Literature Review of Subscapularis Tear, Associated injuries, and the Available Treatment Options

Daniel B. Goldberg MD; Trent M. Tamate MD; Morgan Hasegawa MD;
Thomas J.K. Kane IV MD; Jae S. You MD; Scott N. Crawford MD

Abstract

The population of Hawai'i is uniquely connected to the Ocean and to open water sports. Shoulder injuries, particularly those to the rotator cuff, are among the most common injuries sustained to athletes participating in ocean sports such as surfing, paddling, and swimming. In addition, rotator cuff injuries increase in prevalence with advanced age. As a consequence, the number of patients in Hawai'i who present with an injury to the subscapularis tendon will continue to rise. However, limited research has been done to delineate the involvement of subscapularis injuries in this population. This article covers the anatomy and function of the subscapularis, the epidemiology and classification of tears in this tendon, and the management of tears. The anatomy section will cover innervation, vascular supply and insertional anatomy of the subscapularis tendon. The function of the subscapularis in regards to both stability and motion of the glenohumeral joint will be examined. The focus of the article will then shift to the tears of the subscapularis, starting with an in depth look at the epidemiology and classification of these tears. The article will then cover the different imaging modalities and their utility in regards to subscapularis tears. Finally, the operative and non-operative management and indications for each modality will be discussed in detail.

Keywords

Subscapularis, Rotator cuff, Rotator cable, comma tissue, shoulder, glenohumeral

Abbreviations

MRI = Magnetic Resonance Imaging
SS = Subscapularis

Introduction

The population of Hawai'i is uniquely connected to the Ocean and to open water sports. Hawai'i has the second most surfers per capita of any state and Stand-up Paddling, Out-rigger canoeing and swimming are also popular sports among the residents of Hawai'i. Among surfers, paddlers and swimmers shoulder injuries and particularly those to the rotator cuff are among the most common injuries sustained. However, despite the fact these sports rely heavily on shoulder internal rotation strength, little research has been done to delineate the involvement of subscapularis injuries in this population. The purpose of this article is to review the available research on subscapularis tears and treatment with the aim of bringing awareness to this pathology in Hawai'i's sporting demographic.

Methods

Prior to conducting a literature search, inclusion and exclusion criteria were determined. Inclusion criteria included primary research articles, review, systematic reviews, and meta-analysis investigating subscapularis anatomy, tears, and associated pathology. We included studies whose study-population was limited to adult patients, defined by ages of 18 years old or greater. Epidemiologic, anatomic, imaging, operative techniques, and clinical outcome information was attained from these studies. Any series including patients less than 18-years old were excluded.

Literature Search

Literature search was carried out in May 2021 utilizing two different online databases: PubMed and Google Scholar, for all studies published in the English language in the past 20 years. Search was carried out using key terms: *subscapularis, subscapularis anatomy, subscapularis tear, subscapularis tear treatment, subscapularis treatment outcomes* and *subscapularis associated pathology.*

Content Abstraction

Five reviewers (DBG, TT, MH, JY, and SNC) independently reviewed studies returned from the initial database search, and articles were included or excluded based on the previously described criteria. These same reviewers then performed the subsequent data extraction that included epidemiology, anatomy, imaging, operative techniques, and clinical outcomes. A total of 58 articles were included in this review.

Epidemiology and Classification

Epidemiology

Rotator cuff tears are one of the most common forms of shoulder pathology, with increasing prevalence as individuals age.[1-3] Studies have suggested 25% to 30% of adults over age 60 have a rotator cuff tear, and for adults over 80 this percentage is as high as 62%.[2,3] The prevalence of rotator cuff tears in patients undergoing operative shoulder procedures is higher than the general population and has been estimated at 31.4% - 59%.[4-8] It has been estimated that 27.4% of rotator cuff tears will include a subscapularis tear, but isolated subscapularis tears are much

less common, comprising only 6.4% - 10% of all rotator cuff tears.[4,9,10]

Subscapularis tendon tears more commonly occur with additional rotator cuff or biceps pathology. The most common shoulder pathology associated with subscapularis tears is concomitant biceps pathology. Prior studies have suggested between 20% and 90% of subscapularis tears are accompanied by biceps pathology, including biceps subluxation, fraying, tears, and biceps pulley disruption.[4,11-15] Another commonly associated pathology is the "anterosuperior" rotator cuff tear, a term coined by Warner, et al, to describe a anterior supraspinatus tear with extension involving the superior border subscapularis tendon.[16] Prevalence of this combined tear is between 9.3% and 44.4%.[4,10,15-18] This anteroposterior tear is overall less common than a combined infraspinatus and supraspinatus tear, often referred to as a "posterosuperior" rotator cuff tear.[8,16,18] Literature concerning combined subscapularis and infraspinatus tears is sparse. In a study by Warner, et al, 14 out of 407 patients with operatively managed rotator cuff tears had combined subscapularis and infraspinatus tears.[16] In a study by Zehetgruber, et al, 0 of 332 patients with rotator cuff tears had a combined infraspinatus and subscapularis tear without other rotator cuff tendon involvement.[19] Rotator cuff tears involving the subscapularis and infraspinatus are more commonly accompanied by additional rotator cuff pathology.[20,21]

Classification

There are numerous classification systems available for tears of the subscapularis, however authors have continued to debate their reliability and utility. The 2 most frequently used classification system are the Lafosse[10] and Lyons[23] systems. In the Lafosse classification system, tears are divided into 5 types. Type I tears are partial lesions of the upper one-third of the tendon, Type II tears are complete lesions of the superior one-third of the tendon, Type III tears include the superior two-thirds of the tendon. Types IV and V both represent complete tears of the tendon, with Type V being differentiated by having greater than Goutallier Stage III fatty degeneration.[22] Type V tears also include anterior subluxation of the humerus with subcoracoid impingent.

In the Lyons classification system, tears are broken down into 4 types. Type I tear is a partial-thickness and partial-length tear, Type II is a partial-thickness and full-length tear, Type III is full thickness and full-length, but without retraction and Type 4 is a full thickness and full-length tear with retraction. Thirty-two of the fellowship-trained members of the Multicenter Orthopaedic Outcomes Network (MOON) Shoulder group were surveyed in an attempt to determine the interobserver reliability of these 2 classification systems based on MRI and intra-operative imaging.[23] Interobserver reliability was shown to be poor based on MRI and fair based on arthroscopic images. One major weakness of the study identified by the authors, is that surgeons were required to make their assessments based on still images alone and reliability may be improved if surgeons had the ability to dynamically assess the tissue.

Diagnosis

History

As with posterior cuff tears, subscapularis tears occur far more commonly due to gradual degeneration than a traumatic rupture.[18] As such the patient may not provide a history of a clear inciting event. However, when traumatic tear occurs, it is commonly due to a hyperextension and external rotation mechanism.[24] Subscapularis tears have also been shown to be associated with anterior glenohumeral dislocation.[25,26] While patients may complain of pain in the anterior aspect of the shoulder, this pain is not specific for subscapularis pathology and can also be generated from the bicep, acromioclavicular joint or a superior-labrum-anterior-posterior (SLAP) type lesion. Complaints of weakness with activities that require internal rotation, such as tucking in the back of a shirt or buckling a bra strap, may be more specific to subscapularis pathology.[27]

Physical Exam

The belly-press and lift-off tests are the 2 most frequently utilized tests to assess for tears of the subscapularis tendon. Both tests were described by Gerber and colleagues in 1991 and 1994 respectively. The lift-off test is performed by placing the hand of the affected shoulder on the back, at the mid-lumbar spine, and asking the patient to internally rotate the shoulder to lift the hand away from the back. The test is considered positive if the patient is unable to lift the hand away from the back in this position. The belly-press test is performed with the arm maximally adducted to the side and the elbow flexed at 90°. The patient is asked to hold the palm of the affected arm against their belly and resists, with an internal rotation force, as the examiner attempts to lift the hand away from the patient's body. The test is considered positive if the patient demonstrates weakness compared to the contralateral side. These 2 tests were later studied using electromyography and it was noted that the belly-press test led to activation of the upper portion of the subscapularis, whereas the lift off test activated the lower portion of the muscle.[28] The results of this study led to the development of the theory that a more anterior position of the elbow resulted in increased activation of the upper portion of the subscapularis.

This theory led to the development of the bear-hug test.[7] The bear-hug test is performed with the shoulder flexed forward to 90-degrees, moving the elbow as anteriorly as possible. The hand is placed on the contralateral shoulder and the patient attempts to resist the examiner lifting the patients hand. The test is considered positive if the patient cannot maintain the hand against the contralateral shoulder. In the original study

describing the bear-hug examination, the authors noted this exam maneuver to be more sensitive (60%) than the belly-press or (40%), or lift-off test (17.6%).[29] The lift-off test (100%) was more specific than the belly-press (97.9%) or bear-hug test (91.7%).[7] A separate article evaluating the clinical efficacy of these tests found the belly-press (56.8%) to be more sensitive than the bear-hug (18.8%) or the lift-off test (35.1%), while the lift off test remained the most specific (96.9%).[29] It is logical that clinical tests designed to evaluate the upper portion of subscapularis tendon would be more sensitive, as tears of this tendon routinely propagate from the upper border.

Imaging

Radiographs should be obtained as part of the initial workup of shoulder pain. Indirect signs of subscapularis tendon pathology on x-ray may include lesser tuberosity irregularities or anterior subluxation on an axillary view, and evidence of diminished sub-coracoid space on a scapular-Y view.[30,31] CT scan is rarely utilized for evaluation of subscapularis tears as Magnetic resonance imaging (MRI) has largely replaced it as the modality of choice for evaluation of rotator cuff tears. CT scans, with or without arthrogram may be used for evaluation of rotator cuff tears and fatty muscular degeneration in those with MRI contraindications, with reported sensitivity and specificity of 65% - 85% and 98% - 100% respectively.[32-35] Ultrasound has become a popular modality for testing rotator cuff pathology, in part because it allows for dynamic testing. However, ultrasound is less reliable at identifying tears of the subscapularis compared to tears of the superior cuff due to interference from surrounding anatomic structures. It has a preoperative sensitivity of 12.5%-16% and specificity of 93-97% in the diagnosis of subscapularis tears.[9,21,36] Additional drawbacks include user dependent variability, the inability to detect partial thickness tears, and moderate interobserver reliability.[9, 37-39]

MRI has largely become the modality of choice for evaluation of rotator cuff tears. As with ultrasound, MRI's ability to detect subscapular tendon tears is lower than in other rotator cuff tendons.[32,38] Sensitivities and specificities range from 36%-88% and 90%-100% respectively.[13, 34, 40] Malovolta, et al, included 14 articles in a systematic review assessing the accuracy of MRI for subscapularis tears, and found overall sensitivity was 68% and specificity was 90%, with lower sensitivity and specificity for partial tears.[41] They concluded that while MRI may be an accurate method, it appears to have lower accuracy in comparison with other rotator cuff tears.[41] In an effort to address the perceived inferiority of MRI in detecting subscapularis tears, some authors have advocated for a systematic reading approaches or utilization of alternate MRI views, which demonstrated improved sensitivity and specificity compared to prior literature.[6,13,21,43] Pfirmann, et al, utilized particular findings such as leakage of contrast under the subscapularis tendon, presence of subscapularis fatty infiltration and biceps abnormalities, while Adams, et al, developed a system of imaging evaluation including evaluating axial T2-weighted images, presence of biceps subluxation, fatty infiltration and atrophy of the muscle, and presence of tears on a sagittal oblique view.[36,21] Other authors have suggested alternative MRI techniques which allow for optimal body positioning of patients and may enhance radiographic detection of tears.[38]

Treatment

Non-operative Management

Unfortunately, there is limited evidence available to guide treatment due to the frequent occurrence of concomitant pathology and a dearth of well-designed randomized controlled trials. Nonoperative management of subscapularis tendon tears is similar to that involving other parts of the rotator cuff. Options include activity modification, analgesics and anti-inflammatories, corticosteroid injections, and physical therapy. Indications for surgical versus nonsurgical treatment also mirror that of the posterosuperior cuff. Older, less active patients with chronic degenerative tears are generally considered candidates for conservative treatment. In comparison, acute traumatic tears may benefit from surgical repair in order to prevent tear progression, tendon retraction, and muscle atrophy.[27] Failure of attempted nonoperative management is an indication for surgery.

Treatment in the presence of advanced fatty degeneration remain controversial. Traditionally, rotator cuff tears with advanced fatty degeneration are considered poor candidates for repair. A retrospective review of 52 patients with isolated full-thickness subscapularis tears and Grade 3 or 4 Goutallier fatty degeneration found no difference in pain and functional outcome scores at 2-years when comparing nonoperative and operative management.[43] A 78.6% retear rate was seen in the surgically treated group. The surgical group had worse baseline scores and experienced greater improvement than the nonsurgical group, however, this may have been due to concomitant tenotomy or tenodesis of the biceps. Of note, no evidence of tear progression into the supraspinatus was seen in either group. Advocates of surgical repair argue that it restores the role of the subscapularis in anterior restraint of the humeral head through tenodesis, even without intact contractile function.[44] Contraindications to surgical repair include medical comorbidities that preclude surgery and the presence of glenohumeral arthropathy.

Operative Evaluation and Management

Similar to their results when assessing interobserver reliability of tear classification, Smucny, et al, showed only fair interobserver reliability when determining surgery versus no surgery for subscapularis tears based on either MRI or arthroscopic images.[23] Arthroscopic evaluation remains the gold standard for diagnosis of subscapularis pathology. The standard posterior viewing portal is used to visualize the integrity of the subscapularis, footprint, biceps sling, and quality of the long head of the biceps tendon.

The articular surface of the subscapularis tendon can be more readily assessed by arthroscopy, and partial tears can be identified. The biceps tendon can be evaluated for medial subluxation or evidence of tendinopathy, including fraying, at the level of the sling. A bare area over the subscapularis footprint on the lesser tuberosity can indicate an occult, partial articular sided tear.[23] Techniques to further improve visualization have been described. Use of a 70-degree arthroscope can provide views around the anterior aspect of the humeral head. The "posterior lever push," as described by Burkhart, can increase visualization in the subcoracoid space by 5 mm - 10 mm.[45] In the lateral decubitus position, this is accomplished by an assistant pushing the proximal humerus posteriorly while simultaneously applying an anterior pressure on the distal humerus.

Arthroscopic repair of subscapularis tears can be challenging given the difficulties with obtaining adequate visualization and instrumentation. Intraoperatively, subscapularis repair should be performed prior to other procedures due to the risk of fluid extravasation and swelling, which can compress the subcoracoid space. Proper portal placement is crucial. The standard posterior portal is used for viewing. An anterosuperolateral portal is placed just off of the anterolateral tip of the acromion, angled 5 to 10 degrees towards the lesser tuberosity. The relatively parallel orientation of this portal in relation to the subscapularis allows it to be used as the primary working portal for tendon mobilization and suture passage. The standard anterior portal is made slightly more medial, just lateral to the tip of the coracoid. It's angled 30 to 45 degrees towards the lesser tuberosity and is used for suture anchor placement.[45]

In the setting of a retracted tear, the "comma sign" is used to locate the leading edge of subscapularis tendon. It is an arc of tissue in the shape of a comma, which represents the avulsed medial sling of the biceps, specifically the fibers of the coracohumeral and superior glenohumeral ligaments, as it attaches to the superolateral border of the torn subscapularis.[45]

Associated procedures include biceps tenotomy/tenodesis and coracoplasty. Failure to address an unstable long head of the biceps tendon can stress the subsequent subscapularis repair. In addition, biceps tenotomy/tenodesis removes a possible pain generator and can improve functional outcomes when incorporated with subscapularis repair.[46] Biceps tenodesis can be combined with the subscapularis repair to improve efficiency and cost savings. This can be accomplished either through simultaneous suture passage through both tendons or separate suture passage secured through the same suture anchor.[47] The resulting construct provides secure tenodesis of the biceps at the superior-lateral border of the subscapularis footprint.

Coracoplasty has been recommended to decompress the subcoracoid space and prevent abrasion by the coracoid tip on the subscapularis repair. In this procedure, 2 mm - 10 mm of tissue is burred off of the tip of the coracoid.[45,48,49] However, recent studies have called the necessity of coracoplasty into question. A study of 62 patients with isolated full-thickness subscapularis tears repaired in single-row fashion compared 2-year outcomes with or without coracoplasty. The study found no differences in pain, functional outcomes, strength, range of motion, or retear rates. It was theorized that a shorter coracohumeral distance may be the result of anterior translation of the humeral head following a subscapularis tear, and not the cause.[48] Even in the presence of subscapularis fraying just posterior to the coracoid, concurrent coracoplasty was not found to produce differences in clinical outcomes.[49]

Mobilization of the subscapularis tendon is necessary for a tension-free repair. A window is created in the rotator interval above the upper border of the subscapularis in order to increase visualization and ease suture passage. Skeletonization of the posterolateral coracoid to the level of the coracoid neck further improves tendon mobilization. Suture placement just medial to the junction between the "comma" and the upper border of the subscapularis utilizes the vertically oriented fibers of the "comma" as a lateral rip-stop.[45] In cases of chronic tears that cannot be reduced to the native footprint, the subscapularis can be medialized up to 5 mm to avoid excess tension. Due to native retroversion of the humeral head, it is often necessary for the surgeon to position their hand close to the patient's jaw when preparing the anchor insertion site.[50]

Recommendations for the number of suture anchors required varies, however, it is generally accepted that 1 anchor is needed for each centimeter or tear length in the superior-inferior direction. This roughly translates to 1 anchor for tears < 50%, and 2 anchors for tears > 50%. The superolateral edge of the subscapularis, referred to as the "leading edge," is especially important to address. It is thought of as the initial tear site with progression heading inferiorly and serves as the anterior attachment of the rotator cable, decreasing stress on the adjacent supraspinatus.[51] Repair of tears involving this area of the subscapularis can be addressed in multiple ways. Single anchor fixation has demonstrated sufficient biomechanical strength[52] and significant improvements in functional outcomes.[50] Addition of a second anchor placed superolaterally near the entrance of the bicipital groove has demonstrated increased footprint coverage.[53]

The argument of single versus double-row fixation reflects that of repairs involving the posterosuperior cuff. Biomechanical studies confirm the superiority of double-row repair with regards to ultimate load to failure and construct stiffness specifically in the subscapularis tendon.[54] Double-row repair also provides better footprint coverage at the expense of increased time and added implant costs. Single-row repair is the only option for tendons not mobile enough to allow double-row fixation. Studies evaluating outcomes between single and double-row fixation for isolated tears of the subscapularis have been mixed. In a retrospective review of isolated full-thickness subscapularis tears with Grade 2 fatty infiltration or less, no difference was

seen in pain, function or retear rates between those treated with single versus double-row fixation.[55] In comparison, a descriptive analysis incorporating 8 studies with 115 patients with isolated subscapularis tears found greater improvement in Constant scores and lower retear rates in the studies that performed double-row fixation.[56]

Recent studies show arthroscopic repair has become more commonplace. While an arthroscopic approach offers the advantages of smaller incisions with less soft tissue trauma, as well as a view of the articular side of the subscapularis tendon, it can be difficult to establish proper visualization and instrumentation. A comparison of open versus arthroscopic repair of isolated subscapularis tears found minimal differences between the techniques.[57] It included 9 case series with a total of 216 patients with minimum 1-year follow-up. Constant scores and healing rates were consistent between groups. Pain scores were slightly lower in the arthroscopically repaired group, however, statistical significance could not be determined given the limited data available.

In the event of a massive irreparable tear, tendon transfer, most commonly of the pectoralis major, is an option. This procedure is indicated for young, active patients with an intact or reparable posterosuperior cuff and no glenohumeral arthropathy. Tendon transfer may help to rebalance the forces acting on the humeral head. Improved patient reported outcome scores, range of motion and strength in forward flexion, abduction and internal rotation have been seen when pectoralis major tendon transfer is performed in the setting of irreparable isolated subscapularis tears.[58] Decreased external rotation motion has been noted. Good outcomes were also achieved in patients with multiple tendon involvement as long as the other injured tendons were able to be repaired. The worst outcomes with tendon transfer are in shoulder arthroplasty patients and those with anterior instability, as the pectoralis major does not exactly replicate the force vector of the native subscapularis.

Conflict of Interest

None of the authors identify a conflict of interest.

Authors' Affiliations:
- Department of Orthopedic Surgery, John A. Burns School of Medicine, University of Hawai'i, Honolulu, HI (DBG, TMT, MH, TJKK, SNC)
- Department of Orthopedics, Straub Clinic & Hospital, Honolulu, HI (JSY, SNC)

Corresponding Author:
Scott N. Crawford MD; 888 South King St., Honolulu, HI 96813;
Email: crawford.sn@gmail.com

References

1. Urwin M, Symmons D, Allison T, et al. Estimating the burden of musculoskeletal disorders in the community: the comparative prevalence of symptoms at different anatomical sites, and the relation to social deprivation. *Ann Rheum Dis*. Nov 1998;57(11):649-55. doi:10.1136/ard.57.11.649
2. Dang A, Davies M. Rotator Cuff Disease: Treatment Options and Considerations. *Sports Med Arthrosc Rev*. Sep 2018;26(3):129-133. doi:10.1097/JSA.0000000000000207
3. Tashjian RZ. Epidemiology, natural history, and indications for treatment of rotator cuff tears. *Clin Sports Med*. Oct 2012;31(4):589-604. doi:10.1016/j.csm.2012.07.001
4. Arai R, Sugaya H, Mochizuki T, Nimura A, Moriishi J, Akita K. Subscapularis tendon tear: an anatomic and clinical investigation. *Arthroscopy*. Sep 2008;24(9):997-1004. doi:10.1016/j.arthro.2008.04.076
5. Bennett WF. Subscapularis, medial, and lateral head coracohumeral ligament insertion anatomy. Arthroscopic appearance and incidence of "hidden" rotator interval lesions. *Arthroscopy*. Feb 2001;17(2):173-80. doi:10.1053/jars.2001.21239
6. Furukawa R, Morihara T, Arai Y, et al. Diagnostic accuracy of magnetic resonance imaging for subscapularis tendon tears using radial-slice magnetic resonance images. *J Shoulder Elbow Surg*. Nov 2014;23(11):e283-90. doi:10.1016/j.jse.2014.03.011
7. Barth JR, Burkhart SS, De Beer JF. The bear-hug test: a new and sensitive test for diagnosing a subscapularis tear. *Arthroscopy*. Oct 2006;22(10):1076-84. doi:10.1016/j.arthro.2006.05.005
8. Bennett WF. Arthroscopic repair of anterosuperior (supraspinatus/subscapularis) rotator cuff tears: a prospective cohort with 2- to 4-year follow-up. Classification of biceps subluxation/instability. *Arthroscopy*. Jan 2003;19(1):21-33. doi:10.1053/jars.2003.50023
9. Narasimhan R, Shamse K, Nash C, Dhingra D, Kennedy S. Prevalence of subscapularis tears and accuracy of shoulder ultrasound in pre-operative diagnosis. *Int Orthop*. May 2016;40(5):975-9. doi:10.1007/s00264-015-3043-9
10. Lafosse L, Jost B, Reiland Y, Audebert S, Toussaint B, Gobezie R. Structural integrity and clinical outcomes after arthroscopic repair of isolated subscapularis tears. *J Bone Joint Surg Am*. Jun 2007;89(6):1184-93. doi:10.2106/JBJS.F.00007
11. Deutsch A, Altchek DW, Veltri DM, Potter HG, Warren RF. Traumatic tears of the subscapularis tendon. Clinical diagnosis, magnetic resonance imaging findings, and operative treatment. *Am J Sports Med*. 1997 Jan-Feb 1997;25(1):13-22. doi:10.1177/036354659702500104
12. Grueninger P, Nikolic N, Schneider J, et al. Arthroscopic repair of traumatic isolated subscapularis tendon lesions (Lafosse Type III or IV): a prospective magnetic resonance imaging-controlled case series with 1 year of follow-up. *Arthroscopy*. Jun 2014;30(6):665-72. doi:10.1016/j.arthro.2014.02.030
13. Adams CR, Schoolfield JD, Burkhart SS. Accuracy of preoperative magnetic resonance imaging in predicting a subscapularis tendon tear based on arthroscopy. *Arthroscopy*. Nov 2010;26(11):1427-33. doi:10.1016/j.arthro.2010.02.028
14. Godenèche A, Nové-Josserand L, Audebert S, et al. Relationship between subscapularis tears and injuries to the biceps pulley. *Knee Surg Sports Traumatol Arthrosc*. Jul 2017;25(7):2114-2120. doi:10.1007/s00167-016-4374-9
15. Sakurai G, Ozaki J, Tomita Y, Kondo T, Tamai S. Incomplete tears of the subscapularis tendon associated with tears of the supraspinatus tendon: cadaveric and clinical studies. *J Shoulder Elbow Surg*. 1998 Sep-Oct 1998;7(5):510-5. doi:10.1016/s1058-2746(98)90204-x
16. Warner JJ, Higgins L, Parsons IM, Dowdy P. Diagnosis and treatment of anterosuperior rotator cuff tears. *J Shoulder Elbow Surg*. 2001 Jan-Feb 2001;10(1):37-46. doi:10.1067/mse.2001.112022
17. Kim SH, Ha KI, Cho YB, Ryu BD, Oh I. Arthroscopic anterior stabilization of the shoulder: two to six-year follow-up. *J Bone Joint Surg Am*. Aug 2003;85(8):1511-8.
18. Nové-Josserand L, Collin P, Godenèche A, et al. Ten-year clinical and anatomic follow-up after repair of anterosuperior rotator cuff tears: influence of the subscapularis. *J Shoulder Elbow Surg*. Oct 2017;26(10):1826-1833. doi:10.1016/j.jse.2017.03.037
19. Zehetgruber H, Lang T, Wurnig C. Distinction between supraspinatus, infraspinatus and subscapularis tendon tears with ultrasound in 332 surgically confirmed cases. *Ultrasound Med Biol*. Jun 2002;28(6):711-7. doi:10.1016/s0301-5629(02)00508-2
20. Ide J, Tokiyoshi A, Hirose J, Mizuta H. Arthroscopic repair of traumatic combined rotator cuff tears involving the subscapularis tendon. *J Bone Joint Surg Am*. Nov 2007;89(11):2378-88. doi:10.2106/JBJS.G.00082
21. Adams CR, Brady PC, Koo SS, et al. A systematic approach for diagnosing subscapularis tendon tears with preoperative magnetic resonance imaging scans. *Arthroscopy*. Nov 2012;28(11):1592-600. doi:10.1016/j.arthro.2012.04.142
22. Goutallier D, Postel JM, Bernageau J, Lavau L, Voisin MC. Fatty muscle degeneration in cuff ruptures. Pre- and postoperative evaluation by CT scan. *Clin Orthop Relat Res*. Jul 1994;(304):78-83.
23. Smucny M, Shin EC, Zhang AL, et al. Poor Agreement on Classification and Treatment of Subscapularis Tendon Tears. *Arthroscopy*. Feb 2016;32(2):246-51.e1. doi:10.1016/j.arthro.2015.08.006
24. Hennrikus WL, Mapes RC, Lyons PM, Lapoint JM. Outcomes of the Chrisman-Snook and modified-Broström procedures for chronic lateral ankle instability. A prospective, randomized comparison. *Am J Sports Med*. 1996 Jul-Aug 1996;24(4):400-4. doi:10.1177/036354659602400402
25. Neviaser RJ, Neviaser TJ. Recurrent instability of the shoulder after age 40. *J Shoulder Elbow Surg*. 1995 Nov-Dec 1995;4(6):416-8. doi:10.1016/s1058-2746(05)80032-1
26. Symeonides PP. The significance of the subscapularis muscle in the pathogenesis of recurrent anterior dislocation of the shoulder. *J Bone Joint Surg Br*. Aug 1972;54(3):476-83.
27. Ono Y, Sakai T, Carroll MJ, Lo IK. Tears of the Subscapularis Tendon: A Critical Analysis Review. *JBJS Rev*. Mar 2017;5(3)doi:10.2106/JBJS.RVW.16.00054
28. Tokish JM, Decker MJ, Ellis HB, Torry MR, Hawkins RJ. The belly-press test for the physical examination of the subscapularis muscle: electromyographic validation and comparison to the lift-off test. *J Shoulder Elbow Surg*. 2003 Sep-Oct 2003;12(5):427-30. doi:10.1016/s1058-2746(03)00047-8
29. Yoon JP, Chung SW, Kim SH, Oh JH. Diagnostic value of four clinical tests for the evaluation of subscapularis integrity. *J Shoulder Elbow Surg*. Sep 2013;22(9):1186-92. doi:10.1016/j.jse.2012.12.002
30. Alilet M, Behr J, Nueffer JP, Barbier-Brion B, Aubry S. Multi-modal imaging of the subscapularis muscle. *Insights Imaging*. Dec 2016;7(6):779-791. doi:10.1007/s13244-016-0526-1
31. Wissman RD, Kapur S, Akers J, Crimmins J, Ying J, Laor T. Cysts within and adjacent to the lesser tuberosity and their association with rotator cuff abnormalities. *AJR Am J Roentgenol*. Dec 2009;193(6):1603-6. doi:10.2214/AJR.09.2377

32. Lee J, Shukla DR, Sánchez-Sotelo J. Subscapularis tears: hidden and forgotten no more. *JSES Open Access*. Mar 2018;2(1):74-83. doi:10.1016/j.jses.2017.11.006
33. Charousset C, Bellaïche L, Duranthon LD, Grimberg J. Accuracy of CT arthrography in the assessment of tears of the rotator cuff. *J Bone Joint Surg Br*. Jun 2005;87(6):824-8. doi:10.1302/0301-620X.87B6.15836
34. Omoumi P, Bafort AC, Dubuc JE, Malghem J, Vande Berg BC, Lecouvet FE. Evaluation of rotator cuff tendon tears: comparison of multidetector CT arthrography and 1.5-T MR arthrography. *Radiology*. Sep 2012;264(3):812-22. doi:10.1148/radiol.12112062
35. Asmar G, Goubier JN, Falcone MO. Improving the detection of subscapularis tears using a specific transverse CT arthrography image. *Orthop Traumatol Surg Res*. Oct 2020;106(6):1107-1111. doi:10.1016/j.otsr.2020.04.016
36. Pfirrmann CW, Zanetti M, Weishaupt D, Gerber C, Hodler J. Subscapularis tendon tears: detection and grading at MR arthrography. *Radiology*. Dec 1999;213(3):709-14. doi:10.1148/radiology.213.3.r99dc03709
37. Toprak U, Türkoğlu S, Aydoğan Ç, et al. Diagnostic accuracy of ultrasound in subscapularis tendon abnormalities and the importance of operator experience. *Acta Orthop Traumatol Turc*. Jul 2020;54(4):423-429. doi:10.5152/j.aott.2020.20146
38. Ward JRN, Lotfi N, Dias RG, McBride TJ. Diagnostic difficulties in the radiological assessment of subscapularis tears. *J Orthop*. Mar 2018;15(1):99-101. doi:10.1016/j.jor.2018.01.016
39. Iyengar JJ, Burnett KR, Nottage WM, Harwin SF. The abduction external rotation (ABER) view for MRI of the shoulder. *Orthopedics*. Aug 2010;33(8):562-5. doi:10.3928/01477447-20100625-17
40. Garavaglia G, Ufenast H, Taverna E. The frequency of subscapularis tears in arthroscopic rotator cuff repairs: A retrospective study comparing magnetic resonance imaging and arthroscopic findings. *Int J Shoulder Surg*. Oct 2011;5(4):90-4. doi:10.4103/0973-6042.91000
41. Malavolta EA, Assunção JH, Gracitelli MEC, Yen TK, Bordalo-Rodrigues M, Ferreira Neto AA. Accuracy of magnetic resonance imaging (MRI) for subscapularis tear: a systematic review and meta-analysis of diagnostic studies. *Arch Orthop Trauma Surg*. May 2019;139(5):659-667. doi:10.1007/s00402-018-3095-6
42. Pfirrmann CW, Duc SR, Zanetti M, Dora C, Hodler J. MR arthrography of acetabular cartilage delamination in femoroacetabular cam impingement. *Radiology*. Oct 2008;249(1):236-41. doi:10.1148/radiol.2491080093
43. Yoon TH, Kim SJ, Choi YR, Keum HS, Chun YM. Clinical Outcomes for Isolated Subscapularis Tears With Advanced Fatty Infiltration: Nonoperative Treatment Versus Arthroscopic Single-Row Repair. *Orthop J Sports Med*. Feb 2021;9(2):2325967120975754. doi:10.1177/2325967120975754
44. Burkhart SS, Barth JR, Richards DP, Zlatkin MB, Larsen M. Arthroscopic repair of massive rotator cuff tears with stage 3 and 4 fatty degeneration. *Arthroscopy*. Apr 2007;23(4):347-54. doi:10.1016/j.arthro.2006.12.012
45. Burkhart SS, Brady PC. Arthroscopic subscapularis repair: surgical tips and pearls A to Z. *Arthroscopy*. Sep 2006;22(9):1014-27. doi:10.1016/j.arthro.2006.07.020
46. Burkhart SS, Tehrany AM. Arthroscopic subscapularis tendon repair: Technique and preliminary results. *Arthroscopy*. 2002 May-Jun 2002;18(5):454-63. doi:10.1053/jars.2002.30648
47. Fleck KE, Field LD. Consolidated Proximal Biceps Tenodesis and Subscapularis Repair. *Arthrosc Tech*. Oct 2017;6(5):e1967-e1971. doi:10.1016/j.eats.2017.07.020
48. Kim SJ, Choi YR, Jung M, Yoon YK, Chun YM. Concomitant coracoplasty during arthroscopic subscapularis repair does not yield better clinical outcomes and structural integrity. *Knee Surg Sports Traumatol Arthrosc*. Jan 2018;26(1):56-62. doi:10.1007/s00167-016-4368-7
49. Ayanoğlu T, Ataoğlu B, Özer M, Çetinkaya M, Kaptan AY, Kanatlı U. Is routine coracoplasty necessary in isolated subscapularis tears? *Eklem Hastalik Cerrahisi*. Aug 2019;30(2):112-6. doi:10.5606/ehc.2019.64710
50. Katthagen JC, Vap AR, Tahal DS, Horan MP, Millett PJ. Arthroscopic Repair of Isolated Partial- and Full-Thickness Upper Third Subscapularis Tendon Tears: Minimum 2-Year Outcomes After Single-Anchor Repair and Biceps Tenodesis. *Arthroscopy*. Jul 2017;33(7):1286-1293. doi:10.1016/j.arthro.2017.01.027
51. Denard PJ, Burkhart SS. Arthroscopic recognition and repair of the torn subscapularis tendon. *Arthrosc Tech*. 2013;2(4):e373-9. doi:10.1016/j.eats.2013.05.007
52. Lorbach O, Trennheuser C, Kieb M, Efe T, Kohn D, Anagnostakos K. Reconstruction of 25 and 50 % subscapularis tears: a single anchor with a double-mattress suture is sufficient for the reconstruction. *Knee Surg Sports Traumatol Arthrosc*. Dec 2016;24(12):3855-3862. doi:10.1007/s00167-015-3767-5
53. Dyrna F, Beitzel K, Pauzenberger L, et al. A Superolaterally Placed Anchor for Subscapularis "Leading-Edge" Refixation: A Biomechanical Study. *Arthroscopy*. 05 2019;35(5):1306-1313.e1. doi:10.1016/j.arthro.2018.11.060
54. Wellmann M, Wiebringhaus P, Lodde I, et al. Biomechanical evaluation of a single-row versus double-row repair for complete subscapularis tears. *Knee Surg Sports Traumatol Arthrosc*. Dec 2009;17(12):1477-84. doi:10.1007/s00167-009-0890-1
55. Yoon JS, Kim SJ, Choi YR, Kim SH, Chun YM. Arthroscopic Repair of the Isolated Subscapularis Full-Thickness Tear: Single- Versus Double-Row Suture-Bridge Technique. *Am J Sports Med*. 05 2019;47(6):1427-1433. doi:10.1177/0363546519838281
56. Saltzman BM, Collins MJ, Leroux T, et al. Arthroscopic Repair of Isolated Subscapularis Tears: A Systematic Review of Technique-Specific Outcomes. *Arthroscopy*. Apr 2017;33(4):849-860. doi:10.1016/j.arthro.2016.10.020
57. Mall NA, Chahal J, Heard WM, et al. Outcomes of arthroscopic and open surgical repair of isolated subscapularis tendon tears. *Arthroscopy*. Sep 2012;28(9):1306-14. doi:10.1016/j.arthro.2012.02.018
58. Nelson GN, Namdari S, Galatz L, Keener JD. Pectoralis major tendon transfer for irreparable subscapularis tears. *J Shoulder Elbow Surg*. Jun 2014;23(6):909-18. doi:10.1016/j.jse.2013.12.035