 patients with the highest Constant scores and the 10 patients with the lowest Constant scores were enrolled for analysis of multiple variables. A standard psychomotor skills assessment and electromyography of the latissimus dorsi bilaterally was performed. Both groups had similar preoperative Constant scores, preoperative pain, and preoperative diagnoses. The patients in group one with the best outcomes had improved signal amplitudes on electromyography (EMG) during passive and active testing of the affected latissimus compared with the patients in group two, suggesting that the patients in group one may have learned to activate their transferred muscles more effectively in the rehabilitative period. The authors used Motorische Leistungsserie psychomotor testing, which is a standard test to assess driving abilities. Patients were instructed to tap and retrace lines and to place long and short sticks into sockets. Functional ability using these tests of the nonoperative arm was predictive of strength and motion on the surgically treated side.

Costouros *et al.*¹⁸ evaluated the potential influence of teres minor integrity on the outcome in 16 men and six women with an average follow-up of 34 months after latissimus dorsi tendon transfer using the technique of Gerber *et al.*⁷ The patients were divided into two groups; group A included Goutallier stage 0, 1, and 2 fatty infiltration of the teres minor,^{19,20} and group B included patients with more than stage 2 changes on preoperative scans. The presence of a partial tear of the teres minor had a smaller effect than the degree of fatty infiltration of the teres minor. The presence of fatty infiltration of the teres minor greater than stage 2 was associated with greater pain before and after surgery, worse functional scores, less external rotation after surgery, and less forward elevation after surgery than other patients. The authors recommended assessing the degree of fatty infiltration of the teres minor before proceeding with a latissimus transfer because it was predictive of the end result. The average postoperative external rotation in group A was 36° and in group B was 16°.

Irlenbusch *et al.*²¹ reported muscle function after latissimus dorsi transfer in 45 patients with surface EMGs at 6, 9, and 19 months. The patients were instructed to move their operative and nonoperative arms 10 times into flexion, scaption, and abduction and into the combined extension and internal rotation maneuver. They found a strong correlation between a Constant score and overall EMG activity.

Irlenbusch *et al.*²² evaluated 52 patients treated with a latissimus dorsi transfer for irreparable rotator cuff tears between 2000 and 2002. The results were best when the tendon transfer was a primary procedure in patients who had isolated posterior-superior cuff defect, unaffected subscapularis muscle, no history of instability, no deltoid pathologic lesions, and no previous operations. Consecutive evaluations of the patients were performed at 11, 35, and 50 months. Continuous improvement in the Constant score

was achieved. Revision surgery produced less reliable results than primary surgery.

Birmingham and Neviasser²³ reported the outcome of latissimus dorsi transfer as a salvage procedure for failed rotator cuff repairs with loss of elevation. All 19 consecutive patients with a functionally intact subscapularis were treated for massive irreparable posterior-superior cuff tears with between one and four previous failed repairs and progressive and persistent loss of function and pain. A two-incision latissimus transfer was performed, and the latissimus was secured over the top of the humeral head to the subscapularis and to the supraspinatus footprints. Average improvement of the American Shoulder and Elbow Society (ASES) score ranged from 43 before surgery to 61 after surgery. Ninety-four percent of the patients were satisfied with their results. Active elevation of the arm improved from 56° before surgery to 137° after surgery. External rotation improved from 31° to 45°. The authors reported that the latissimus dorsi transfer using the original technique as described by Gerber *et al.*⁷ (Figure 1B) can be as effective as a salvage procedure for failed rotator cuff repair with loss of elevation.

Gerber *et al.*²⁴ used a two-incision latissimus dorsi transfer to treat 67 patients with 69 irreparable full-thickness cuff tears and evaluated them clinically and radiographically at a mean follow-up of 53 months. The approach involved proximal detachment of the lateral deltoid. The latissimus was transferred to the tip of the greater tuberosity and sewn from the greater to the lesser tuberosity superiorly. Shoulders were immobilized in 45° of abduction and from 30° to 45° of external rotation for 6 weeks. Patients with a poorly functioning subscapularis did not do as well as patients with an intact subscapularis. Improvements in pain, flexion, abduction, external rotation, Constant score, and subjective shoulder value were identified. Active external rotation improved from 22° before surgery to 29° after surgery. Despite radiographic evidence demonstrating progression of degenerative joint changes, clinical improvements in latissimus dorsi transfers or posterior-superior cuff tearing were significant.

Miniaci and MacLeod²⁵ reported the results of latissimus dorsi transfer after failed repair of massive tears of the rotator cuff in 17 patients at 2-year to 5-year follow-up. They used a two-incision approach as described by Gerber *et al.*⁷ that included a deltoid split and a posterior incision. The latissimus dorsi alone was transferred in 16 patients, and the latissimus dorsi with the teres major was transferred in one patient. Significant improvements in pain, patient satisfaction and function were noted at a minimum of 2 years after surgery. Three failures occurred in work-related injuries. No infectious or neurovascular injuries were encountered. They concluded that using this procedure in patients with previous failed rotator cuff surgery can improve pain and function.

Gerber *et al.*²⁶ presented a preliminary report a reverse total shoulder replacement combined with a latissimus dorsi transfer. Twelve shoulders with an average follow-up of 18 months were treated with a combined reverse shoulder replacement and an isolated transfer of the latissimus dorsi harvested through a posterior incision and transferred to the

posterior-inferior portion of the greater tuberosity. Mean external rotation improved from 12° before surgery to 19° after surgery. Preoperative flexion was 94°, and postoperative flexion was 139°. Significant improvements in pain, subjective shoulder value, and absolute and relative Constant scores also were achieved. The authors stated that the absence of the subscapularis, which is a contraindication for a latissimus dorsi transfer without arthroplasty is not a contraindication for reverse shoulder arthroplasty. Nonetheless, they suggested repairing the subscapularis if possible during the insertion of a reverse shoulder prosthesis when doing a latissimus dorsi transfer.

Moursy *et al.*²⁷ used isolated latissimus dorsi tendon transfer to treat 42 patients with massive irreparable posterior-superior cuff tears. The tendon was transferred to the greater tuberosity of the humerus in all patients. After the first 22 patients (group A), they modified their technique to improve tendon transfer integrity, harvesting the latissimus with a chip of bone off the humerus separated (group B, n = 20 patients). MRI was performed to assess the integrity of the transferred muscle. The Constant score improved from 43 before surgery to 54 after surgery in group A and from 40 before surgery to 74 after surgery in group B. Eight patients had unsatisfactory results. Of the six patients in group A, four had a ruptured latissimus transfer that was documented on MRI, and one had a postoperative subscapularis deficiency. Of the two patients with unsatisfactory results in group B, one had a postoperative spontaneous subscapularis rupture, and one had an unknown cause. In group A, four patients showed no healing and retraction of the latissimus dorsi transfer on MRI with fatty infiltration and muscle atrophy. In group B, all patients showed a normal course of the transferred muscle without signs of tendon tearing from the greater tuberosity or signs of fatty degeneration or atrophy. The authors concluded that, although all sources of failure might not be treated by harvesting a small fragment of humerus along with the latissimus dorsi tendon during a latissimus dorsi transfer, the end result of tendon integrity appeared to be improved with the modification technique, including a small fragment of bone. Subscapularis failure remains a problem.

To reduce deltoid morbidity, Gervasi *et al.*²⁸ developed an arthroscopically assisted approach to latissimus dorsi transfer. They used mini-open harvesting of the tendon followed by an arthroscopic repair of the transferred tendon to the upper subscapularis and the footprint of the supraspinatus and infraspinatus. No results were discussed.

In a midterm follow-up study, Pearsall *et al.*²⁹ used latissimus dorsi transfer as a salvage procedure for failed debridement and attempt to repair massive cuff tears in seven patients. The patients were treated with a latissimus dorsi transfer using a modification of the two-incision technique described by Gerber. In addition to using the latissimus dorsi, an allograft patch was used to provide added length to the transfer. Constant score, University of California-Los Angeles, and Short Shoulder Form scores and pain improved.

Nové-Josserand *et al.*¹⁵ presented a group of 26 patients treated with latissimus dorsi transfer for irreparable rotator cuff tears using the technique described by Gerber *et al.*⁷

All patients had Goutallier stage 2 or higher infraspinatus and supraspinatus fatty infiltration, and 13 patients also had stage 2 or more teres minor atrophy. All patients with subscapularis fatty infiltration were excluded. At a minimum 24-month and average 34-month follow-up, 85% of patients were satisfied or very satisfied and 15% were disappointed or dissatisfied with their results. The mean subjective shoulder value score was 68.4. Modest improvement in external rotation was achieved and averaged 7°. Some patients lost external rotation. Patients with a history of surgery on the same shoulder had significantly worse results. Latissimus dorsi tendon transfer appeared to be reasonably reliable for restoring elevation; however, strength restoration was not as reliable in patients with a fatty infiltrated teres minor. They had a poorer prognosis than those with a healthy teres minor.

Codsi *et al.*³⁰ demonstrated their surgical technique for latissimus dorsi tendon transfer for irreparable posterior-superior rotator cuff tears. Using the surgical technique of Gerber, the latissimus dorsi tendon was transferred and attached onto the superior portion of the humeral head, tenodesing the latissimus to the upper aspect of the subscapularis.

Latissimus Dorsi and Teres Major Together

In a preliminary study, Boileau *et al.*³¹ prospectively followed 11 patients who had a combined loss of active elevation (elevation of less than 90°) and active external rotation (less than 0° of rotation) and had reverse shoulder arthroplasty and a modified latissimus dorsi and teres major tendon transfer for shoulder pseudoparalysis associated with dropping arm. All patients had stage 3 or 4 fatty infiltration of the infraspinatus according to the Goutallier classification and had either an atrophic or fatty infiltrated teres minor. Shoulder arthrosis was stage 3, 4 or 5 according to the Hamada classification. In this procedure, the latissimus dorsi and teres major were attached to the posterolateral aspect of the greater tuberosity in most cases. However, in four patients the tendons were attached to the diaphysis at the pectoralis major tendon stump. Mean improvements in elevation of 70° and in external rotation of 36° appeared to be superior to those previously reported in the standard two-incision technique.

Gerhardt *et al.*³² evaluated 20 patients at 2 and 5 years after a modified L'Episcopo tendon transfer for posterior-superior rotator cuff deficiency. Described in 1934 for the treatment of obstetric brachial plexus injury, the L'Episcopo procedure involves transferring the latissimus dorsi and teres major together. Gerhardt *et al.*³² reattached the tendons to the proximal humeral shaft at the metadiaphysis of the proximal humerus. They evaluated the transfer intensity with ultrasound or MRI at 5 years. Additional surface EMG was done, and the acromiohumeral interval was assessed both preoperatively and 5 years postoperatively. Active forward elevation improved from 119° before surgery to 170° at 5-year follow-up. Active external rotation improved from 12° to 23°. An ultrasound and MRI demonstrated that the transferred tendons were intact at 2 years and 5 years after surgery. Significant improvements in pain,

activities of daily living, active range of motion, and abduction strength were found at the 5-year follow-up. Interestingly, cuff tear arthropathy increased based on the Hamada classification, but it was not associated with a decrease in functioning.

Lehmann *et al.*³³ modified the originally described technique by Gerber *et al.*⁷ using information published by Herzberg *et al.*³⁴ and performed a single posterior incision, transferring the latissimus and teres major. These transfers were done with the intent of attaching the tendon at the anatomic insertion of the infraspinatus footprint. This procedure was used in 26 patients over 3 years. All patients had at least grade III retraction of the supraspinatus and infraspinatus tendons based on the Patte³⁵ classification. The improvements in adjusted Constant score from 26 to 70 ($P \leq 0.001$) was identified 2 years after surgery, including improvement in pain, activities of daily living, and active range of motion. Eighty-five percent of their patients were subjectively content with the result. In all cases in which biceps tenotomy had not been done in previous surgery, an arthroscopic biceps tenotomy was performed before initiating the open tendon transfer. Subscapularis rupture was considered a contraindication to this procedure in this report. Lehmann's technique involved a single longitudinal posterior incision starting at 5 cm below the posterolateral edge of the acromion posterior and heading along the triceps, allowing for elevation of the deltoid in identification of the tendon of the latissimus and teres major. With an average operative time of 54 minutes and a low complication rate, the Herzberg modification showed promise.

Boileau *et al.*³⁶ reported a novel technique for a latissimus and teres major transfer through a deltopectoral exposure (Figure 1A). The results were reported in 15 patients with an average follow-up of 38 months. The upper half of the pectoralis is tenotomized at the myotendinous junction with heavy stay sutures placed to allow for reattachment. The latissimus and teres major are sharply transected and rerouted around the posterior portion of the humerus to be reattached onto the pectoralis stump. Alternatively, transosseous repair at the greater tuberosity can be accomplished as during a reverse shoulder arthroplasty. The humerus is distalized, and the attachment to the tuberosity is facilitated. Results were stratified based on patients' preoperative loss of external rotation alone or of external rotation and forward elevation. The seven patients who maintained forward elevation but lost external rotation preoperatively had an average improvement in external rotation of 27°. Active elevation and internal rotation were maintained. The six patients who lost external rotation and elevation were managed with tendon transfer and reverse shoulder prosthesis. This group had an average elevation increase of 75° and external rotation increase of 28°. Two patients had tumor excision that involved the proximal humerus and were able to maintain their activities of daily living. Subjective and objective measurements of patient satisfaction were high, with an improvement of the subjective shoulder value from 34–72% after surgery ($P \leq 0.009$) and improvement in the Constant score. One patient fell during the postoperative period, ruptured the transfer, and had a return of external rotation lag; however,

the patient noted subjective improvement. The results appear to be similar to those obtained through a two-incision approach. The authors reported no neurologic complications. The advantages of this approach were that it was done through the familiar deltopectoral approach and could be performed at the same time as a total shoulder replacement, reverse shoulder replacement, and biceps tenodesis. The improvement of external rotation of nearly 30° appeared to be superior to the results from an isolated latissimus transfer. The authors cautioned that the transfer should be considered only in patients with significant loss of posterior cuff resulting in the inability to maintain the forearm in neutral rotation.

Boileau *et al.*³⁷ reported reverse shoulder arthroplasty with the modified L'Episcopo procedure for a combined loss of active elevation and external rotation. They classified patients with massive irreparable rotator cuff tears into three categories: (1) isolated loss of active elevation with maintained external rotation, (2) isolated loss of external rotation with maintained elevation, and (3) combined loss of external rotation and elevation. Patients with isolated loss of active elevation responded well to reverse shoulder arthroplasty. Patients with isolated loss of external rotation responded well to the L'Episcopo procedure done through a deltopectoral exposure. Patients with a combined loss of elevation and external rotation responded well to a combined reverse shoulder arthroplasty and the L'Episcopo procedure performed through a deltopectoral exposure. They described the operative technique to effectively perform a combined latissimus and teres major transfer through a single anterior approach. After harvesting the latissimus and teres major, the two tendons are sewn together using heavy nonabsorbable suture and passed around the posterior aspect of the humerus. They are attached with a transosseous suture with four drill holes in the humeral shaft before insertion of the final humeral component. The upper half of the pectoralis major is tenotomized at the beginning of the procedure and repaired at the end of the procedure after the transfer. Postoperatively, the arm is immobilized in 30° of abduction and 30° of external rotation for 6 weeks, and the brace is removed only for maintaining personal hygiene. After 6 weeks of immobilization in a custom-made orthosis, the patient starts a supervised program of elevation and rotation exercises, limiting internal rotation to neutral until week 9 and to the greater trochanter of the hip until week 12. After 12 weeks, progressive stretching and strengthening of internal and external rotation is allowed. The authors described a new score called the *activities of daily living requiring active external rotation* (ADLER). Ten functional activities are questioned, and each activity can be scored from 0 to 3, depending on whether the activity is not possible or not difficult at all. The maximum score of 30 indicates that activities requiring external rotation for activities of daily living are not difficult at all. They reported 17 patients receiving combined reverse shoulder arthroplasty and a modified L'Episcopo procedure through a single deltopectoral exposure at a mean follow-up of 23 months. They were evaluated with the Constant score, ADLER score, subjective shoulder value, and subjective rating of satisfaction. Significant improvements in active

elevation, external rotation, Constant score, average score, and subjective shoulder value were identified. All patients were either satisfied or very satisfied. The authors recommended not attaching the transferred tendon to the greater tuberosity because the quadrilateral space could be narrowed, resulting in potential quadrilateral space syndrome. The authors further clarified that their original description of their repair location (to the stump of the pectoralis major tendon)³⁶ had been changed to a transosseous attachment on the opposite side of the humerus. This change of attachment site helped to reduce a potential loss of internal rotation that can be seen with the pectoralis attachment site. Finally, they stressed that patient compliance and rehabilitation are critical and that the patient should be cautioned that rehabilitation might need to be continued for 6 to 12 months after surgery.

PECTORALIS MAJOR

Galano *et al.*³⁸ used either split pectoralis major transfers or Eden-Lang procedures to treat wing scapulae in 16 patients from 2000 to 2006. They performed 11 split pectoralis major transfers for serratus anterior palsy. Two patients had concomitant trapezius palsy and required an Eden-Lang procedure. All 10 patients treated with split pectoralis tendon transfers had EMG evidence of long thoracic nerve palsy before surgery. Six patients underwent modified Eden-Lang procedures for spinal accessory nerve and subsequent injury in trapezius palsy. Three of these six patients had iatrogenic injury from lymph node biopsy, radical neck dissection, or posterior cranial fossa decompression. The other three were traumatic injuries from water skiing, motor vehicle accident, or football. All patients had preoperative EMG demonstrating spinal accessory nerve palsy. The surgical technique is described as an isolated sternal head transfer to the inferior border of the scapula. The pectoralis is secured with horizontal mattress sutures through drill holes in the scapula through a two-incision technique. The Eden-Lang procedure was performed with a 10-cm incision, and the atrophied trapezius was incised to access the medial border of the scapula and the rhomboid minor and major. These were transferred to suture holes in the scapula, and a second incision was made superiorly for the transfer of the levator scapula. The authors found that these dynamic transfers allowed predictable improvement in pain, function, and range of motion. They stressed the importance of an adequate nonoperative approach before considering surgery for these relatively uncommon diagnoses.

Gavriilidis *et al.*³⁹ reported pectoralis major transfer for the treatment of irreparable anterior-superior rotator cuff tears. Between 2000 and 2006, they treated 15 patients by transfer of the clavicular part of the pectoralis major through a deltopectoral approach to the lesser tuberosity after a subscapularis injury. This technique involved the transfer of the pectoralis major under the conjoint tendon for a subcoracoid pectoralis transfer repaired with suture anchors in the lesser tuberosity. The Constant score was improved significantly after surgery. Strength did not improve dramatically after surgery, and it was not possible

to achieve full elevation of the arm after this procedure. No musculocutaneous nerve injuries were encountered. Improvements in pain and activities of daily living can be expected after a subcoracoid pectoralis major tendon transfer.

Elhassan *et al.*⁴⁰ evaluated pectoralis major tendon transfer for subscapularis ruptures in three scenarios: (1) isolated irreparable subscapularis after a failed instability procedure (group I), (2) rupture of the subscapularis after a shoulder arthroplasty (group II), and (3) rupture of the subscapularis associated with a massive rotator cuff tear (group III). An isolated transfer of the sternal portion of the pectoralis major was performed anterior to the conjoined tendon, but the tendon was passed beneath the clavicular head of the pectoralis to improve the pulley effect and was attached to the anterior portion of the greater tuberosity. The patients in group II fared the worst after a pectoralis major tendon transfer, with the least improved Constant score and with only one of eight patients indicating an improvement in pain. In addition, six of the eight patients in group II ruptured the pectoralis transfer, and five of the eight had recurrent anterior subluxation of the humerus. In group I, seven of the 11 patients improved their subjective shoulder scores and seven indicated that their pain had decreased. In group III, seven of the 11 patients had improved shoulder score and pain. The authors indicated that the split transfer of the pectoralis to treat the subscapularis failure was not as reliable as they had hoped and that other options needed to be considered.

DELTOID OR TRAPEZIUS FLAP PROCEDURES

Lu *et al.*⁴¹ reported the long-term outcomes after deltoid muscular flap transfer for irreparable rotator cuff tears in 18 patients (20 shoulders) at a mean of almost 14 years. The operation was suggested primarily for active individuals who had good muscle status and had recovered almost complete active motion through rehabilitation but who still had significant pain and functional muscle fatigability that prevented a return to activity. The surgical technique involved harvesting a flap of deltoid through a deltoid-splitting approach and reattaching the deltoid to the retracted supraspinatus with multiple nonabsorbable sutures medially and the remaining anterior and posterior cuff. The remaining deltoid was repaired side-to-side after the flap had been secured to the residual rotator cuff. Postoperative rehabilitation averaged 9.4 months. Preoperative to postoperative improvements in the Constant score from 49 to 71 and significant improvements in pain from 5.3 to 13.8 (on a 15-point scale) were achieved. However, the mean active elevation of these patients before surgery was 144° and after surgery was 149°. Mean external rotation was 47° before surgery and 48° after surgery. Nineteen patients were very satisfied or satisfied with the results. The only patient who was dissatisfied had an early rupture of his flap. Through MRI or ultrasound, the authors noted that 10 flaps remained intact and 10 flaps were ruptured completely. The difference in postoperative Constant score between these two groups was not significant. Moderate or severe stages of osteoarthritis occurred in 14 of the 20 shoulders (70%) at the most

recent follow-up, and more severe arthritic radiographs were present in patients whose deltoid flap had ruptured. When evaluating the longer-term results of this procedure, the authors did not recommend it for treating irreparable tears because similar results might be achievable through less destructive means.

Glanzmann *et al.*⁴² reported mid-term and long-term functional and structural results of 31 consecutive deltoid flap reconstructions from massive rotator cuff tears performed by three different surgeons between 1991 and 1997 (average follow-up = 53 months). The surgical technique followed the description by Apoil and Augereau.⁴³ Pain on the visual analog scale significantly improved. Improvements in active elevation and in strength from before to after surgery were not significant. Sixty-four percent of the patients were satisfied with their results. Via ultrasound, only 19% of the deltoid flaps remained intact. At mid-term follow-up, all but one shoulder showed signs of degeneration. Of these 31 patients, 16 were available for longer-term follow-up at an average of 175 months. At 175 months, overall pain, function, and strength remained similar to the mid-term follow-up. Four of the 16 patients had an intact deltoid flap and had better function and Constant scores than those who did not. All humeral heads had migrated proximally, and the subacromial space was less than 5 mm. Arthritic changes in the shoulder were present in all patients, with some having severe cuff tear arthropathy. The authors presented the largest group with the longest follow-up reported in literature. They found no advantage of this operation over arthroscopic debridement and did not recommend this procedure.

Hadjicostas *et al.*⁴⁴ retrospectively evaluated 61 patients at an average of 46 months who had a split deltoid flap to treat massive cuff defects. This procedure was technically different from previous descriptions because the authors used a flap more from the posterior than the anterior portion of the middle deltoid. The authors believed that this harvesting location resulted in less donor site morbidity. The mean forward elevation increase from 90° before surgery to 165° after surgery was significant. The Constant score improved from 33 to 77. In 42 of 45 patients, the flap was intact on MRI. Osteoarthritis did not increase in 48 patients, but it progressed from mild to moderate, according to the Samilson and Prieto⁴⁵ classification, in 12 patients. The use of a split-thickness deltoid flap from the posterior portion of the middle deltoid had a more favorable outcome in this study than in previous reports.

Elhassan *et al.*⁴⁶ reported a case of trapezius transfer to restore external rotation in a patient with brachial plexus injury. The supraspinatus was intact, but the posterior cuff was not. The middle to lower portions of the trapezius were harvested and transferred with an Achilles allograft and human dermis allograft wrapping to the infraspinatus footprint, resulting in postoperative improvement in external rotation of 30° and significant resistance to strength testing.

CONCLUSION

Deltoid flap procedures appear to have lost their favor in longer-term follow-up, whereas pectoralis tendon transfers,

both under and over the coracoid for subscapularis failures, remain an imperfect but viable option for subscapularis deficiency. The Eden-Lang procedure for spinal accessory nerve palsy and the pectoralis transfer for long thoracic nerve palsy remain reasonable options for these uncommon problems. Exciting changes in the management of external rotation loss have taken us from the original description of Gerber *et al.*⁷ in 1988 of a two-incision single-tendon transfer on top of the humeral head to a single-incision, two-tendon transfer that is no longer attached onto the humeral head but rather onto the humeral shaft. Although reverse arthroplasty can improve overhead elevation in massive cuff-deficient shoulders with pseudoparalysis, the addition of a tendon transfer (latissimus alone or combined with teres major) can improve external rotation in the small subset in which this is recognized preoperatively. The practicing orthopaedic surgeon should be aware of these surgical options when preparing to treat complex motor deficiency around the shoulder, particularly in younger patients.

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