REVIEW ARTICLE

Pectoralis major tendon transfer for irreparable subscapularis tears

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Background: Subscapularis insufficiency is a debilitating condition with few treatment options. Historically, pectoralis major tendon transfer has been suggested when the subscapularis tendon or muscle is deemed irreparable; however, the results of this salvage procedure have been mixed.

Methods: A comprehensive review of the peer-reviewed literature addressing pectoralis major tendon transfers was performed. The clinical presentation, relevant anatomy, biomechanical rationale, surgical indications, technical considerations, reported outcomes, and significant complications are reviewed in this report. Where possible, attempts at direct comparison of outcomes among surgical techniques and surgical indications have been made.

Results and Conclusions: Despite the heterogeneous reporting of clinical results, it is clear that surgical indications affect outcomes. Specifically, isolated subscapularis insufficiency shows the best prognosis with pectoralis major tendon transfer. Patients with anterosuperior instability after large rotator cuff tears or shoulder arthroplasty have the least predictable pain relief and worse functional outcomes.

Level of evidence: Review Article.

Keywords: Subscapularis; irreparable rotator cuff tear; pectoralis major; tendon transfer

Tendon transfers remain a viable treatment for patients with certain patterns of rotator cuff insufficiency. Most commonly, tendon transfers are indicated in younger patients with irreparable cuff tears, shoulder pain, and dysfunction. Whereas most tears involve the posterosuperior cuff, tears of the subscapularis tendon can also present with pain and limited function. Given the relative infrequency of these tears compared with posterosuperior tears, many patients have a delay in diagnosis.\textsuperscript{23,29,33} Once torn, the subscapularis may retract, leading to rapid fatty degeneration of the muscle. Both shortening and adhesions may render the muscle irreparable. Several authors have noted that primary repair of chronic tears produces unsatisfactory results.\textsuperscript{23,29,33}

It is hypothesized that the subscapularis tendon is critical to balancing muscular forces around the glenohumeral joint.\textsuperscript{3,4} Because it is the sole rotator cuff musculotendinous unit anterior to the glenohumeral joint, insufficiency due to a tendon tear, muscle injury, or neurologic insult leaves the humeral head unbalanced, producing functional disabilities.\textsuperscript{3,4} This often manifests as either static or dynamic proximal humeral migration with decreased acromiohumeral...
distance. In some instances, recurrent anterior subluxation and instability are also prominent features of anterior rotator cuff deficiency. Reductions in the coracoacromial interval have been shown to be associated with degenerative changes in the subscapularis, occurring more commonly in patients with a reduced acromiohumeral distance.

For patients with irreparable subscapularis tears or in whom attempted repair has failed (with persistent shoulder pain and dysfunction), salvage procedures are offered. Depending on the patient’s age, activity level, and concomitant glenohumeral joint disease, arthroplasty has also been used in these settings, with and without pectoralis major transfer. Hemiarthroplasty has been attempted with varying levels of success and restoration of function; however, anatomic total shoulder arthroplasty is contraindicated in the setting of rotator cuff dysfunction because of concern for eccentric glenoid wear, early loosening, and poor functional results. More recently, reverse total shoulder arthroplasty has gained popularity for selected older and lower-demand patients.

Although arthroplasty may be appropriate in older patients, the management of high-demand, active, or young patients with an irreparable subscapularis tear continues to represent a significant therapeutic challenge. Several authors have advocated tendon transfers in this setting, assuming that the patient has a well-preserved glenohumeral joint. Non-arthroplasty reconstruction options include arthroscopic debridement with biceps tenotomy or tenodesis and tendon transfer, commonly involving the pectoralis major. The pectoralis major can be transferred in its entirety, or it can be split. The tendon is then rerouted beneath the conjoint tendon or transferred superficially. In this way, a transfer is used to rebalance the forces on the humeral head through an inferiorly directed force vector. If rerouted deep to the conjoint tendon, the pectoralis transfer is thought to also reduce subcoracoid impingement through a soft-tissue interposition effect that aids in pain relief. These techniques can be used for subscapularis tears in isolation, for subscapularis tears with anterior supraspinatus tears, or in combination with posterior cuff repair for posterosuperior tears. In addition, they have been used for subscapularis insufficiency after failure of subscapularis repair after open shoulder stabilization or shoulder arthroplasty. The latter case, subscapularis insufficiency after arthroplasty, presents a significant therapeutic challenge, often because of recurrent instability. We will review the relevant surgical anatomy, surgical techniques, biomechanical rationale, and clinical outcomes of pectoralis transfers.

Anatomic considerations

Tendinous anatomy

The pectoralis major insertion consists of 2 distinct layers. The anterior lamina is the terminal portion of the clavicular head, whereas the posterior lamina originates from the sternal head. A variable third layer, the abdominal lamina, is derived from the aponeurosis of the external oblique muscle medially. The sternal and clavicular lamellae fuse into a single tendon that then rotates nearly 180° about its longitudinal axis before insertion on the anterior humerus. This rotation results in the inferior (sternal) fibers attaching superior and posterior to the clavicular fibers on the humerus when the arm is in an adducted position. Jennings et al found the anterior lamina (clavicular head) to be 1.5 cm long and 2.9 cm wide at the musculotendinous junction and 4.7 cm wide at the humeral insertion. The posterior lamina (sternal head) had dimensions of 3.7 cm, 2.1 cm, and 4.3 cm, respectively. At the humeral insertion, the two tendons overlap approximately 2.7 cm, producing a total footprint between 5.7 and 6.3 cm.

Muscular anatomy

The muscle of the pectoralis major arises primarily from the anterior surfaces of the medial clavicle, the length of the sternum, the cartilage of ribs 2 through 7, and the aponeurosis of the external oblique muscle. The clavicular muscle belly constitutes 61% of the total muscle bulk. The two primary muscle bellies, clavicular and sternal, are separated by an intermuscular septum that is more distinct laterally near the musculotendinous junction than within the muscle proper. The three muscle bellies are morphologically indistinct medially at their bony origins, beginning at a point about 10.5 cm medial to the humeral insertion.

Neurovascular anatomy

Two branches of the subclavian artery, thoracoacromial and lateral thoracic, provide the primary blood supply to the pectoralis major. The thoracoacromial artery travels medial to the muscular division, whereas the lateral thoracic artery crosses the septum between the two muscle bellies at a mean of 8.5 cm medial to the humeral insertion. The innervation of the pectoralis major conveniently allows for separation of its two muscle bellies. The lateral pectoral nerve arises from the lateral cord of the brachial plexus, passes medial to the pectoralis minor, and enters the clavicular head superior to the intermuscular septum. In a separate study, the lateral pectoral nerve was found to enter the clavicular head at a mean of 12.5 cm (range, 10-14.9 cm) medial to its humeral insertion.

The medial pectoral nerve begins as a terminal branch of the medial cord. In most instances, it travels through the substance of the pectoralis minor before entering the undersurface of the pectoralis major. Klepps et al reported variable paths for the medial pectoral nerve, noting that it sometimes passed lateral to the pectoralis minor. Jennings et al further confirmed this, reporting that it passed lateral to the pectoralis minor in 4 of 24 cadavers whereas the nerve divided in 2 specimens (8%), with one branch...
Biomechanics of transfer techniques

Konrad et al. investigated the biomechanics of supracoracoid and subcoracoid transfers. Six fresh-frozen specimens were mounted into a novel apparatus for testing glenohumeral kinematics. Four scenarios were tested: intact shoulder, complete subscapularis tear, transfer of the clavicular head superficial to the conjoined tendon, and subcoracoid transfer of the clavicular pectoralis head. The forces applied were determined based on values used in previous finite-element modeling. The complete subscapularis tear condition displayed less than 50% of the maximum abduction achieved with the intact condition (40.8° vs 86.3°). As expected, maximum external rotation (91.8°) and anterior (net, 6.4 mm) and superior (net, 6.1 mm) translation were also increased significantly. Both tendon transfer scenarios resulted in more physiological shoulder motion compared with the tear condition. Specifically, maximum abduction and superior stability were restored in both transfer scenarios. The subcoracoid transfer, however, also produced decreased maximum external rotation and decreased anterior translation, resulting in more physiological outcomes in all parameters tested.

Surgical indications

Pectoralis major transfer can be indicated for a variety of clinical scenarios involving an irreparable subscapularis tear. Most patients are aged younger than 60 to 65 years, such that a reverse shoulder arthroplasty is not considered appropriate. Patients must have a functioning deltoid muscle, minimal glenohumeral joint arthritic changes, and ideally, an intact or reparable posterosuperior cuff. The most common indications include pain and limited shoulder function from a chronic isolated subscapularis or anterosuperior cuff tear. Pectoralis transfers may also be considered in cases of failure of subscapularis healing after shoulder arthroplasty or open shoulder stabilization. In these scenarios, decreased pain is expected; however, less predictable functional results are also expected in the setting of recurrent glenohumeral subluxation and instability.

A pectoralis major transfer has been described for the treatment of anterior-superior escape in the setting of rotator cuff arthropathy and/or failed rotator cuff repair. Although the reverse shoulder arthroplasty has become a more standard treatment in this clinical scenario, a pectoralis major transfer can still be considered in younger patients or in patients in whom a reverse shoulder arthroplasty is not indicated. The results of a transfer in this setting are not as promising; however, pain relief and some functional improvement are anticipated. Contraindications include deltoid injury or denervation, advanced glenohumeral arthritis, and an irreparable posterosuperior cuff tear.

Surgical techniques

The transferred tendon may take 1 of 3 typical courses. First, it can be passed in the plane of its normal course but merely in a more superior direction and can then be attached to the tuberosities of the proximal humerus. Second, the sternal lamina may be passed deep to the clavicular tendon but superficial to the conjoined tendon. Third, the tendon (complete or partial) can be routed deep, through the interval between the conjoined tendon (superficial) and the musculocutaneous nerve. In an anatomic cadaveric study, a fourth position was investigated: subcoracoid transfer with the tendon passing deep to the musculocutaneous nerve. This position, however, was consistently found to place undue tension on the musculocutaneous nerve and was believed to be too risky for clinical practice.

The sub–conjoined tendon transfer has the theoretic advantage of producing a force vector that better simulates that of the native subscapularis tendon. This inferior and posterior vector of the subscapularis has been well documented and is thought to balance the net superior pull of the deltoid, keeping the humeral head centered in the glenoid fossa. A second advantage of the subcoracoid transfer is that the transferred tendon produces a static soft-tissue interposition between the humerus and the coracoid process, minimizing anterior humeral translation and decreasing the risk of coracohumeral impingement.

One potential downside of the subcoracoid technique is that surgical dissection, as well as the increased bulk of the
transferred musculotendinous unit, risks injury to the musculocutaneous nerve and surrounding brachial plexus. Klepps et al.\textsuperscript{20} reported that in 6 of 20 cadaveric specimens, a subcoracoid transfer of the entire pectoralis major placed the musculocutaneous nerve under excess tension, necessitating a release of the proximal branch to relieve the tension. In addition, there are clinical reports of musculocutaneous nerve injuries; therefore, split-tendon transfers are more frequently advocated.\textsuperscript{29} If a partial transfer of the pectoralis is chosen, the two laminae are bluntly separated for selective transfer.\textsuperscript{18} This is achieved by retracting the clavicular head proximally and initiating the separation at the level of the musculotendinous junction. The split can then be propagated both medially and laterally. Despite overlapping insertions, either the anterior or posterior lamina can be elevated while leaving one intact on the humerus. If the posterior lamina is chosen for transfer, the most inferior portion of the anterior lamina may need to be elevated but the majority of the insertion may be left intact. Klepps et al. found that a split transfer tensioned the musculocutaneous nerve in only 2 of 20 specimens, although this was also relieved with release of the proximal nerve branch.

Compression of the other terminal branches of the brachial plexus has also been reported,\textsuperscript{28} albeit quite infrequently. In 1 reported case, median and ulnar nerve symptoms developed and progressed over postoperative days 1 and 2. On postoperative day 3, the patient underwent repeat surgical exploration and rerouting of the transfer from a subcoracoid position to a superficial transfer overlying the conjoined tendon, after which the neurologic symptoms resolved.

**Our preferred technique**

Our preferred technique is a subcoracoid transfer of the sternal head of the pectoralis major. In brief, the patient is positioned in the beach-chair position, and a standard deltopectoral incision is used. The deltoid is retracted laterally with the cephalic vein. Subdeltoid, subacromial, and subcoracoid adhesions are bluntly released. A biceps tenodesis or tenotomy is commonly undertaken. The lesser tuberosity is exposed (Fig. 1). The axillary and musculocutaneous nerves are identified and protected (Fig. 2), and an attempt is made to identify and mobilize the torn subscapularis tendon. Significant care must be taken at this point because the retracted subscapularis may be encased in adhesions medially, placing the brachial plexus, and specifically the axillary nerve, at risk. If the subscapularis is deemed irreparable, a pectoralis major transfer is performed.

The superior insertion of the pectoralis on the humerus is identified lateral to the intertubercular sulcus. It is important to remember that the sternal head rests deep to the clavicular head, forming the posterior lamina, and inserts slightly superior to the clavicular head that forms the anterior lamina. Next, the plane between the two is identified and developed bluntly. To facilitate this, an army-navy retractor is used to retract the muscle bellies inferiorly, exposing the upper tendinous portion of the sternal head. This insertion is tagged with a heavy nonabsorbable suture. This tagging stitch is helpful to maintain the orientation of the tendon. Sliding one’s finger medially from the tendinous insertion will allow for blunt dissection between the muscular portions of the sternal and clavicular heads. Next, the inferior border of the pectoralis major is exposed. Because the laminae are often continuous inferiorly, the superior demarcation should be used as a landmark for distinguishing the two heads. With the clavicular head retracted, the sternal head is sharply elevated in a superior-to-inferior direction from its insertion on the humerus (Fig. 3). Adhesions from the undersurface of the sternal head are bluntly released to allow for adequate...
tendon excursion. Medial dissection limited to 6 to 8 cm will avoid injury to the medial pectoral nerve and lateral thoracic artery. Attention is then turned toward the coracoid process and conjoined tendon. The plane medial to the conjoined tendon and lateral to the pectoralis minor is bluntly developed. The musculocutaneous nerve is again identified, entering the conjoined tendon a mean of 6.1 cm (range, 3.5-10 cm) distal to the coracoid process. A path is bluntly cleared for passage of the tendon superior to the musculocutaneous nerve and deep to the conjoined tendon (Fig. 4). Muscle passed inadvertently deep to the musculocutaneous nerve puts excessive stretch on the nerve and may result in a symptomatic neurapraxia. If a proximal nerve branch is encountered that would be under tension from the muscle bulk of the transfer, this nerve branch can be released with minimal morbidity. The arm is internally rotated to expose the tuberosities. The tendon is transferred to the upper lesser tuberosity or the anterior aspect of the greater tuberosity depending on the length and excursion of the tendon. We prefer to attach the transferred tendon to the greater tuberosity if possible. The site of attachment is burred, providing a surface of punctate bleeding bone. The tendon is then passed deep to the conjoined tendon and secured to the tuberosity, crossing the biceps groove, by use of transfosseous sutures or bone anchors. Between 2 and 4 nonabsorbable sutures are placed by a Krackow or similar tendon-grasping technique to securely engage the thin tendon of the distal pectoralis major muscle.

A deep surgical drain is always placed to reduce the risk of postoperative hematoma. We routinely wrap the shoulder circumferentially with a pressure dressing to minimize the risk of hematoma, which can be common, especially when the pectoralis muscle is split. The patient’s arm is placed in a sling.

Postoperative care is similar to that after a massive anterosuperior rotator cuff repair. The operative shoulder is immobilized for 4 to 6 weeks. Passive exercises are used early to encourage tendon gliding and prevent adhesions; however, motion is typically restricted within a safe range determined at the time of surgery to protect the tendon transfer. Active-assisted and strengthening exercises are postponed until the 6-week point. Internal rotation against resistance is restricted until 12 weeks after surgery. After this, patients will notice functional gains throughout the first year. Fortunately, the subscapularis and pectoralis major are in phase, and transfers do not require retraining protocols.

Clinical outcomes

Transfer for isolated subscapularis tears

Pectoralis major tendon transfer for isolated subscapularis tears reliably produced significant improvements across several case series, regardless of whether patient complaints stemmed from degenerative tears or traumatic anterior dislocations. The most common complaints were activity-related pain, decreased motion, and recurrent instability. Postoperatively, patients saw improvements in subjective shoulder scores. Resch et al assessed Constant scores and found a mean increase from 22.6 to 54.4 (Table I) among a cohort averaging 65 years of age. Similarly, Elhassan et al saw increases from 40.9 to 60.8 in a younger cohort (mean age, 37 years). Likewise, Jost et al reported a final mean relative Constant score of 79% in their series of isolated irreparable subscapularis tears.

Range of motion and strength also benefited from successful pectoralis transfer. Wirth and Rockwood published a series of transfers superficial to the conjoined tendon. Ten of 13 shoulders achieved elevation between 120° and 170° (mean, 143°). These patients also noted improvement in exercise tolerance and reduced pain. For
<table>
<thead>
<tr>
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<th>No. of shoulders</th>
<th>Surgical indication</th>
<th>Surgical technique</th>
<th>Mean postoperative Constant score</th>
<th>Mean ASES functional score</th>
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<td>Wirth and Rockwood(^3)</td>
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<td>Superficial transfer of superior one-half of PM tendon or pectoralis minor/CA complex</td>
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<td>67.10</td>
<td>9.6 of 15 (0.64)</td>
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<td>129</td>
<td>113</td>
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<td>Unsatisfactory</td>
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<td>Resch et al(^2)</td>
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<td>Subcoracoid transfer of superior two-thirds of PM tendon (Resch)</td>
<td>54.4</td>
<td>67.10</td>
<td>9.6 of 15 (0.64)</td>
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<td>113</td>
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<td>Subcoracoid transfer of complete PM tendon (Resch)</td>
<td>47.7</td>
<td>3.2 of 10 (0.32)</td>
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<td>Jost et al(^1)</td>
<td>30</td>
<td>Varied</td>
<td>Complete PM tendon transfer superficial to conjoined tendon</td>
<td>62 ± 21</td>
<td>70 ± 23</td>
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<td>132 ± 33</td>
<td>126 ± 33</td>
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<td>Group 1</td>
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<td>79 ± 21</td>
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<td>Miller et al(^4)</td>
<td>3</td>
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<td>59.5</td>
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<td>Varied</td>
<td>Transfer of PM sternal head deep to clavicular head and superficial to conjoined tendon</td>
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<td>60.8</td>
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<td>Massive cuff tear</td>
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<td>52.3</td>
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<td>Gavriildis et al\textsuperscript{14}</td>
<td>15</td>
<td>Chronic irreparable SSC and SS tears</td>
<td>Subcoracoid transfer of superior two-thirds of PM tendon (Resch)</td>
<td>68.17 ± 8.84</td>
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<td>Lederer et al\textsuperscript{22}</td>
<td>54</td>
<td>Isolated SSC tear</td>
<td>Subcoracoid transfer of superior two-thirds of PM tendon (Resch)</td>
<td>63.4</td>
<td>80</td>
<td>4.0 of 9</td>
<td>142.59</td>
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<td>29</td>
<td></td>
<td>Bone chips</td>
<td>64.4</td>
<td>82</td>
<td>3.9 of 9</td>
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<td>Group 2</td>
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<td></td>
<td>Tenotomy</td>
<td>62.2</td>
<td>78</td>
<td>4.2 of 9</td>
<td>133.8</td>
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</table>

\textsuperscript{11} Elhassan et al. \textsuperscript{12} Lederer et al. ASES, American Shoulder and Elbow Surgeons; CA, coracoacromial ligament; PM, pectoralis major; SS, supraspinatus; SSC, subscapularis; TSA, total shoulder arthroplasty; VAS, visual analog scale.
the 3 transfers that failed, the mean range of motion was significantly lower (110°; range, 60°–140°). Mean improvements in forward flexion and abduction (from 93° to 129° and from 85° to 113°, respectively) were reported by Resch et al.29 Forward flexion and abduction strength at 90° also improved (0.6 kg and 0.8 kg, respectively, to 2 kg in each position), as did internal rotation strength; when tested in 90° of shoulder forward flexion and elbow flexion, it was found to improve from 4.5 kg to 5.6 kg. Five patients stated that they were able to achieve preinjury or pre-complaint levels of shoulder function, and another 6 were able to perform physically rigorous tasks but not at the same level as that before symptoms developed. In contrast, external rotation was limited after successful pectoralis major transfer, due to a tenodesis effect of the transferred tendon, decreasing by a mean of 25°.19,29

**Subscapularis insufficiency in large (multi-tendon) rotator cuff tears**

Several studies have reported outcomes of large anterosuperior rotator cuff tears involving both the subscapularis and the supraspinatus, as well as—variably—the infraspinatus. These patients also regularly benefited from salvage tendon transfer with measured mean Constant score increases from 28.7 to 52.3,11 52 to 68,14 and 38.8 to 63.4.22 Jost et al19 reported another excellent mean relative Constant score (79%) in this cohort (group 2). This study also showed that the ability to repair the supraspinatus improved the outcome compared with concomitant irreparable supraspinatus tears (group 3). Group 3 patients displayed a greater amount of supraspinatus retraction and fatty degeneration preoperatively. The added rotator cuff disease probably accounts for the worse outcome scores; in fact, the postoperative Constant score was significantly inversely correlated with preoperative scores (0.6 kg and 0.8 kg, respectively, to 2 kg in each position), as did internal rotation strength; when tested in 90° of shoulder forward flexion and elbow flexion, it was found to improve from 4.5 kg to 5.6 kg. Five patients stated that they were able to achieve preinjury or pre-complaint levels of shoulder function, and another 6 were able to perform physically rigorous tasks but not at the same level as that before symptoms developed. In contrast, external rotation was limited after successful pectoralis major transfer, due to a tenodesis effect of the transferred tendon, decreasing by a mean of 25°.19,29

**Subscapularis insufficiency after shoulder arthroplasty**

The most guarded prognoses are reserved for patients with symptomatic subscapularis insufficiency after shoulder arthroplasty. In 2005, Miller et al22 reported surgical outcomes in 4 patients treated with a pectoralis major tendon transfer. Postoperatively, these patients had mixed results. Only 2 of 4 patients reported their satisfaction, with ratings of 9 of 10 (good-excellent) in 1 patient and 4 of 10 (poor) in 1 patient. Three of the four patients reported no pain at the time of final follow-up. The fourth patient rated her pain as 5 of 10. This patient had the worst outcome, with regular use of pain medication for chronic shoulder pain and painless use of the arm limited to waist-level activity.

The second group (group 2) in the study of Elhassan et al11 consisted of 8 patients with subscapularis tears after either hemiarthroplasty (n = 3) or total shoulder arthroplasty (n = 5). Although indications for arthroplasty varied, all patients displayed pain, internal rotation weakness, increased external rotation range, positive liftoff and belly-press tests, and anterior instability or apprehension. Five of the 8 patients also had static anterior subluxations. At the time of tendon transfer, most of these patients required concomitant revision procedures, including contracture release, polyethylene exchange, allograft reconstruction of glenoid defects, and humeral component exchange. The results in the revision arthroplasty group were unpredictable. Only 1 of 8 patients reported a significant improvement in pain and function (Table I). The belly-press test was positive in all patients. There were no statistically significant improvements in mean Constant scores or pain scores. Six of the eight patients reported no improvement in function or pain, and several required repeat surgical intervention, including revision total shoulder arthroplasty for infection, conversion to reverse total shoulder arthroplasty, and teres major transfer.

In general, clinical outcomes after pectoralis major transfers in cases of subscapularis insufficiency have been satisfactory for salvage procedures. Reasonable pain relief can be expected, although functional gains are often unpredictable.27 Although comparisons are difficult because of the heterogeneity of data and operative techniques, the best results are achieved in patients with an isolated subscapularis tear or an anterosuperior tear when the supraspinatus can also be repaired. These patients routinely displayed substantial improvements in Constant scores, as well as increases in mean range of motion to within near-normal range. The worst functional outcomes occur in patients who present with anterosuperior escape. This is not surprising given that they have the most advanced rotator cuff dysfunctions preoperatively. In addition, the pectoralis major transfer does not completely restore the force vector provided by a functional subscapularis. The transferred pectoralis exerts its force along a vector that is still anterior to the native subscapularis. It can be hypothesized that patients with anterior instability
have the least improvement because, despite subcoracoid transfers, the pectoralis is unable to restore the posterior and medial vector of the subscapularis, which creates concavity-compression and shoulder stability.

Patients with total shoulder arthroplasty also fared poorly but were not treated uniformly, making it difficult to draw clear conclusions. When the two cohorts were compared, however, the total shoulder arthroplasty group had higher Constant scores whereas the massive cuff tear patients had lower postoperative pain scores.

Surprisingly, improvements in pain were unpredictable across all surgical indications. In a few cases, patients had complete pain relief, whereas other patients only had partial relief. When self-reported pain levels are compared via visual analog scales, it appears that mean pain improvement was generally equivalent across all studies (Table I). With regard to surgical technique, Jost et al19 reported the best final outcomes, using a complete tendon transfer superficial to the conjoined tendon. This, of course, does not solve the issue of which surgical technique is superior because controlled comparisons cannot be easily made across such heterogeneous studies (Table I).

Conclusions

In conclusion, pectoralis major transfer can be an effective treatment for subscapularis tears that reduces pain and improves function when nonoperative therapies and attempts at anatomic restoration have failed, especially in patients too young or too active for salvage via reverse total shoulder arthroplasty. Moreover, it appears that the best outcomes occur in patients with subscapularis tears in isolation or combined with reparable supraspinatus tears. Further studies are necessary to determine the best surgical candidates, how to reliably improve pain as well as function, and the most advantageous surgical technique.

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References


