The Etiology and Assessment of Subscapularis Tendon Tears: A Case for Subcoracoid Impingement, the Roller-Wringer Effect, and TUFF Lesions of the Subscapularis

Ian K. Y. Lo, M.D., F.R.C.S.C., and Stephen S. Burkhart, M.D.

Abstract: With the advent of arthroscopy and arthroscopic repair techniques, the diagnosis and treatment of subscapularis tears have been significantly advanced. The precise etiologic factors related to subscapularis tears remain unclear. We propose that subcoracoid stenosis and subcoracoid impingement cause a “roller-wringer effect” on the subscapularis tendon. This effect increases the tensile loads on the articular surface of the subscapularis tendon that may lead to tensile undersurface fiber failure (TUFF) of the subscapularis insertion. Collectively, these factors may in part contribute to the pathogenesis of subscapularis tears. Key Words: Arthroscopy—Subscapularis—Roller-wringer effect—TUFF—Subcoracoid impingement—Coracoid.

Subscapularis tears are being increasingly recognized as a cause of shoulder pain. Recently, a number of published reports specifically focused on tears of the subscapularis tendon. In 1996, Gerber et al. reported on 16 patients with isolated complete subscapularis tears, and in 1997, Deutsch et al. reported on 14 patients with isolated complete subscapularis tears. Although the overall incidence of complete subscapularis tears is low compared with supraspinatus tears, disruptions of the subscapularis, particularly partial tears, are probably under-reported.

The advent of arthroscopy, however, has allowed a more complete evaluation of the subscapularis tendon. In particular, partial tears involving the articular surface of the subscapularis tendon are more readily appreciated from an arthroscopic perspective.

For example, a study by Bennett reported that the incidence of tears of the subscapularis may be as high as 27% during arthroscopic evaluation of patients with rotator cuff, labrum, or ligament disorders. The senior author (S.S.B.) has had a long interest in the arthroscopic evaluation and treatment of subscapularis tendon tears. During this time, he has noted that in cases of subscapularis tearing, a prominent coracoid and a stenotic subcoracoid space were common associated findings. This report describes a method of evaluation of the subscapularis tendon tears and the subcoracoid space. In particular, we draw attention to subcoracoid stenosis and subcoracoid impingement that cause a “roller-wringer effect” on the subscapularis tendon. This roller-wringer effect causes tensile loads on the undersurface of the subscapularis tendon and can lead to fiber failure of the articular surface of the subscapularis insertion (TUFF, tensile undersurface fiber failure). These mechanisms may potentially be exacerbating or etiologic factors in subscapularis tendon tears.

Surgical Technique
We perform all shoulder arthroscopies in the lateral decubitus position. General anesthesia is administered,
and a warming blanket is applied to prevent hypothermia. Five to 10 lb of balanced suspension is used with the arm in 20° to 30° of abduction and 20° of forward flexion (Star Sleeve Traction System; Arthrex, Naples, FL).

**Subscapularis Evaluation**

Diagnostic glenohumeral arthroscopy is performed through a standard posterior portal with an arthroscopic pump maintaining pressure at 60 mm Hg. Visualization of the subscapularis and particularly its footprint on the lesser tuberosity is first performed through a posterior viewing portal with the arm in internal rotation. Although some authors have argued that only a small portion of the subscapularis tendon can be visualized arthroscopically, we have found that the tendon insertion is clearly seen. We agree with Bennett that with appropriate manipulation of the arm in abduction and internal rotation, the subscapularis insertion footprint can be easily visualized. These maneuvers lift the fibers of the intact portion of the subscapularis away from the footprint, allowing excellent visualization of its insertion (Fig 1).

Occasionally, a 70° arthroscope or an anterosuperolateral viewing portal is necessary to allow complete assessment of the subscapularis insertion (Fig 2). Because degeneration of the subscapularis begins on the articular side of the upper portion of the subscapularis, partial ruptures are also easily diagnosed by observing a “bare footprint,” or bare bone bed, on the lesser tuberosity revealed by tearing of the fibers (Fig 3). Estimation of the extent of tearing is performed by relating the size of the observed bare area to the known mean dimensions of the subscapularis footprint.

**Biceps Tendon Evaluation**

The long head of the biceps tendon is evaluated next. Subluxation of the biceps tendon is a common finding associated with subscapularis tears and can be dynamically evaluated by rotating the arm into internal and external rotation. The long head of the biceps is also assessed for degeneration, and the amount of partial tearing is estimated. A complete assessment of the biceps tendon is performed by pulling the intertubercular portion of the biceps tendon intra-articularly. Particular attention is also paid to the junction of the medial sling, the subscapularis tendon, and the posterior rotator cuff, an area of confluent structures that is commonly abnormal in biceps disorders. A
proximal biceps tendon situated posterior to the projected fibers of the subscapularis tendon is suggestive of medial subluxation of the biceps tendon (Fig 4).

Our indications for biceps tenodesis include degeneration involving > 50% of the thickness of the tendon or biceps tendon instability. If any evidence of biceps tendon instability is seen, particularly if associated with a subscapularis tear, we perform an arthroscopic biceps tenodesis. In the senior author’s experience of repairing subscapularis tears (both open and arthroscopic) with associated biceps dislocation, attempts to preserve and relocate the biceps by stabilizing it within the bicipital groove commonly fail secondary to redislocation of the biceps. This can lead to disruption of the subscapularis repair. We now always perform a biceps tenodesis whenever we do a subscapularis repair if medial subluxation of the biceps tendon is seen.

Subcoracoid Space Evaluation

After inspection of the subscapularis tendon insertion and the biceps tendon, we turn our attention to the coracoid and the subcoracoid space. Gerber et al. defined the subcoracoid space as the interval between

![Figure 2](image1.png)  
**Figure 2.** Arthroscopic “aerial” view of a right shoulder from a posterior portal using a 70° arthroscope showing a full-thickness tear of the upper portion of the subscapularis tendon. Note the bare area of the subscapularis footprint (shown by the bracket) with only the most inferior portion of the tendon intact (−) and the biceps tendon, which is subluxed posterior to the upper subscapularis tendon (BT, biceps tendon).

![Figure 3](image2.png)  
**Figure 3.** Arthroscopic view of the subscapularis insertion of a right shoulder from an anterolateral portal with the arm in 30° of abduction and internal rotation showing a partial tear of the articular surface of the subscapularis tendon. Note how the tearing of the fibers exposes the underlying footprint of the subscapularis insertion (arrow) (H, humeral head).

![Figure 4](image3.png)  
**Figure 4.** Arthroscopic view of a left shoulder from an anterosuperolateral portal showing a degenerative and subluxed biceps tendon (BT), an attenuated medial sling (M), and a degenerative subscapularis tendon (SSc). Note how the proximal biceps tendon appears to be situated posterior to the projected fibers of the subscapularis tendon suggestive of medial subluxation.
the tip of the coracoid and the humeral head (the coracohumeral interval). This space must be large enough to accommodate the articular cartilage of the humerus, the subscapularis tendon, the subscapularis bursa and the rotator interval tissue, and portions of the insertions of the coracoacromial ligament and the conjoint tendon. The normal coracohumeral interval has been shown in anatomic and imaging studies to be between 8.4 and 11.0 mm. We and others have defined subcoracoid stenosis (narrowing of the subcoracoid space) as a coracohumeral interval less than 6 mm. Although one can gain an initial appreciation of the size of the coracohumeral interval on magnetic resonance imaging (Fig 5), we prefer to directly measure the coracohumeral interval intraoperatively.

In patients with complete subscapularis tears, the coracoid can be felt as a bony prominence in the anterior soft tissues behind the subscapularis tendon (Fig 6). The size of the coracohumeral interval is estimated by introducing an instrument of known size (5.0-mm Resector; Stryker Endoscopy, Santa Clara, CA) through an anterosuperolateral portal and placing it between the coracoid and humerus. In many cases, particularly those involving combined subscapularis, supraspinatus, and infraspinatus tears, the coracoid will be so prominent and the subcoracoid space so tight that even a 5-mm shaver will not fit between the coracoid and humerus. When evaluating the subcoracoid space and measuring the coracohumeral interval (particularly when associated with massive rotator cuff tears), traction must be applied to the arm manually or by a traction boom to minimize any potential effect of proximal humeral migration.

If the coracohumeral interval is less than 6 mm, a diagnosis of subcoracoid stenosis (narrowing of the subcoracoid space) is made. However, in and of itself, this may not be pathologic or symptomatic. To diagnose subcoracoid impingement, defined as impingement of the coracoid against the humerus (usually the lesser tuberosity), one must show direct contact of the coracoid against the lesser tuberosity in a coracoid impingement position. To show this, the arm is brought into a combination of flexion, adduction, and internal rotation (Fig 7), a position that generally corresponds to the position of discomfort determined during preoperative physical examination. If subcoracoid stenosis and subcoracoid impingement are diagnosed intraoperatively with correlative signs and symptoms clinically, then we proceed with subcoracoid decompression and coracoplasty, as previously described (Fig 8).

In many cases, however, the subcoracoid space will be so tight and the coracohumeral interval so small that the coracoid will impinge against the subscapularis tendon.
laris tendon and the humerus in adduction and rotation (usually slight internal rotation). This is not in the classical position of flexion, adduction, and internal rotation as described by Gerber et al. In contrast to the situation described previously, these cases are frequently associated with full-thickness partial tears of the subscapularis tendon or partial articular surface tears of the subscapularis tendon.

At arthroscopy, the coracoid will typically appear as a prominent bulge anterior to the upper subscapularis tendon, “bowstringing” the subscapularis fibers across the prominent coracoid process (Fig 9). Furthermore, by rotating the arm in internal and external rotation with the shoulder in adduction, the coracoid can be seen “rolling” behind the subscapularis tendon, indenting the superficial surface of the subscapularis while stretching (tensile loading) the deep surface of the subscapularis (Fig 10). We call this the roller-wringer effect, after the old-fashioned clothes wringer, and propose that the tensile loading caused by the prominent coracoid and the narrow subcoracoid space may be an etiologic or exacerbating factor in subscapularis tears.

Furthermore, we have noted that while the arm is rotated in adduction, the prominent coracoid will roll

![Image 7](image7.png) Confirming subcoracoid impingement: posterior arthroscopic view of a right shoulder using a 70° arthroscope. Manipulation of the arm in flexion, adduction, and internal rotation shows subcoracoid impingement with contact between the coracoid and the lesser tuberosity of the humerus (C, coracoid; LT, lesser tuberosity of the humerus).

![Image 8](image8.png) Posterior arthroscopic view of a right shoulder showing an increased coracohumeral space (double arrow) after subcoracoid decompression and coracoplasty allowing room for the subscapularis repair. Compare with Fig 6.

![Image 9](image9.png) Posterior arthroscopic view of a right shoulder using a 70° arthroscope showing a tear of the upper 50% of the subscapularis tendon and a corresponding bare subscapularis footprint. Note that the prominent coracoid appears as a bulge anterior to the upper subscapularis tendon, “bowstringing” the subscapularis fibers (C, coracoid; SSc, subscapularis tendon; FP, bare footprint of the subscapularis tendon).
towards the lesser tuberosity, stretching (tensile loading) the undersurface of subscapularis tendon in the exact location of the subscapularis tear (Fig 11). As stated previously, these tears may be full-thickness partial tears of the subscapularis, but are more commonly partial thickness articular surface subscapularis tears. We call these lesions TUFF (tensile undersurface fiber failure) lesions in which the tensile loads on the undersurface of the subscapularis tendon (created by the prominent coracoid) lead to fiber failure of the articular surface of the subscapularis insertion.

**DISCUSSION**

Although the pathology associated with supraspinatus tendon degeneration has been well documented, the pathologic findings associated with subscapularis tendon tears have only recently been elucidated. In addition, the various etiologic factors associated with rotator cuff tears, in particular subscapularis tears, remain unclear.

One commonly cited contributing factor in supraspinatus tears is tendon degeneration. Recently, this has also been investigated in the subscapularis tendon. In 1998, Sakurai et al. reported on the gross morphologic and histology findings in 46 cadaveric shoulders. Twenty shoulders had supraspinatus tears and an almost equal number (17) of cadavers had subscapularis tears. All of these tears were partial-thickness articular sided tears and all of the subscapularis tears appeared to begin at the most superior portion of the insertion where the majority of tendon degeneration was seen. In 1999, Sano et al. histologically evaluated the supraspinatus, infraspinatus, and subscapularis tendons in 76 cadaveric shoulders. They showed that a similar amount of degeneration (such as fiber thinning, granulation tissue, incomplete tearing) was present in all 3 tendons, and that this degeneration was most prominent on the articular (as opposed to bursal) surface of the tendon. These findings collectively suggest that intrinsic tendon degeneration may be an important etiologic factor in tears of the subscapularis tendon.

Our observations suggest that subcoracoid stenosis and subcoracoid impingement may also contribute to subscapularis tendon tears. In patients with subcoracoid stenosis and subcoracoid impingement, the subscapularis tendon appears to “bowstring” tightly across the prominent coracoid. During rotation of the shoulder, the coracoid can be seen “rolling” along the subscapularis tendon. As the arm is rotated particularly into slight internal rotation, the subscapularis tendon is forced to travel between a prominent coracoid and the “relatively” prominent humerus (Fig 12). This situation is analogous to an old-fashioned clothes wringer, in which an article of clothing (representing...
the subscapularis tendon) is squeezed between 2 rollers (the coracoid and lesser tuberosity) to wring the water from the clothes (Fig 13).

In contrast to what has been commonly suggested in subacromial impingement and supraspinatus tears, it is unlikely that the coracoid would act like the acromion and abrasively compress and erode the subscapularis tendon (after all, tendons more commonly fail in tension than in compression). Alternatively, in our scenario, the mechanical forces across the convex surface of the subscapularis tendon would be primarily tensile and would be located at the articular surface. Thus, the tensile load would be greatest at the articular surface or the undersurface of the subscapularis tendon.

Conceptually, this scenario can be modelled after a simply supported beam, where the subscapularis tendon is the beam and the lesser tuberosity of the humerus and scapula are the supports on either end of the beam (Fig 14). Coracoid impingement would be rep-
resented by a load directed perpendicular to the top of the beam. In this situation, the stress distribution would be compressive on the top half of the beam and tensile on the bottom half of the beam. In addition, the tensile fiber stress would increase as one progressed from the neutral axis of the beam toward the bottom of the beam, reaching a maximum at the undersurface of the beam, which corresponds to the articular surface of the subscapularis tendon.38

Interestingly, as our model predicts, the highest amount of tensile stress would occur on the deep articular surface of the subscapularis tendon, exactly where Sano et al.31 have shown that the tendon degeneration is most prominent. Previous studies by Sano et al.33 and Uhthoff et al.34 have shown an inverse correlation between the tensile strength of a tendon insertion and the amount of degeneration. That is, as the amount of degeneration of the tendon insertion increases (as measured by histologic analysis of fiber thinning and granulation tissue) the tendon insertion becomes weaker. Therefore, although the tensile loads on the deep articular surface of the subscapularis tendon (created by subcoracoid impingement and the roller-wringer effect) may in part contribute to degeneration, they may also lead to mechanical failure by tensile overload of the weakened degenerative articular surface fibers of the subscapularis tendon.

This sets up the scenario of a TUFF lesion, in which the tensile undersurface loads are focused on the weakened degenerative tissue leading to fiber failure. This scenario correlates with the cadaveric study of Sakurai et al.,18 who reported that the most common pattern of subscapularis tearing was the partial-thickness articular surface tear. This situation can be further compounded by an eccentric load on the subscapularis tendon (forced external rotation), a common cause of subscapularis tendon tears.4

Although these observations clearly do not provide evidence that subcoracoid impingement and the roller-wringer effect are the primary or sole etiologic factors in subscapularis tendon tears, they do suggest that subcoracoid impingement and the roller-wringer effect may in part contribute to subscapularis tendon tears. In particular, we believe that the failure to address this concern by concomitant coracoplasty at the time of subscapularis tendon repair may contribute to rerupture of the repair construct.

In conclusion, subscapularis tears, subcoracoid ste-
nosis, and subcoracoid impingement can all be adequately assessed arthroscopically using the principles outlined above. Subcoracoid impingement and subcoracoid stenosis are common findings associated with subscapularis tears and may in part contribute to the pathogenesis of subscapularis tears and TUFF lesions by the roller-wringer effect.

REFERENCES