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Subscapularis tendon tears: management and arthroscopic repair

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- Tears of the subscapularis tendon have been under-recognised until recently. Therefore, a high index of suspicion is essential for diagnosis.

- A directed physical examination, including the lift-off, belly-press and increased passive external rotation can help identify tears of the subscapularis.

- All planes on MR imaging should be carefully evaluated to identify tears of the subscapularis, retraction, atrophy and biceps pathology.

- Due to the tendency of the tendon to retract medially, acute and traumatic full-thickness tears should be repaired. Chronic tears without significant degeneration should be considered for repair if no contraindication exists.

- Arthroscopic repair can be performed using a 30-degree arthroscope and a laterally-based single row repair; one anchor for full thickness tears ⩽ 50% of tendon length and two anchors for those ⩾ 50% of tendon length.

- Biceps pathology, which is invariably present, should be addressed by tenotomy or tenodesis.

- Timing of post-operative rehabilitation is dictated by the size of the repair and the security of the repair construct. The stages of rehabilitation typically involve a period of immobilisation followed by range of movement exercises, with a delay in active internal rotation (IR) and strengthening in IR.

Introduction

Tears of the subscapularis tendon were first reported by John Gregory Smith in 1834.[1] Then 100 years later, Codman also referenced the subscapularis in his landmark text,[2] along with his description of tears of the posterosuperior rotator cuff. Surgical repair was described in 1954, when Hauser reported two cases of full thickness tearing treated by an open suture repair via trans-osseous tunnels lateral to the biceps groove.[3] McLaughlin also mentioned subscapularis pathology as it relates to tendinous pathology and instability.[4,5] Publications on this topic were limited and, thus, tears of the subscapularis tendon were not well recognised and largely excluded from the orthopaedic literature until more recently. It was not until the first major series by Gerber and Krushell in 1991[6] that the focus returned to include the anterior rotator cuff.

With the advent of arthroscopy, advances in the clinical and radiographic detection of tears and improvements in surgical instrumentation and technique, there has been a renewed focus on recognition and repair of the torn subscapularis tendon. Knowledge of presentation, detection, and repair of subscapularis tears are paramount for any practising orthopaedist who treats common shoulder conditions, as these lesions are at times identified on diagnostic shoulder arthroscopy or during repair of the posterosuperior rotator cuff or associated biceps pathology that are missed on pre-operative imaging.[7-10] The focus of this review is on arthroscopic management of tears of the subscapularis.

Anatomy

The subscapularis muscle arises from a wide surface area of the subscapularis fossa of the scapula medially and inserts laterally on the lesser tuberosity inferior to the humeral articular surface and medial to the bicipital groove. By gross and histological analysis, Clark and Harryman[11] identified the distinct layers of the rotator cuff tendons, along with the interdigitation of fibres of the supraspinatus and subscapularis to form the floor of the bicipital groove. The insertion site on the lesser tuberosity contains both a purely tendinous insertion and a muscular portion. In a cadaveric study, the tendinous portion was found to have an average height of 2.5 cm and a width of 1.8 cm.[12,13]

Table 1. Physical exam findings

Test	Positive findings
Passive ER	Increased ER *versus* contralateral normal shoulder
IR strength	Weakness
Belly-press	Inability to keep elbow in line with or in front of trunk
Napoleon's sign	Inability to exert pressure on the abdomen
Lift-off test	Inability to lift the hand off the back
Modified lift-off test	Inability to maintain hand off the back when lifted away by the examiner

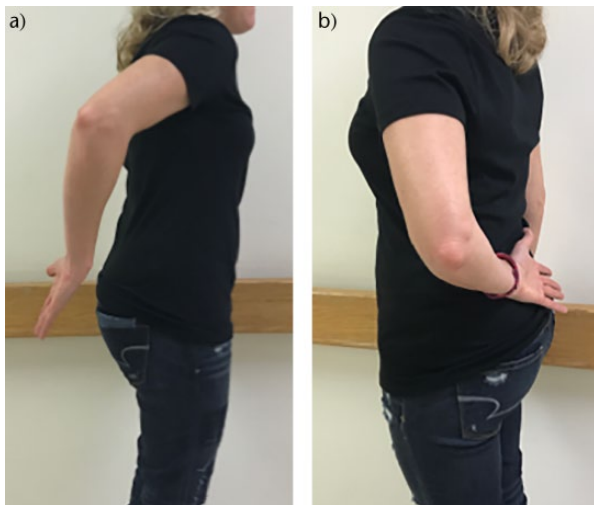ER, external rotation; IR, internal rotation

Fig. 1 'Lift-off' test: a) normal lift-off test; b) positive lift-off test when the patient is unable to maintain the hand off the back.

Larger height measurements have been reported in a similar cadaveric study[14] and via an intra-articular measurement,[15] which could represent inclusion of the muscular portion of the insertion. The subscapularis footprint has been found, on average, to be larger than that of the infraspinatus and the supraspinatus.[14,16,17]

Diagnosis

Typically patients can be both young and old, and tend to be more often male rather than female. The patient often reports a history of forced external rotation (ER) and describes pain located in the anterior shoulder. Isolated tears of the subscapularis are often traumatic tears, and can be associated with glenohumeral dislocation.[5] More commonly, patients present with subscapularis tears in conjunction with tearing of the anterior supraspinatus and structures compromising the rotator interval, or with large multi-tendon tears of the rotator cuff. Tendon degeneration has been shown to occur in the subscapularis at similar rates to that in the superior and posterior rotator cuff.[18,19] Subcoracoid impingement may also be a factor to a limited degree.[20]

Physical examination

Subscapularis pathology can often be diagnosed via clinical examination alone.[21] The surgeon must assess the biceps tendon for pathology, as it nearly always occurs concomitantly with injury to the subscapularis due to the intimate nature of these anatomical structures. Assessment of the posterosuperior cuff and acromioclavicular (AC) joint are included.

A directed physical examination includes inspection, range of movement (ROM), internal rotation (IR) strength and special tests (Table 1). The AC joint, coracoid, long head of the biceps tendon and lesser tuberosity should be palpated for tenderness. The position of the biceps muscle is noted, which may be more distal if ruptured. Passive and active ROM of the shoulder are assessed, including in IR, ER and forward elevation, noting any deficiencies relative to a normal contralateral shoulder. Patients with large full thickness tears of the subscapularis often have increased passive ER compared with the contralateral side, especially in chronic tears. IR strength is assessed as the patient is asked to place the hand on the abdomen while bringing the elbow forward. The examiner attempts to pull the hand off the abdomen while externally rotating the arm at the elbow.

Several specific tests are used to identify tears of the subscapularis. Gerber and Krushell[6] first described the 'lift-off' technique, where the arm is internally rotated behind the torso with the elbow flexed (Fig. 1). The patient with subscapularis tearing is unable to lift the dorsum of the hand off the back. A modified version of this special test requires the examiner to lift the hand off the back and then release.[22] The test is positive when the patient is unable to maintain positioning of the hand off of the back. In order to adequately assess patients with limited IR or extreme pain limiting the utility of the lift-off test, Gerber et al[22] also described the 'belly-press' technique. The patient presses the abdomen with the hand flat, keeping the shoulder in IR and maintaining the elbow at or in front of the mid-coronal plane of the trunk (Fig. 2). A positive test is when the elbow drops back behind the trunk. The examiner can elicit a positive sign with a posteriorly directed force on the elbow. The 'Napoleon' sign is when the elbow falls back and the wrist flexes, the position in

Fig. 2 'Belly-press' test. The patient's right arm demonstrates the normal belly-press test. The patient's left arm demonstrates a positive belly-press test, when the patient is unable to maintain the elbow at or in front of the mid-coronal plane of the trunk.
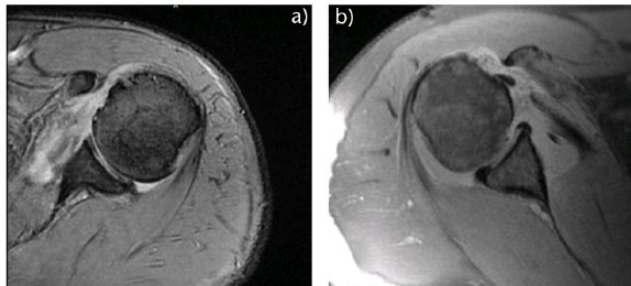

Fig. 3 Axial MR imaging of a tear in the subscapularis: a) full thickness tearing of the subscapularis in a left shoulder; b) full thickness tearing of the subscapularis with biceps tendon subluxation.

which Napoléon Bonaparte held his arm during portraits.[23] The 'bear-hug' test has proved sensitive for tears of the subscapularis.[24] The patient's hand is placed across the body on top of the opposite shoulder with the elbow elevated and the examiner attempts to pull the hand off of the shoulder. The test is considered positive if the examiner is able to lift the patient's hand off the shoulder.

Imaging

A full shoulder series of plain radiographs should be obtained in each patient specifically to assess for evidence of trauma, AC joint and glenohumeral arthritis, coracoid as well as acromial morphology and pathology, humeral subluxation and any bony or cystic changes at the lesser tuberosity. However, MR imaging remains the standard for imaging assessment and diagnosis. Using a combination of axial, sagittal and coronal planes, MR imaging has a high sensitivity and specificity for diagnosing lesions of the subscapularis.[25,26] It has recently been suggested that
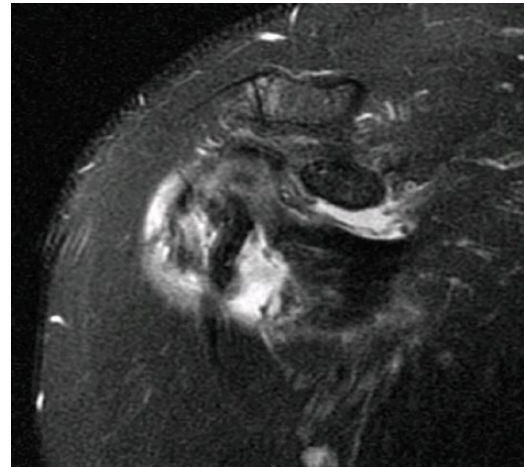

Fig. 4 Coronal MR imaging of a tear in the subscapularis in a right shoulder. A full thickness tear can be seen, as well as fluid signal inferior and medial to the coracoid which is suggestive of tearing. The biceps is displaced medially from the groove.

tear size correlates to MR imaging sensitivity, with larger tears having higher sensitivity than smaller tears.[10,27]

We recommend a systematic review of all MR imaging planes and sequences. Axial imaging is most easily used to identify tearing of the subscapularis (Fig. 3). However, examination of coronal and sagittal images aids in characterisation of tears, including partial articular sided-type and intra-substance variants, limited detachment of the superolateral portion of the tendon, full thickness tearing of a portion of the tendon and full thickness tearing of the entire tendon insertion. Coronal imaging can help identify the extent of tearing in the cranio-caudal direction. Furthermore, a fluid signal medial to the coracoid on coronal imaging can be suggestive of tearing of the subscapularis (Fig. 4). Narrowing of the coracohumeral interval < 7 mm can also be indicative of tearing of the subscapularis. Lastly, the degree of muscle atrophy and retraction or the presence of oedema should be carefully evaluated and are best seen on axial and sagittal images.

Biceps subluxation, dislocation and/or tearing are consistently found as a result of the intimate association of the subscapularis, biceps sheath and coracohumeral ligament.[28] Medial dislocation of the biceps tendon (Fig. 4) is considered by many to be diagnostic of tearing of the subscapularis,[25] although there are rare circumstances of the biceps dislocating anterior to an intact subscapularis tendon. MR imaging will characterise biceps pathology as well as associated tearing of the superior and posterior rotator cuff to aid in pre-operative planning. Lastly, any cystic changes or defects in the lesser tuberosity that could compromise anchor fixations should be identified. CT arthrogram or ultrasound studies may be indicated under certain circumstances and can be useful in the diagnosis.

Table 2. Classification of subscapularis tears

	Fox et al 2002[29]		Lyons and Green 2005[30]		LaFosse et al 2010[32]		Touissant et al 2012[33]
I	Partial thickness	I	Partial thickness, partial length	I	Partial superior 1/3rd lesion	1	Partial tendon tear with intact bicipital sling
II	Complete tear of upper 25%	II	Full thickness, partial length	II	Complete superior 1/3rd lesion	2	Partial tendon tear with partial bicipital sling injury with intact SGHL
III	Complete tear of upper 50%	III	Full thickness, full length without retraction	III	Complete superior 2/3rd lesion	3	Complete tendon tear with complete bicipital sling injury, minimal tendon retraction
IV	Complete rupture of entire tendon	IV	Full thickness, full length with retraction	IV	Complete lesion, centered HH, fatty infiltration ≤ grade 3	4	Complete tendon tear with complete bicipital sling injury, with retraction
				V	Complete lesion, subluxated HH, coracoid conflict and fatty infiltration ≥ grade 3		

HH, humeral head; SGHL, superior glenohumeral ligament

Table 3. Arthroscopic portals, with approximate locations based on individual anatomy and function

Portal	Placement	Function
Posterior	2 cm inferior, 1 cm medial to posterolateral corner of acromion	Viewing
Anterior	Lateral to coracoid, slightly more medial and inferior than standard anterior rotator interval portal	Suture passage, suture tying, tendon mobilisation, anchor insertion
Lateral	1 cm inferior to lateral edge of acromion, anterior to line bisecting acromion through a posterosuperior cuff tear	Viewing during tendon mobilisation, suture tying
Anterolateral	2 cm superior and 2 cm lateral to standard anterior portal, just off tip of anterolateral edge of acromion for isolated subscapularis tear repairs	Suture management
Accessory anterolateral	Localised with a spinal, tangential to the lesser tuberosity	Traction suture in tendon

Classification

There is no consensus on any classification system for tears of the subscapularis. Many authors have described variants of an anatomically-based classification system, with tears progressing from the superior portion of the tendon and extending inferiorly. The most commonly reported are variants of a classification that divides the tendon insertion into three equal parts – a superior third, middle third and an inferior third – or those that classify tears based on the relationship to the biceps sling and superior glenohumeral ligament (Table 2).[29-34]

Indications for repair

Indications for arthroscopic subscapularis repair include a patient with a painful shoulder with evidence of a full-thickness subscapularis tear or a partial-thickness tear which has failed non-operative treatment. Contraindications to repair include pain-free, grade 4 Goutallier fatty degeneration on MR imaging, glenohumeral arthropathy, infection, the non-compliant patient and significant medical comorbidities precluding anaesthesia.[35]

There has been some debate over repair of chronic subscapularis tears. The tendon edge does retract further medially than in tears of the posterosuperior rotator cuff.[36,37] However, we have found the tendon to be mobile, aided by releases as necessary; therefore, we believe that repair should be attempted if there is no contraindication, in particular in the dominant arm in a physically active individual. The subscapularis has been suggested to function as an anterior restraint and contribute to elevation of the arm. Thus, even in the setting of fatty degeneration an argument for repair can be made.[38,39] In addition, with combined tears of the rotator cuff, repair of the subscapularis facilitates repair of the posterosuperior rotator cuff and reduces tension on the complete repair construct.[40,41]

Operative technique

A standard set of arthroscopic instruments is required to perform a successful repair of the subscapularis. Key instruments used for mobilisation include straight and angled arthroscopic elevators, electrocautery and ablation wands. Shuttling instruments for retrograde passing of the suture through the tendon include straight and curved suture hooks, as well as piercing instruments. Although not used by the authors, anterograde suture passing instruments may also be used when inserted through a separate anterolateral approach. An atraumatic suture retriever is essential. Knot-tying tools are used, though the approach described below is amenable to a knotless repair; single-row, for example. The authors prefer to use a 30° scope with adjusting arm position as needed for visualisation, and have found little need for a 70° scope. However, the latter may be used to aid visualisation in difficult cases.

Implants

Absorbable biocomposite or PEEK anchors in diameters and lengths available for posterosuperior rotator cuff

repair may be used. These anchor types most often require two to three steps for insertion, including punching of the hole in the lesser tuberosity and sometimes tapping of that hole before anchor insertion. The lesser tuberosity is one location which may benefit from the use of metal anchors which require only one step for insertion, as this avoids potential angle mismatch, as well as decreasing the chances for widening of the punch or tap hole and loss of fixation created by a two- or three-step insertion. These anchors also have the advantage of a pointed tip which helps prevent skiving on the lesser tuberosity. Anchors which are double- or triple-loaded with #2 high tensile suture are available; however, the authors often use double-loaded anchors in repair of the subscapularis to simplify suture management, passing and tying where space can be a limiting factor.

In addition to the type of anchor used, the number of anchors used is determined more by the amount of tendon torn than any other factor. For example, a full-thickness tear of approximately 33% of the subscapularis, thus the upper third, is repaired with a single double-loaded anchor. A tear of 100% of the subscapularis is repaired with two anchors, often double-loaded, especially the more inferior of the two anchors. A tear of 50% to 66% of the subscapularis may be repaired with two double-loaded anchors, or a single triple-loaded anchor, dictated by the tear configuration and the local anatomy. These sutures are passed in a simple fashion and tied, though the second suture limb can be passed through lateral tissue in a horizontal mattress fashion if the circumstances present. Single-row knotless techniques are described, and rarely employed by the authors. Double-row techniques have not been found necessary in our more than 16-year experience repairing subscapularis tendon tears in an arthroscopic manner.

Patient positioning and anaesthesia

Although the surgery may be performed in the 'beach-chair' or lateral position, the author's preference is the 'beach-chair' position. This position allows movement of the arm to facilitate repair, familiarity with orientation and anatomical visualisation. For the novice arthroscopist or the unusual case, this position also allows for easy conversion to an open procedure, if needed. Use of an intra-operative sterile arm holder is recommended. We prefer laryngeal mask or general endotracheal tube anesthesia in combination with interscalene regional nerve block,[42] the latter which helps to reduce time spent in the recovery room and reduce opioid usage in the immediate post-operative period. Before the incision is made, an examination under anaesthesia should be performed to identify shoulder ROM and stability. Any prior surgical scars, if present, are accounted for.

Portal placement

A standard posterior portal is established and is used throughout the repair primarily as a viewing portal. An anterior portal is planned with a spinal needle, the incision is made and a cannula is inserted. This portal will be used for suture passing and tying and, in some cases, can be used for anchor insertion. It is often slightly more medial than the standard anterior rotator interval portal, and slightly more inferior. The portal will be along the lateral edge of the coraco-acromial ligament. When there is a full-thickness defect in the supraspinatus, a lateral subacromial portal can be made about 1 cm inferior to the edge of the acromion at a line bisecting the anterior to posterior length of the acromion or anterior to that line in the setting of smaller posterosuperior cuff tears. This portal will facilitate suture management and is used as a viewing portal when performing medial release of the subscapularis. Anchor placement is often achieved via placement of a percutaneous anterolateral portal, and is planned with a spinal needle to allow for anchor insertion at the desired location in the lesser tuberosity. If a two-anchor repair is required this portal can be more inferior, at a mid-point between the sites of planned anchor insertion to allow for placement of both anchors through one percutaneous approach. In the event of an isolated repair of the subscapularis, the anterolateral portal can be used for suture management with a cannula in lieu of the lateral subacromial portal. Lastly, an accessory anterolateral portal is made percutaneously under direct visualisation with a spinal needle in line with the subscapularis and tangential to the lesser tuberosity. This portal is used to retrieve a traction stitch, when used, which is placed in the superolateral aspect of the subscapularis to reduce the tendon during releases, suture passing and knot tying (Table 3, Fig. 5).

Diagnostic arthroscopy

Once the posterior viewing and anterior working portals have been established, diagnostic arthroscopy is performed. Careful evaluation of the glenoid and humeral articular surfaces and the anterior and posterior labrum is performed to identify any degenerative changes or tearing requiring treatment. The posterosuperior rotator cuff is inspected to identify any concomitant pathology that may affect portal placement during repair. At this time, a full evaluation of the long head of the biceps tendon for instability and tearing should be undertaken, as well as at the superior labrum biceps anchor, with any treatment initiated before repair of the subscapularis. With partial tears of the subscapularis, there should be a high index of suspicion for hidden lesions and defects of the biceps pulley in the biceps groove[43] (Fig. 6). Early tenotomy or tenodesis removes the biceps from obstructing later repair of

Fig. 5 Patient positioning and portal placement in the left shoulder. The patient is placed in the upright 'beach-chair' position with the operative arm held in an arm holder (right lower inset). The skin markings identify the posterior viewing portal and the anterior and lateral working portals. The lateral and inferior skin marking is the location for the stab incision for the traction suture, parallel to the direction of the subscapularis.

Fig. 6 An arthroscopic image of a seemingly simple partial tear of the subscapularis in a right shoulder (a). With internal rotation of the arm and advancement of the arthroscope into the shoulder, a hidden lesion is seen with appearance of the biceps tendon on the right side of the image in the white circle (b).

Fig. 7 Arthroscopic image of a normal subscapularis tendon viewed from the posterior portal in a right shoulder. The asterisk (*) marks the middle glenohumeral ligament, which is lateral to the glenoid.

the subscapularis. With advancement of the arthroscope to the anterior glenohumeral joint, the subscapularis is evaluated. The tendon is viewed for discontinuity across the anterior joint extending from the lesser tuberosity, keeping in mind that only a portion of the tendon is visible arthroscopically.[44] The middle glenohumeral ligament (MGHL) and anterior band of the inferior glenohumeral ligament (IGHL) are intimately associated with the tendon and cover the articular surface (Fig. 7, normal subscapularis tendon). The subscapularis tendon is probed for any intra-substance or articular-sided tearing and the integrity of the superolateral upper rolled border. The medial wall of the biceps groove denotes the lateral aspect of the lesser tuberosity and, thus, the subscapularis tendon. Full thickness tears typically occur here, and progress inferiorly through the length of the tendon. With full thickness and complete tears, the tendon retracts medially. In some cases where scar tissue may conceal a tendon stump, identification of the superior glenohumeral ligament and coracohumeral ligament complex, the 'comma' tissue, can aid in identification of the subscapularis tendon as it commonly remains attached at its superolateral corner.[20] The position of the MGHL, normally at, or lateral to, the glenoid joint line with an intact subscapularis, is often noted medial to the glenoid joint line with retraction of a
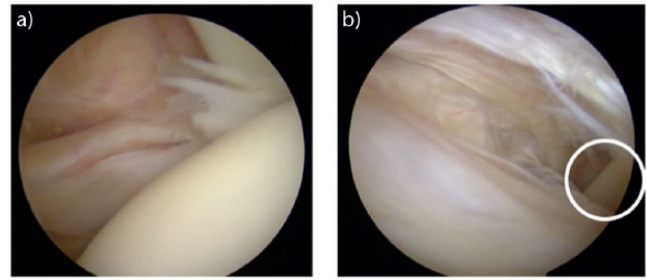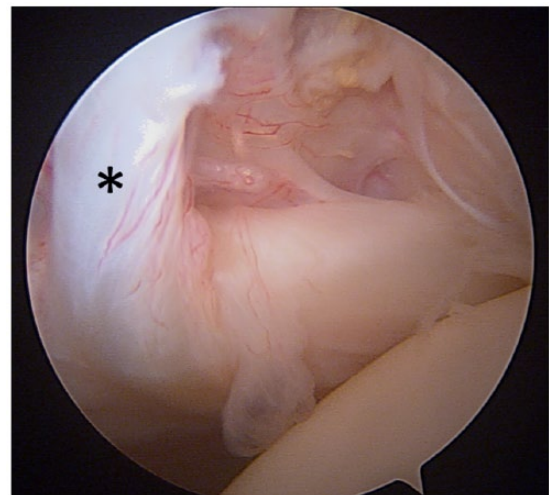
subscapularis tear. Treatment of the biceps tendon pathology, by tenodesis or tenotomy, or rarely reconstruction of the pulley, is carried out early in this procedure to remove the tendon from the field. The technique chosen for the biceps is beyond the scope of this paper.

Tendon debridement and mobilisation

A glenohumeral approach to repair of the subscapularis is used. We have not found a subacromial approach particularly useful as a primary technique. With identification of the subscapularis tear and confirmation of the need to repair the tendon, a larger anterior portal screw-in cannula, 8 mm or more in diameter, is inserted. This can accommodate the instruments and devices necessary for tear preparation and repair. Using an ablation wand, the rotator interval is cleared and the coracoid is visualised. The area anterior to the lateral aspect of the subscapularis
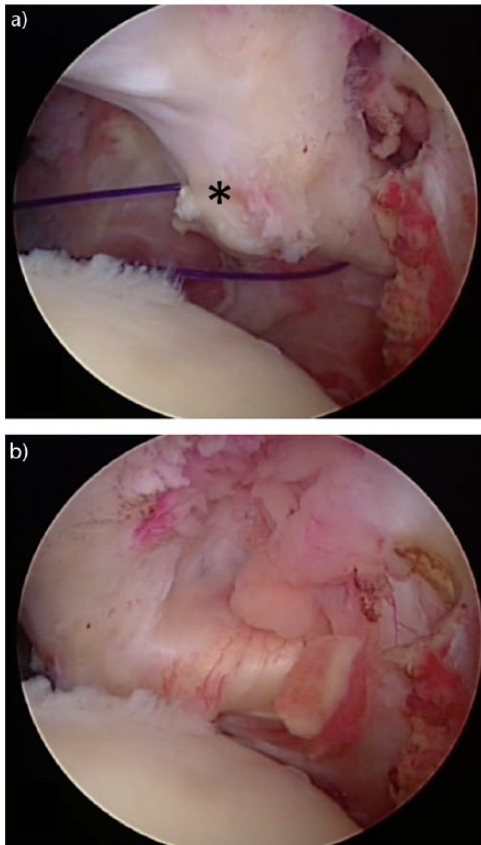
Fig. 9 Arthroscopic image of a posterosuperior rotator cuff tear before (a) and after (b) repair of the subscapularis tendon to the lesser tuberosity in a left shoulder. The 'comma' tissue link to the posterosuperior cuff will translate the posterosuperior rotator cuff tear more laterally, facilitating repair.

Fig. 8 a) Arthroscopic image of a traction stitch placed in the upper border of the subscapularis tendon in a left shoulder. The asterisk (*) marks the lower part of the comma tissue; b) reduction of the subscapularis with traction on the traction suture. The middle glenohumeral ligament can be seen on the right side of the image.

is cleared for subsequent work in this space. This will include suture passage and, especially, suture tying. The MGHL is resected, and releases are carried out anterior, superior, and posterior to the subscapularis. This includes releasing a portion of the IGHL. The arm can be externally rotated to facilitate these releases. The lesser tuberosity can be better visualised with some forward flexion of the arm. The lesser tuberosity is denuded of soft tissue to expose the bone from lateral to the articular margin to just medial to the biceps groove. A shaver can be inserted through the lateral portal when the tear includes the supraspinatus, or through the anterolateral portal in an isolated subscapularis tear repair. If a traction suture is deemed advantageous, this is placed with a curved or crescent hook device inserted via the anterior cannula and passed through the superolateral corner of the subscapularis (Fig. 8). A #1 PDS suture (Ethicon Inc, Somerville NJ) is used as the colour is easily visualised and is retrieved percutaneously as described above. With retracted
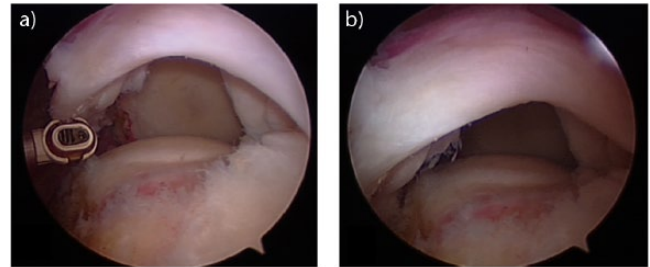
tendon tears, the traction suture is usually necessary to aid with many stages of the technique. With traction of the PDS, while viewing from a lateral vantage point, the releases around the subscapularis to the base of the coracoid are completed. While a wand is most often used, an elevator can also be used. The muscle of the subscapularis is often seen when the tendon is retracted laterally.

It is important to maintain the comma tissue in continuity between the subscapularis and the supraspinatus. When the subscapularis is repaired to the lesser tuberosity, the comma tissue link to the posterosuperior cuff will translate the supraspinatus tendon tear more laterally and aid this aspect of the repair (Figs 9, 10 and 11). By pulling on the traction suture with the arm in neutral rotation, the extent of the releases can be assessed from the posterior and lateral portals. If the releases are complete, the point to which the lateral edge of the tendon translates is the approximate position for the planned anchor placement on the lesser tuberosity. The amount of lateral translation of the supraspinatus, if involved, can be further assessed at this time.

Tendon repair

The stages of preparation are completed at this point, though these steps are no less important than those of the repair. With the arthroscope in the posterior portal, anchor placement in the lesser tuberosity is planned. This can be achieved through the anterior cannula, if the angle allows, or via a percutaneous approach identified by a spinal needle. The arm can be flexed to improve visualisation inferiorly on the lesser tuberosity. In addition, the arm can be rotated to permit an optimal anchor insertion angle, including ER for most percutaneous approaches. The position of the anchor is where the lateral edge of the tendon translates to when the traction suture is tensioned. A 45° angle of insertion may be achieved, but a lesser angle may lead to skiving of the anchor or poor placement. The anchor trajectory must be clearly into the bone of the
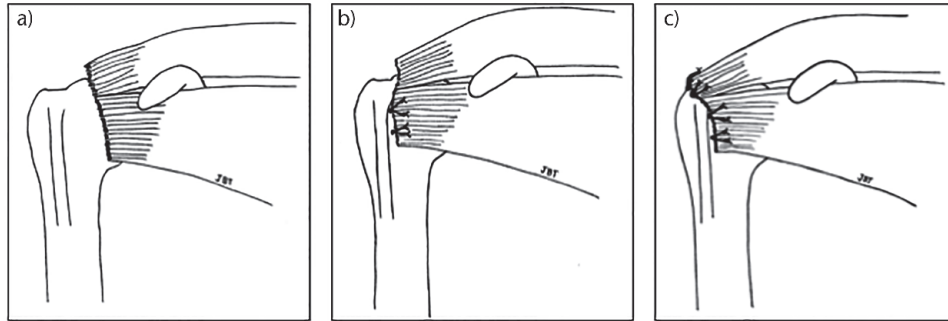
Fig. 10 Schematic representation of a full-thickness subscapularis and posterosuperior rotator cuff tear as seen from the anterior view (a). Repair of the subscapularis helps reduce the posterosuperior rotator cuff (b) and facilitate its repair (c).[40]
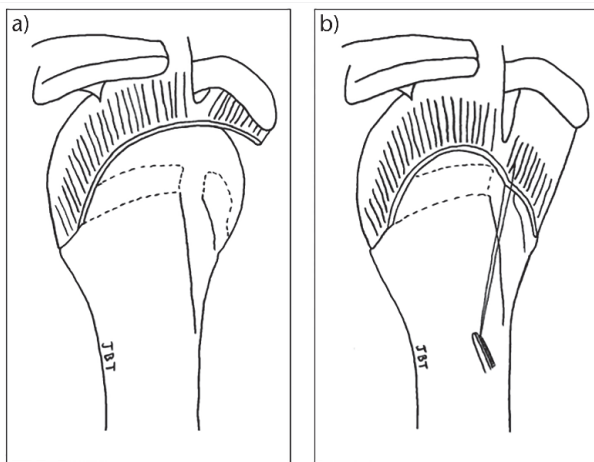

Fig. 11 Schematic representation of full thickness subscapularis and posterosuperior rotator cuff tear as seen from the lateral view (a). Traction and repair of the subscapularis helps to reduce the posterosuperior rotator cuff (b).[40]

lesser tuberosity and lateral to the articular surface. The example described below is for a 100% subscapularis tear with an associated supraspinatus tear.

After the first anchor is inserted into the inferior portion of the lesser tuberosity and as laterally as possible, it is tested to ensure secure fixation. One limb of one suture is retrieved through the lateral portal cannula. Often it is apparent that one of the two sutures in the anchor is more inferior and the medial limb of that suture is retrieved for passage through the tendon in a more inferior location. A crescent hook is introduced through the anterior cannula for a retrograde suture passage technique. For this 100% tear of the subscapularis tendon, four suture limbs are passed through the tendon in a simple fashion; the first suture is passed at about 2 cm inferior to the superior edge of the subscapularis, with the additional sutures passed at about 1.5 cm, 1 cm and 0.5 cm inferior to the superior edge. With traction on the PDS suture and the arthroscope advanced forward to see over the rolled edge of the subscapularis, the hook is passed into and through the tendon (Fig. 12a). As this is an oblique line of passage through the tendon, it often starts approximately 1.5 cm medially on the anterior side and can exit approximately 2 cm medially on the posterior side of the subscapularis tendon, for example. A #0 Prolene suture (Ethicon, Somerville, NJ) is shuttled through the device into the joint and retrieved through the lateral portal cannula, which has the limb of suture from the anchor. Outside the cannula, a half-hitch is tied in the Prolene creating a loop and the anchor suture limb is secured in the tightened loop. The hook device is withdrawn from the anterior cannula and the first suture limb is shuttled through the tendon (Fig. 12b). The second limb from the first anchor, from the second suture, is now passed through the tendon with the same steps (Fig. 12c).

We prefer to tie the sutures from the first anchor at this point, which simplifies suture management and does not compromise subsequent steps. Both limbs of the second suture are retrieved through the lateral portal cannula to leave the first suture pair in the anterior cannula for tying (Fig. 12d). The arm is placed in neutral or slight IR, and the traction suture is tensioned to translate the subscapularis tendon toward the anchor position. The arthroscope in the posterior portal is advanced further into the joint anteriorly to view the knot-tying steps. The limbs of the first suture are tied in the surgeon's preferred manner with the medial limb as the post. The knot is advanced down the cannula onto the tendon and secured. A sliding-locking knot is preferred for a secure loop, with three alternating half-hitches for knot security. The suture limbs are trimmed, and the second suture pair is retrieved back into the anterior cannula and tied in a similar manner (Figs 12e and 12f). The two knots can be viewed via the anterior cannula to assess knot placement, tendon indentation and suture spread. The traction suture is usually removed at this point.

The second anchor is inserted into the superior portion of the lesser tuberosity, and as laterally as possible. The
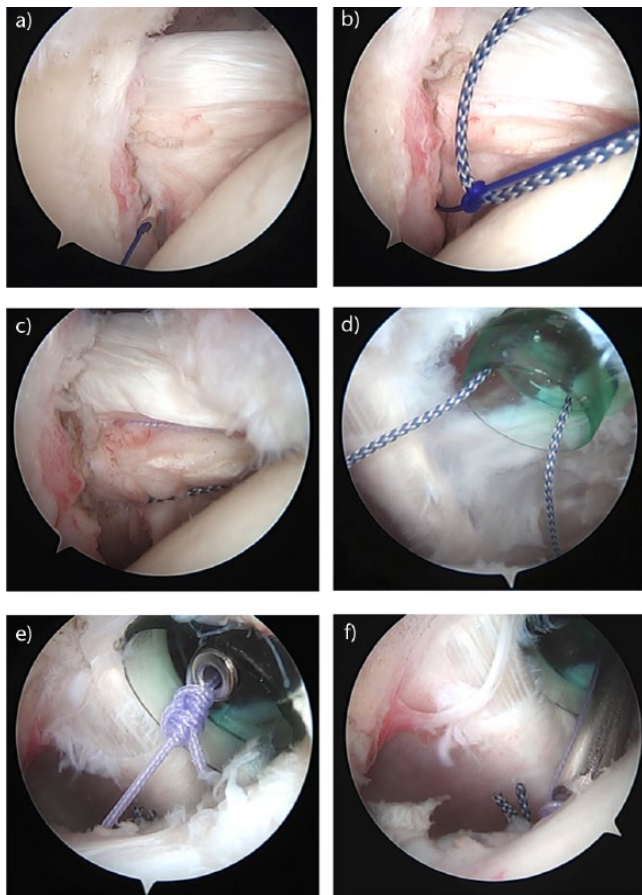
Fig. 12 Suture passing, management and knot tying in an arthroscopic subscapularis repair in a right shoulder: a) using a suture-shuttling device inserted in the anterior cannula, the inferior portion of the subscapularis tendon is pierced and a #0 Prolene is shuttled into the joint to be retrieved laterally; b) the medial limb of the anchor suture is also in the lateral portal and is shuttled through the tendon by a loop in the Prolene stitch as the hook device is withdrawn anteriorly; c) the solid blue and violet suture limbs can now both be seen passing through the tendon; d) both limbs of the first suture are in the anterior cannula for knot tying; e) a sliding-locking knot of the second suture is advanced; f) with the medial limb as the post, the knot is secured onto the tendon by the knot pusher.

same steps as for the first anchor and sutures are followed, including some ER for anchor insertion and some IR for knot tying. There are circumstances where the sutures from the second anchor are passed in a horizontal mattress fashion, based on the tear configuration and repair. If this is chosen, the second, more lateral, limb of a suture is passed through the lateral aspect of the subscapularis tendon maintaining an approximately 1.5 cm soft-tissue bridge between the medial and lateral suture limb passes. Knot tying is carried out in the same manner described above.

The completed subscapularis repair is viewed to insure a complete secure repair (Fig. 13). With the arthroscope
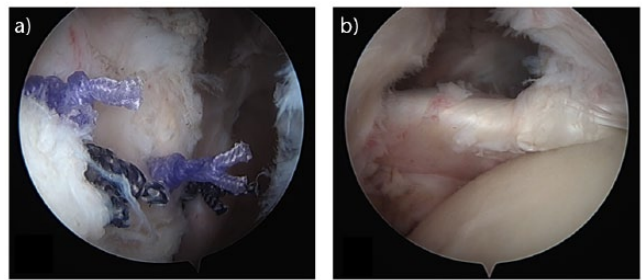

Fig. 13 a) Arthroscopic image of a typical repair of the subscapularis, showing the anterior surface viewed from the lateral portal in a right shoulder; b) arthroscopic image of the subscapularis tendon showing the repair in external rotation, viewed from the posterior portal.

in the posterior portal and the arm in a neutral position, the arm is then externally rotated to assess the stability of the repair. If the forearm externally rotates past 50 degrees, this is noted for the post-operative rehabilitation limits. The next steps to finish the procedure include repair of any posterior superior component of the tear and any other related steps. These are beyond the scope of this paper.

Post-operative management

The patient is discharged on the same day after recovering from anaesthesia. The extremity is kept in a sling with no ROM to the shoulder. Cryotherapy is initiated in the immediate post-operative period. Wrist and hand active ROM are allowed immediately, and elbow movement is allowed unless the biceps has been addressed. Shoulder extension is avoided with support under the elbow. The outpatient physical therapy protocol is influenced by the tendon and bone quality, the degree of tendon involvement, the repair security and the patient's medical comorbidities as the major considerations. When combined pathology with posterosuperior cuff repair, we follow our subscapularis protocol when a small to medium posterosuperior component is involved. When the posterosuperior component is large or massive, this aspect of the repair will tend to dictate the rehabilitation protocol.

Typically, with full-thickness tears of the entire subscapularis tendon insertion, ROM is delayed until six weeks post-operatively, with only pendulums and table slides initiated at the fourth week post-operatively. After six weeks, gentle pain-free forward elevation and ER are initiated in the supine position. At eight to nine weeks post-operatively, progression of ROM to the sitting and standing positions is begun. Active ROM in IR is initiated at nine weeks; strengthening of the scapula and posterior shoulder is initiated at ten weeks with strengthening in IR delayed until 12 weeks post-operatively. Patients with a

sedentary job can return to work in a sling within a week or two weeks from surgery, while those with manual labour jobs are allowed to return to work light duty by approximately 16 weeks. At six months post-operatively, most patients are allowed to return to work without restriction, and to return to sports involving the upper extremity when possible.

Complete rehabilitation protocols for tears of 50% and 100% of the subscapularis tendon length can be found as supplementary material.

Outcomes

The first successful open repair of the subscapularis was reported by Hauser in 1954.[3] The largest subsequent case series was that of 16 patients with isolated tears of the subscapularis who underwent successful open repair via a transosseous technique.[6] Several series of successful open repairs were reported.[22,45] Burkhart and Tehrany[8] published the first series of arthroscopic repair of the subscapularis. A total of 25 patients with partial or complete tears underwent consecutive arthroscopic repair. At short-term follow-up, good to excellent results were found in 92% of patients based on UCLA scoring. Half of the patients had biceps tendon pathology, and were treated with debridement, tenotomy or tenodesis. Bennett[46] reported on two separate case series, one being 35 patients with arthroscopic repair of combined subscapularis and supraspinatus tendon tears at minimum two-year follow-up, and the second being a small series of eight patients with isolated tears of the subscapularis.[47] In both studies, American Shoulder and Elbow Surgeons and Constant scores significantly improved with repair. Biceps tenotomy or tenodesis were not routinely performed, as the author believed that repair of the subscapularis tendon along with reconstruction of the medial wall of the bicipital sheath with the coracohumeral ligament could restore biceps function. The subscapularis tendon was repaired with one or two fixation devices and involved simple or mattress suture configurations, the latter for repair of the inferior portion.

Several more recent series of arthroscopic repairs of isolated subscapularis tears[31,48-51] and combined repairs of the subscapularis with supraspinatus[32,36,52-60] have shown comparable results. Re-tearing of the tendon reported via MR imaging or CT arthrography ranges from 8% to 35%, with multi-tendon tears, higher patient age, tear size and tear retraction correlating with recurrent tearing.[31,48,50,51,56-60] Identification and treatment of biceps pathology is not consistently reported in these studies. Thus, the impact of biceps tenotomy or tenodesis remains unclear.

The largest long-term series of 79 patients showed good to excellent results in 83.3% of cases at 104.7 months average follow-up after arthroscopic repair.[54]

There are reports of double-row suture-bridge constructs and transosseous-equivalents; however, a significant improvement in outcomes scores or failure rate over traditional single row repair has yet to be shown.[59]

Conclusions

When a subscapularis tendon tear is suspected, surgeons should carefully assess patients on physical examination with specific tests, thoroughly evaluate pre-operative MR imaging and fully inspect the subscapularis during arthroscopy. With increasing identification of tears of the subscapularis, knowledge of repair techniques is paramount to restoring anatomy and returning function. The results of recent studies confirm that successful arthroscopic repair of the tendon can lead to an improvement in patient outcomes, shoulder movement and strength, as well as a reduction in pain. We recommend arthroscopic single-row repair with one anchor for tears less than half the length of the tendon, and two anchors for tears greater than half the length. We also recommend treating concomitant biceps pathology with tenotomy or tenodesis individualised per patient, although the impact of treatment of the biceps pathology has yet to be determined. The advantage of one specific repair technique over another has not yet been demonstrated. Further prospective comparative studies are needed.

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