Lesser Tuberosity Osteotomy Versus Subscapularis Tenotomy: Technique and Rationale
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Subscapularis dysfunction after tenotomy for the deltopectoral approach to the shoulder has recently been identified in the orthopedic literature as an under-recognized complication of total shoulder arthroplasty. Attempts to improve the postoperative function of the subscapularis and mitigate rupture of the muscle-tendon unit have focused on alternative methods for subscapularis takedown and repair. Lesser tuberosity osteotomy for release of the subscapularis has been described by multiple authors as an effective way to decrease subscapularis dysfunction and maintain tendon integrity after total shoulder arthroplasty. Proponents of this technique cite maintenance of the integrity of the tendon, direct bone-to-bone healing of the osteotomy, improved strength of repair, and the ability to monitor the integrity of the subscapulairs repair radiographically in the postoperative period as distinct advantages. Short-term clinical studies have documented improved subscapularis function after the osteotomy technique and biomechanical studies have also shown improved strength of repair when compared with tenotomy. However, there are several concerns about the osteotomy technique that have not yet been resolved, including significantly increased operative complexity, inability to medialize the tendon to adjust subscapularis tension, risk of intraoperative humeral fracture, and lack of long-term clinical outcomes. Although lesser tuberosity osteotomy shows promising improvements in short-term clinical results, subscapularis tenotomy has a long proven track record of excellent clinical outcomes and the choice between the 2 methods of subscapularis takedown remains one of surgeon comfort and experience.

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The standard deltopectoral approach to the shoulder is one of the most common exposures used for total shoulder arthroplasty (TSA). This approach traditionally requires division of the subscapularis muscle insertion for full exposure of the arthritic joint and correction of internal rotation contractures. Attenuation of the subscapularis tendon after TSA can lead to subtle joint instability, weakness in internal rotation, and poor patient satisfaction. Complete rupture of the subscapularis tendon after TSA also can occur, leading to gross instability of the prosthesis and requiring complicated revision surgery.1

Recent clinical evidence has suggested that the incidence of subscapularis dysfunction may have been previously underrecognized as a clinical entity, with up to 67% of patients demonstrating subscapularis dysfunction or tears by clinical examination.2 In addition to confirming the prevalence of subscapularis dysfunction after TSA, recent reports have also highlighted the difficulty in assessing postoperative subscapularis function via clinical examination or routine radiography.3 This finding has been further delineated by Armstrong et al4, where the belly press test was noted to have a low sensitivity, specificity, and positive predictive value for the assessment of subscapularis integrity as determined by ultrasound.

These and other recent findings have spurred a burst of both clinical and biomechanical research to determine whether an alternative method of subscapularis takedown could prevent postoperative subscapularis dysfunction and failure. Specifically, attention has been focused on the performance of a lesser tuberosity osteotomy as a method of preserving subscapularis tendon integrity, increasing repair site strength, and allowing for assessment of the integrity of the repair radiographically. Both Gerber et al5, and Ponce et
have reported their clinical results for lesser tuberosity osteotomy with TSA. The authors of these 2 studies documented return of subscapularis function in 82% to 89% of patients after osteotomy repair, although there was no control group included in either study. However, a recent retrospective trial by Scalise et al. directly compared tenotomy with osteotomy for subscapularis takedown in TSA and found that lesser tuberosity osteotomy resulted in greater clinical outcome scores and a lower rate of subscapularis tears compared with tenotomy as assessed by physical examination and ultrasound.

Several recent biomechanical evaluations comparing subscapularis tenotomy and lesser tuberosity osteotomy demonstrate varying results. Both Krishnan et al. and Van den Berghe et al. found lesser tuberosity osteotomy to be superior to subscapularis tenotomy under cyclic loading conditions by the use of both bone tunnel suture repair and suture repair over a buttress plate. However, Van Thiel et al. did not find a statistically significant difference in cyclic elongation, maximum load, mode of failure, or stiffness between osteotomy and tenotomy techniques and hypothesized that the clinical differences seen between the 2 methods may be a result of the healing potential rather than the specific repair construct. Currently, a biomechanical rationale for the improved clinical results of lesser tuberosity osteotomy is a subject of significant debate among shoulder surgeons.

Surgical Anatomy

The subscapularis muscle originates from the anterior aspect of the scapula in the subscapularis fossa and inserts onto the lesser tuberosity of the humerus. At its humeral insertion, the superior 60% is tendinous whereas the inferior 40% is predominantly muscle fibers. The anterior humeral circumflex artery and its concomitant veins mark the division between the 2 distinct areas of the insertion. The axillary nerve and posterior humeral circumflex artery descend on the anterior surface of the muscle 3 to 5 cm medial to the musculotendinous junction before passing inferiorly between the lower border of the subscapularis and the upper border of the teres major into the quadrilateral space. The circumflex scapular artery similarly passes around the inferior border of the subscapularis into the more medial triangular space.

The subscapularis is innervated by fibers from the upper (C5) and lower (C5/6) subscapular nerves. The upper subscapular nerve exits the posterior cord and innervates the upper 50% of the muscle. The lower subscapular nerve most commonly originates from the posterior cord, but can also originate from the thoracodorsal nerve or axillary nerve. The fibers of the upper and lower subscapular nerves have been described as lying as close as 1 to 1.5 cm medial to the anterior glenoid rim and conjoint tendon, which can be a useful landmark during surgery to prevent denervation of the subscapularis.

Subscapularis Tenotomy Technique

A standard deltopectoral approach is used to expose the proximal humerus from the insertion of the pectoralis major to the rotator interval. The long head of the biceps tendon is identified in its groove, and a tenotomy and subsequent tenodesis may be performed if the tendon is diseased or according to surgeon preference. The axillary nerve is then palpated on the inferior medial aspect of the subscapularis muscle belly and protected at all times. A vertical incision is made by the use of a scalpel or electrocautery through the tendinous and muscular portion of the subscapularis 1 to 2 cm medial to its insertion of the lesser tuberosity, with attention being paid to ligate or cauterize the anterior humeral circumflex artery as it crosses the inferior 40% of the tendon. Simple traction sutures are then placed in the lateral edge of the subscapularis tendon along the line of the tenotomy to facilitate mobilization.

A full 360-degree mobilization of the subscapularis is then performed, including release of subcoracoid adhesions, the coracohumeral ligament, and medial capsular attachments. An anterior and inferior capsulectomy is also performed. The subscapularis tendon is then protected until the completion of placement of the humeral and glenoid components. After component placement, the subscapularis is tensioned to determine balance between the posterior and anterior aspects of the shoulder. Using the traction sutures to maintain adequate tension, 6 #2 nonabsorbable braided sutures are placed in a simple fashion through the tendon and the lateral stump to reapproximate the tendon to its insertion. Other modifications of the tenotomy technique include the use of Mason-Allen or figure-of-eight sutures in the tendon, or repair of the tendon through bone tunnels in the lesser tuberosity and humeral neck osteotomy.

Rationale

Subscapularis tenotomy during the deltopectoral approach for TSA has a long history of excellent clinical outcomes, including good-to-excellent results in greater than 90% of patients at midterm follow-up. The authors of recent studies, however, have shed doubt on the effectiveness of the subscapularis tenotomy to maintain the integrity and functionality of the subscapularis muscle. Although this is indeed a concern, another recent clinical study of 45 arthroplasties by Caplan et al. demonstrated excellent clinical results with retained function of the subscapularis using the subscapularis tenotomy technique.

Subscapularis tenotomy offers multiple benefits during TSA, including simplicity of technique, maintenance of the integrity of the cortex of the humerus, and the ability to release tension on the anterior shoulder via medialization of the subscapularis insertion. Providing adequate soft-tissue balance to the shoulder is an important consideration in TSA because a clinically significant internal rotation contracture is frequently present. Correction of this contracture is possible by both circumferential soft-tissue releases of the subscapu-
laris to maximize its lateral excursion, as well as by medialization of the insertion of the subscapularis to the humeral neck or anterior capsule. The combination of these techniques can allow for increased subscapularis tendon excursion of 1.5 to 3 cm. It has been estimated that every 1 cm of length gained by medialization of the subscapularis results in 20° of increased external rotation. A potential disadvantage of medializing the insertion of the subscapularis to restore external rotation is that the mechanical advantage and lever arm of the lesser tuberosity is lost.

Osteotomy of the lesser tuberosity has recently been proposed as a method for increasing the strength of fixation of the subscapularis as well as maintaining the integrity of the tendon. However, this procedure has significant drawbacks when compared with tenotomy because it is time consuming, carries the risk of tuberosity nonunion, and prevents the surgeon from being able to independently adjust the tension of the subscapularis via medialization. Some of the purported benefits of lesser tuberosity osteotomy may be more theoretic than actual. Specifically, the claim of improved strength of repair has been questioned by the recent work of Van Thiel et al, who failed to find a statistically significant difference between osteotomy and tenotomy techniques in either cyclic elongation or maximum load to failure. In addition, osteotomy of the lesser tuberosity is also a technically demanding procedure. Given the age and osteoporotic nature of the TSA population, the risk of increased operative time to perform an osteotomy and the possibility of intraoperative fracture must be taken into account when considering what is ultimately most beneficial to the patient.

Although new methods for takedown and repair of the subscapularis during TSA are being extensively investigated at this time, subscapularis tenotomy during a deltopectoral approach to the shoulder continues to be a proven and reliable method for exposure, with well-documented satisfactory clinical results in the setting of adequate tendon healing.

**Lesser Tuberosity Osteotomy Technique**

A standard deltopectoral approach is used to expose the proximal humerus from the insertion of the pectoralis major to the rotator interval. The roof of the bicipital groove is incised, and the incision extended medially along the rotator interval to define the superior and lateral borders of the subscapularis insertion. The long head of the biceps tendon is identified in its groove, and a tenotomy and subsequent tenodesis is performed in all cases. The axillary nerve is palpated on the inferior medial aspect of the subscapularis muscle belly and protected at all times. The author’s preferred technique for lesser tuberosity osteotomy is that developed by Hertel (oral personal communication, 2008) with several small modifications. A 2-mm drill bit is used to make 5 drill holes lateral to the bicipital groove to be used for later suture and wire passage and repair of the lesser tuberosity osteotomized fragment. An oscillating saw is used to make 2 osteotomies in the cortex of the humerus along the lateral and inferior aspects of the lesser tuberosity in an L-shaped pattern (Fig. 1). The vertical osteotomy is made in the base of the bicipital groove, and the horizontal osteotomy is made just below the inferior border of the subscapularis at the level of the inferior anatomic neck of the humerus. The osteotomy is then completed medially with a 1-inch curved osteotome, providing a cortical fragment with an approximate area of 4 by 2 cm and a thickness of 7-10 mm. Simple traction sutures are placed around the osteotomized tuberosity fragment to facilitate mobilization. A full 360-degree mobilization of the subscapularis is then performed, including release of subacromial adhesions, the coracohumeral ligament, and medial capsular attachments. The anterior and inferior glenohumeral capsule is released. The osteotomy is protected throughout the remainder of the case until placement of the humeral stem. Before impaction of the stem, both ends of 4 #2 or #5 nonabsorbable braided sutures are passed via free needles through the previously made drill holes on the lateral aspect of the bicipital groove so the sutures will be tied over a bone bridge. An 18-gauge wire is passed through the central drill hole so that 2 of the bone sutures are above the wire and 2 are below.

Attention should be paid to allow the wire to lie on the posterior cortex of the humeral canal so the humeral stem will pass through the loop of the wire to prevent cut out (Fig. 2). The humeral stem is then impacted into the humerus in its final position. One end of each bone suture is passed around...
the lesser tuberosity fragment at the bone-tendon junction on
a large free needle. The wire is then passed around the tuber-
osity fragment at the bone-tendon junction. The tuberosity
fragment is reduced to the osteotomy bed with the traction
sutures. The wire is then tensioned and twisted to provide
direct compression across the osteotomy site. After cutting
the wire, the ends are buried in the soft tissue to prevent
irritation. The bone sutures are then tied on the anterior
aspect of the osteotomy to provide additional fixation and
rotatory stability (Fig. 3).

A separate, well-described technique is the wafer or fleck
osteotomy of the lesser tuberosity.6 The exposure for this
technique is the same as the above description; however, a
thinner, smaller piece of cortical bone (2.5 mm2 × 4- to
5-mm thick) mirroring the size of the subscapularis insertion
is taken for the osteotomy. Four parallel drills holes are then
drilled both medially and laterally to the osteotomy site and
Number-5 Fiberwire sutures (Arthrex, Naples, FL) are
passed from lateral to medial with attention paid to allow the
sutures to pass around the stem as it is inserted. The osteot-
yomy is then secured by tying the sutures over the bone frag-
ment using a modified Mason-Allen technique. A similarly
described technique passes the suture ends out the lateral aspect
of the humerus where they are tied over a titanium suture button
to increase the pull out strength of the construct.5

Rationale
TSA provides excellent pain relief and return of function to
greater than 90% of patients.18 However, despite these excel-
lent results, numerous complications remain, including in-
stability, frank dislocation, rotator cuff tears, and aseptic
loosening of the components.23 Historically, problems re-
lated to healing of the subscapularis tenotomy have been
underreported and subscapularis dysfunction has recently
been identified as a common complication of TSA, occurring
in as many as 67% of TSA.2

In an attempt to prevent subscapularis dysfunction asso-
ciated with tenotomy, several authors have proposed a lesser
tuberosity osteotomy as a method of subscapularis release
during the deltopectoral approach to the shoulder.5-8 The
benefits of an osteotomy include protection of the integrity of
the substance of the tendon, direct bone-to-bone healing of the
osteotomy, improved strength of repair, enhanced exposure of
the glenoid, and the ability to monitor the integrity of the sub-
scapularis repair radiographically. Recent clinical studies have
demonstrated the effectiveness of the lesser tuberosity in pro-
ducing a clinically functional subscapularis muscle unit in
80% to 90% of patients.5,6,8 Scalise et al7 have also docu-
mented the clinical superiority of the osteotomy technique
when compared with subscapularis tenotomy. Biomechani-
cal studies comparing the 2 techniques have also consistently
shown increased strength of repair for the osteotomy tech-
nique8,10 although a recent study by Van Thiel et al10 failed to
show a statistically significant difference between techniques.
Osteotomy also allows for radiographic evaluation of the in-
tegrity of the subscapularis, which is significant because the
ability to detect subscapularis incompetence and dysfunction
after tenotomy has proven extremely difficult on a clinical
basis (Figs. 4 and 5).3,4

One criticism leveled against the lesser tuberosity osteot-
yomy technique is the inability to adjust the tension of the
subscapularis because the osteotomy must be replaced
within its bed. This concern is mitigated by the fact that
aggressive soft-tissue releases and mobilization of the sub-
scapularis can restore lateral excursion, and hence external

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**Figure 3** Osteotomy secured into position after placement of the
humeral stem.

**Figure 4** Preoperative radiographs for TSA with lesser tuberosity
osteotomy.

**Figure 5** Postoperative radiographs after TSA with lesser tuberosity
osteotomy.
rotation, even in cases of severe internal rotation contracture without the need for medialization of the subscapularis insertion. Similarly, there is apprehension about the time and complexity of the osteotomy compared with simple tenotomy. Although this is certainly a valid concern, the additional time in the operating room is rarely greater than 5-10 minutes for the experienced surgeon and the benefits in strength of fixation and radiographic evaluation of the integrity of the subscapularis are considerable.

Lesser tuberosity osteotomy for subscapularis release is a clinically proven method for exposure of the shoulder joint that provides high fixation strength and bone-to-bone healing while preserving the integrity of the subscapularis tendon. Although long-term definitive clinical data have not yet been published, the benefits of lesser tuberosity osteotomy could significantly improve the clinical outcomes and decrease complications for patients undergoing total shoulder arthroplasty.

**Conclusions**

Both techniques of subscapularis release have clinical and biomechanical data supporting their routine use during total shoulder arthroplasty. Subscapularis tenotomy offers the benefits of simplicity, ability to adjust the tension of the repair, and a long, proven clinical track record. Lesser tuberosity osteotomy offers the benefits of bone-to-bone healing, enhanced exposure of the glenoid intraoperatively, maintenance of the substance of the tendon, and the ability to determine the integrity of the repair radiographically. Although lesser tuberosity osteotomy has shown promising short-term clinical results, the choice between the 2 methods of subscapularis takedown at this time remains one of surgeon comfort and experience.

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**References**