Orthopaedics & Traumatology: Surgery & Research 106 (2020) 1107–1111

Contents lists available at ScienceDirect

Orthopaedics & Traumatology: Surgery & Research

journal homepage: www.elsevier.com

Original article

Improving the detection of subscapularis tears using a specific transverse CT arthrography image

Ghada Asmar [a], Jean-Noël Goubier [a,b], Marc-Olivier Falcone [a,b,*]

[a] Ramsay Générale de Santé - Capio - Hôpital Privé Paul d'Egine, 4, avenue Marx Dormoy, 94500 Champigny-sur-Marne, France
[b] Clinique Internationale du Parc Monceau, 21, rue de Chazelles, 75017 Paris, France

ARTICLE INFO

Article history:
Received 9 December 2019
Accepted 23 April 2020

Keywords:
Subscapularis tendon tear
Subscapularis clinical tests
Subscapularis imaging
Shoulder arthroscopy
Rotator cuff repair

ABSTRACT

Background: The prevalence of subscapularis (SSC) tendon tears is often underestimated. This negatively impacts the shoulder function because the SSC muscle is a powerful internal rotator. The primary aim of this study was to compare a blended clinical and radiological preoperative index of suspicion for SSC tears to the arthroscopic findings. The secondary aim was to compare the surgeon's and radiologist's index of suspicion to determine which is more accurate.
Hypothesis: Analyzing a transverse image passing under the tip of the coracoid process, in combination with clinical examination, will be the standard for detecting SSC tears.
Methods: This prospective study enrolled 50 consecutive patients who underwent shoulder arthroscopy. Preoperatively, four clinical tests were doneto detect SSC tears: lift-off, internal rotation lag sign, bear-hug, belly-press. A CT arthrography slice passing under the coracoid process tip was analyzed by the surgeon. The surgeon deduced a radiological index of suspicion for SSC tears then a blended clinical and radiological index of suspicion based on the clinical examination. Lastly, the surgeon looked at the radiologist's findings and index of suspicion for a lesion. The three indexes of suspicion were compared with the actual arthroscopy findings.
Results: The surgeon's blended clinical and radiological index of suspicion was similar to his radiological index. Both of the surgeon's indexes of suspicion were higher than the radiologist's. The prevalence of SSC tears was 58 %.
Discussion: We recommend doing multiple clinical tests as they complement each other in detecting SSC tears, since each one activates a different portion of the muscle. We advise surgeons to supplement their clinical examination by analyzing a specific image of the tendon below the coracoid, as the reference view for the starting point of SSC tears.
Level of evidence: IV, prospective diagnostic study on consecutive patients.

1. Introduction

Subscapularis (SSC) tendon tears are known to be difficult to diagnose. Nevertheless, it is critical to repair them to maintain the anteroposterior tendon balance in the shoulder. Up to 24% of SSC tears [1] are only diagnosed at the time of surgery. Thus, it is important to find a simple and reproducible method to optimize their preoperative diagnosis.

Several clinical tests have been described for detecting SSC tears: the lift-off test [2], the belly-press test [3], the lag sign to increase the sensitivity of the lift-off test [4], the belly-off sign for partial lesions of the superior portion [5], the Napoleon sign for the extent of a SSC tear [6], and the bear-hug test for the superior portion [7]. All these tests complement each other when looking for a tear and estimating its extent [8].

While CT arthrography is recommended for detecting SSC tears when the surgeon has even the slightest clinical suspicion [9], this imaging modality does not allow every tear to be diagnosed [10]. MRI does not appear to be reliable enough when less than 50% of the tendon is torn [11]. MR arthrography (1.5 T) is not better than CT arthrography for detecting rotator cuff tears [12] and ultrasonography is not very reliable for detecting small SSC tears [13].

To optimize the preoperative diagnosis of SSC tears, our working hypothesis is that a blended clinical and radiological index of suspicion combining four clinical tests and analysis of a specific CT arthrography slice would improve SSC tear detection. More precisely, the first transverse slice under the tip of the coracoid process

* Corresponding author at: Ramsay Générale de Santé - Capio - Hôpital Privé Paul d'Egine, 4, avenue Marx Dormoy, 94500 Champigny-sur-Marne, France.
E-mail address: falcone.research@gmail.com (M.-O. Falcone).

https://doi.org/10.1016/j.otsr.2020.04.016
1877-0568/

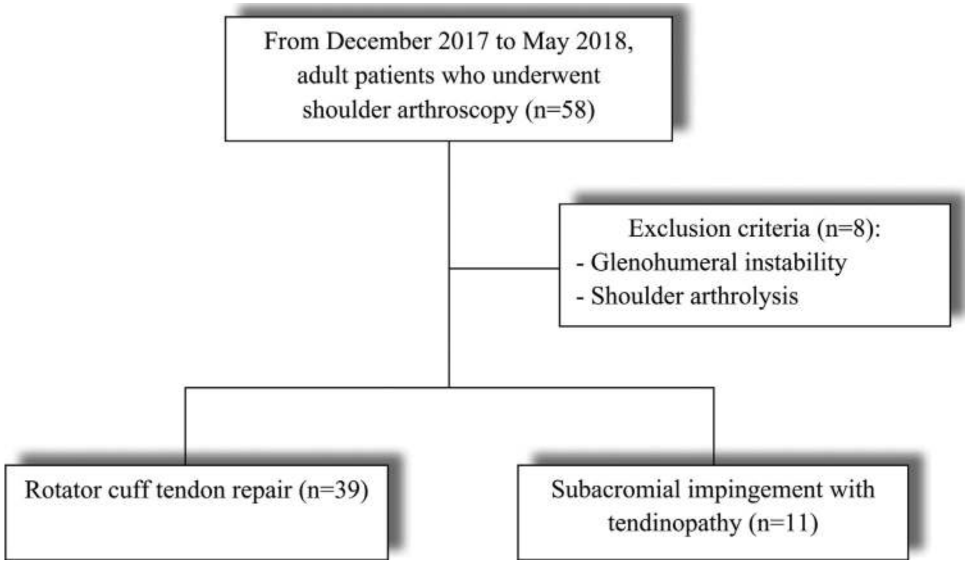

Fig. 1. Flow chart for patient inclusion over study period.

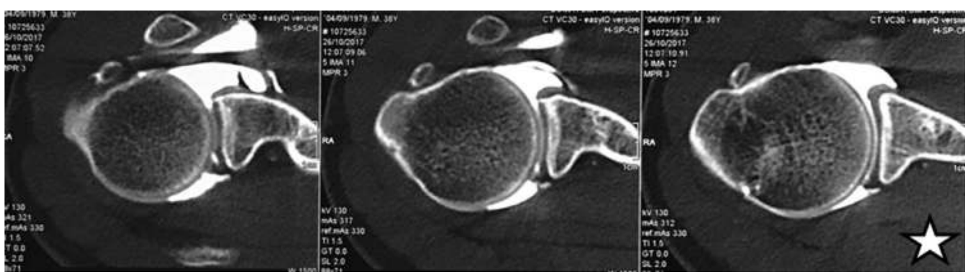

Fig. 2. Transverse CT arthrography slice showing the last millimeters of the coracoid process and absence of subscapularis tear (right shoulder). *Specific slice on upper edge of tendon.

corresponds to the upper edge of the SSC tendon, generally the starting point for tears [9].

The primary aim of this study was to compare a blended clinical and radiological preoperative index of suspicion for SSC tears to the arthroscopic findings. The secondary aim was to compare the surgeon's and radiologist's index of suspicion to determine which is more accurate preoperatively.

2. Patients and methods

2.1. Patients

This prospective study was conducted over a 6-month period. It involved consecutive adult patients who were operated by two surgeons for shoulder arthroscopy. All patients provided their informed consent to participate in this study and for use of their de-identified health data. The study was approved by our institutional review board. The inclusion and exclusion criteria are listed in Fig. 1.

2.2. Methods

2.2.1. Clinical tests

The surgeon did four clinical screening tests for SSC tears on each patient – lift-off test, internal rotation lag sign, bear-hug test, and belly-press test – as described in the original articles [1–4,7]. The clinical index of suspicion for an SSC tear was positive if loss of strength was found during one or more of these tests.

2.2.2. Radiological analysis

A CT arthrography, done within 6 months of the arthroscopy, was analyzed by the surgeon before looking at the radiology report. The reference view for detecting SSC tears was the first transverse slice passing under the distal tip of the coracoid process. The SSC tendon is examined on this specific slice (Fig. 2), then distally over its entire height. Classically, the SSC tears start proximally and extend distally [9]. Detachment of the deep layer is visible by interposition of contrast agent between the tendon and the lesser tuberosity. Fig. 3 is an example of a CT arthrography view showing a tear in the opinion of the surgeon, but not the radiologist. SSC muscle atrophy was also evaluated.

2.2.3. Surgical phase

The surgery consisted of shoulder arthroscopy. Patients were operated in a beach-chair position under general anesthesia with an interscalene block, with or without limb traction. The 30° scope was inserted through the posterior portal to evaluate the deep aspect of the SSC tendon, looking for even the smallest of tears, which can be seen by manually applying posterior translation on the humeral head (Fig. 4). The tears found were classified according to the "New Endoscopic Classification for Subscapularis Lesions" published by the Francophone Society of Arthroscopy (SFA) [14]. Whether a tear was present or absent and its extent was recorded.

2.3. Assessment methods

The surgeon recorded his preoperative analysis of the CT image by specifying the estimated extent of the tear. This is the surgeon's

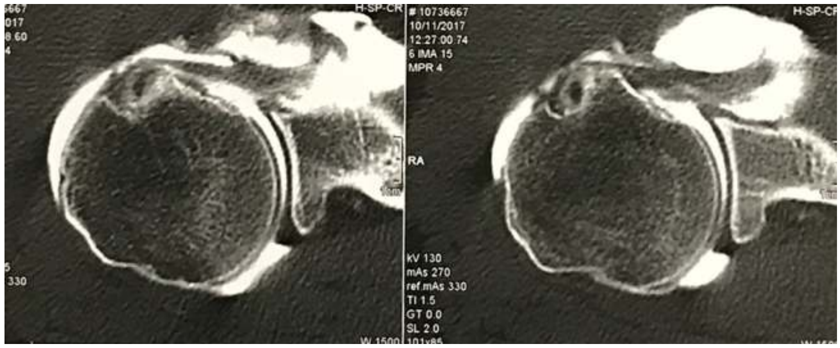

Fig. 3. Suspicion of a subscapularis tear, with partial detachment from lesser tuberosity (right shoulder).

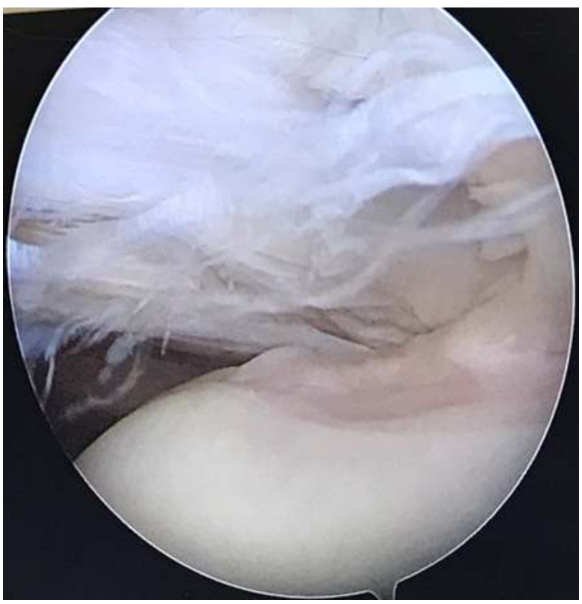

Fig. 4. Arthroscopic confirmation of type II lesion in SFA classification [14] corresponding to the tear suspected in the CT arthrography image shown in Fig. 3; the tear was revealed by translating the humeral head posteriorly.

radiological index of suspicion. After adding the results of the clinical tests, the surgeon obtained a blended clinical and radiological index of suspicion. The findings about the SSC in the radiology report were taken as the radiologist's index of suspicion. These three preoperative indexes of suspicion were then compared to the actual intraoperative arthroscopy findings.

2.4. Statistical analysis

The study variables were the surgeon's radiological index of suspicion, the surgeon's blended clinical and radiological index of suspicion and the radiologist's radiological index of suspicion. The response variable was the presence of a tear on arthroscopy.

The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), accuracy, positive likelihood ratio (LR+) and negative likelihood ratio (LR-), and the odds ratio for each study variable were calculated using three 2×2 contingency tables.

A Fisher's exact test was done on the contingency tables with a type I error $\alpha = 5\%$. The relationship between a positive study variable and the actual arthroscopy findings was considered significant when the p-value for Fisher test was less than 0.05.

Table 1
Demographics of the operated patients.

Variable	Data, *n* (min; max)
Sex (men/women)	34/16
Side (right/left)	28/22
Age (years)	54.1 (26; 72)
Rotator cuff lesion	39
Subacromial impingement	11

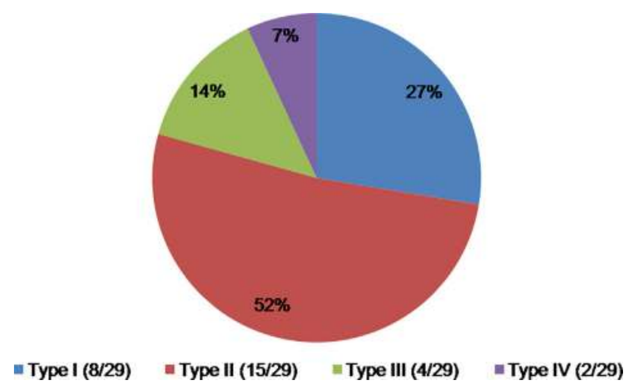

Fig. 5. Distribution of the subscapularis tendon lesions using SFA classification [14].

Cohen's kappa was used to determine the inter-observer agreement between the surgeon and radiologist based on the radiological analysis only.

3. Results

3.1. Study population

Fifty patients were included. Their demographics are listed in Table 1.

3.2. Classification of SSC tears

We found 29 SSC tears in the 50 patients that fit into one of the four types (Fig. 5) defined by the SFA [14] (Table 2).

3.3. Index of suspicion

The comparison of the three indexes of suspicion to the presence of a tear on arthroscopy is shown in Table 3. All the Fisher exact tests were statistically significant, thus there was a relationship between each study variable and the arthroscopic findings. The surgeon's blended clinical and radiological index of suspicion was the most sensitive and specific, while the radiologist's index of suspicion was the least sensitive. The PPV and NPV were the highest for the

Table 2
Arthroscopic classification for subscapularis tears developed by the SFA [14].

Injury type	Abnormality found
I	Partial separation of fibers from lesser tuberosity with a normal bicipital sling
II	Partial separation of fibers from lesser tuberosity combined with partial injury to the anterior wall of the bicipital sling
III	Complete separation of fibers from lesser tuberosity with extensive cleavage of the bicipital sling
IV	Complete separation from humerus due to full thickness tear, leaving lateral edge free

surgeon's blended index of suspicion. It was also the most accurate and reliable based on the LR+ and odds ratio. This index of suspicion was higher than the two others. The inter-observer agreement between the surgeon and radiologist was moderate ($K = 0.57$).

4. Discussion

The SSC muscle is a powerful shoulder internal rotator. It plays an important role in the anterior dynamic stability of the glenohumeral joint and the balance of the force couples around the shoulder [15]. A cadaver study has shown that the SSC itself participates in 53% of the total rotator cuff moments and that it tends to pull the humeral head anteriorly, while the three other rotator cuff muscles are external rotators and tend to pull the head posteriorly [16]. Historically, the SCC received little attention [17] because SSC tears were underestimated and considered rare, said to make up only 3.5% of rotator cuff tears [18]. But we now know the importance of detecting and repairing SSC tears to improve the functional outcomes [17]. Ignoring a SSC tear could result in only the posterior tendons being repaired, which results in an incomplete repair of the rotator cuff, force imbalance and leads to poor functional outcomes [15].

The exact cause of SSC tendon tears is not fully understood. Lo and Burkhart [19] contend that a roller-wringer effect is at the origin of the tear: the impingement arises from subcoracoid stenosis and impingement. These increase the tensile forces on the articular surface of the tendon and its insertional fibers, which can contribute to weakening and eventually rupture. No matter the injury mechanism, SSC tears must be diagnosed before they can be repaired. And yet, 24% of these tears are only diagnosed during arthroscopy [1].

SSC tears are usually diagnosed based on an imaging assessment interpreted by radiologists. A large study [13] showed that ultrasound imaging had a low sensitivity (27%) for type 1 and 2 SSC tears in the Lafosse classification [20]. Consequently, ultrasonography is not recommended for small SSC tears. According to Bernageau and Goutallier [9], CT arthrography is recommended when there is even a minimal clinical suspicion of SSC tear. It must be done in neutral arm rotation to avoid masking a tear [9]: internal rotation brings the lesser tuberosity closer to the glenohumeral joint and interferes with the interpretation of the SSC's condition. External rotation must be avoided because it flattens the tendon against the lesser tuberosity and may mask its detachment by pushing out the contrast agent. In the radiology literature, one study recommends analyzing both parasagittal and transverse slices to improve the specificity of detecting SSC tears on MR arthrography [21]. If one wants to use contrast agent, it must be injected into the rotator interval, not by an inferomedial approach, to avoid injecting it into the tendon itself and in the capsulolabral complex [22]. A few articles in the orthopedics literature describe how to optimize the interpretation of imaging views when they are analyzed by surgeons [23]. The latter need a reliable and reproducible method to interpret images by themselves and compare them to clinical findings. This need, which is the reason for our study, is expressed by the authors who propose a systematic approach to detecting SSC tears on MRI [23], but also on plain radiographs and CT slices by calculating angles that help predict SSC tears [24]. Similarly, we propose a systematic approach that supports our hypothesis: based on a reference slice under the tip of the coracoid on CT arthrography, the preoperative diagnosis better matches the actual findings, especially when it is reinforced by various clinical tests. In fact, each clinical test activates a different part of the SSC muscle according to an electromyographic study [25].

We also showed that the surgeon's indexes of suspicion (radiological and blended) were superior to the radiologist's. The agreement was moderate between the surgeon and radiologist in the radiological analysis. By analyzing specifically the SSC on the reference CT arthrography slice, the sensitivity of the surgeon's radiological index of suspicion in our study was 89%, while other teams have reported an overall sensitivity for MRI of 25% to 37% [15,26], concluding that SSC tears are more common that we think. These results are similar to those of a 286-patient study that found MRI sensitivity of 30% and ultrasonography sensitivity of only 13% [27]. But these deviate from other studies reporting sensitivity of 78% with 1.5 T MRI [28] and overall sensitivity of MRI of 68% in a meta-analysis [29].

Our study has a few limitations. First, the sample size was limited. Second, we used CT arthrography not MRI to detect SSC tears in the reference image. In our experience, CT arthrography is superior to MRI without injection and avoids the false positives of non-ruptured rotator cuff lesions. Only 1.5T MRI gives equal results to CT arthrography, but the former is more expensive and less available [12]. Next, the prevalence of these lesions varies in the literature from 30% [30] to 53% [28], while Barth et al. [7] found 29% SSC tears, all arthroscopy procedures pooled and 58% when only rotator cuff tears are included. We found a 58% incidence of SSC tears in our study using arthroscopy, all types of lesions pooled. We excluded patients who were undergoing arthroscopy for shoulder instability; this selection bias may in part explain the higher tear prevalence in our study. Another limitation is that the intra-observer or inter-observer agreement between the two surgeons was not calculated.

Table 3
Results of index of suspicion for detecting subscapularis tears.

	Surgeon's radiological index	Surgeon's blended clinical-radiological index	Radiologist's radiological index
Sensitivity	89% [72–97]	89% [72–97]	62% [43–77]
Specificity	90% [69–98]	95% [75–100]	95% [75–100]
PPV	92%	96%	94%
NPV	86%	87%	64%
Accuracy	90%	92%	76%
LR+	9.4	18.8	13
LR−	0.1	0.1	0.3
Odds ratio	82.3 [14.6-462.1]	173.3 [23.5-1277.8]	32.7 [5.3-200.7]
P-value	< 0.0001	< 0.0001	< 0.0001

95% confidence intervals for sensitivity, specificity, odds ratio, PPV: Positive predictive value, NPV: Negative predictive value, LR+: positive likelihood ratio, LR−: negative likelihood ratio.

Lastly, there is a bias related to different radiologists having different levels of experience with analyzing rotator cuff lesions on CT arthrography.

5. Conclusion

Our study shows that the first CT arthrography slice under the coracoid, combined with clinical tests, improves the analysis of the SSC insertion on the humeral head. It would be interesting to compare the accuracy of radiological screening for SSC tears using CT arthrography versus 3T MRI without contrast (which is non-invasive and non-irradiating) when using the same reference image.

Ethics committee approval

This study was approved by our institutional review board under number COS-RGDS-2019-04-003-FALCONE-MO.

Informed consent

All patients provided their informed consent for participating in this study and for the analysis of their de-identified clinical and radiological data.

Disclosure of interest

The authors declare that they have no competing interest.

Funding

This research did not receive any specific grants from the public, commercial or non-profit sectors.

Authors' contributions

Ghada Asmar: wrote manuscript, acquired and analyzed data.
Jean-Noël Goubier: provided critical review of manuscript.
Marc-Olivier Falcone: designed study, acquired data, provided critical review of manuscript.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.otsr.2020.04.016.

References

[1] Barth J, Audebert S, Toussaint B, Charousset C, Godeneche A, Graveleau N, et al. Diagnosis of subscapularis tendon tears: are available diagnostic tests pertinent for a positive diagnosis? Orthop Traumatol Surg Res 2012;98(8 Suppl):S178–85.
[2] Gerber C, Krushell RJ. Isolated rupture of the tendon of the subscapularis muscle. Clinical features in 16 cases. J Bone Joint Surg Br 1991;73:389–94.
[3] Gerber C, Hersche O, Farron A. Isolated rupture of the subscapularis tendon. J Bone Joint Surg Am 1996;78:1015–23.
[4] Hertel R, Ballmer FT, Lombert SM, Gerber C. Lag signs in the diagnosis of rotator cuff rupture. J Shoulder Elbow Surg 1996;5:307–13.
[5] Scheibel M, Magosch P, Pritsch M, Lichtenberg S, Habermeyer P. The belly-off sign: a new clinical diagnostic sign for subscapularis lesions. Arthroscopy 2005;21:1229–35.
[6] Burkhart SS, Tehrany AM. Arthroscopic subscapularis tendon repair: technique and preliminary results. Arthroscopy 2002;18:454–63.
[7] Barth JR, Burkhart SS, De Beer JF. The bear-hug test: a new and sensitive test for diagnosing a subscapularis tear. Arthroscopy 2006;22:1076–84.
[8] Lee J, Shukla DR, Sánchez-Sotelo J. Subscapularis tears: hidden and forgotten no more. JSES Open Access 2018;2:74–83.
[9] Bernageau J, Goutallier D. Isolated lesions of the subscapularis tendon and internal malpositions of the biceps tendon. J Radiol 1997;78:1255–63.
[10] Szymanski C, Staquet V, Deladerrière JY, Vervoort T, Audebert S, Maynou C. Reproducibility and reliability of subscapularis tendon assessment using CT-arthrography. Orthop Traumatol Surg Res 2013;99:2–9.
[11] Adams CR, Schoolfield JD, Burkhart SS. Accuracy of preoperative magnetic resonance imaging in predicting a subscapularis tendon tear based on arthroscopy. Arthroscopy 2010;26:1427–33.
[12] 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 2012;264:812–22.
[13] 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 2016;40:975–9.
[14] Toussaint B, Barth J, Charousset C, Godeneche A, Joudet T, Lefebvre Y, et al. New endoscopic classification for subscapularis lesions. Orthop Traumatol Surg Res 2012;98(8 Suppl):S186–92.
[15] Foad A, Wijdicks CA. The accuracy of magnetic resonance imaging and magnetic resonance arthrogram versus arthroscopy in the diagnosis of subscapularis tendon injury. Arthroscopy 2012;28:636–41.
[16] Keating JF, Waterworth P, Shaw-Dunn J, Crossan J. The relative strength of rotator cuff muscles. A cadaver study. J Bone Joint Surg [Br] 1993;75–B:137–40.
[17] Denard PJ, Burkhart SS. Arthroscopic recognition and repair of the torn subscapularis tendon. Arthrosc Tech 2013;2:e373–9.
[18] Denard PJ, Lädermann A, Burkhart SS. Arthroscopic management of subscapularis tears. Sports Med Arthrosc Rev 2011;19:333–41.
[19] Lo IK, Burkhart SS. The etiology and assessment of subscapularis tendon tears: a case for subcoracoid impingement, the roller-wringer effect, and TUFF lesions of the subscapularis. Arthroscopy 2003;19:1142–50.
[20] 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 2007;89:1184–93.
[21] Pfirrmann CW, Zanetti M, Weishaupt D, Gerber C, Hodler J. Subscapularis tendon tears: detection and grading at MR arthrography. Radiology 1999;213:709–14.
[22] Rhee RB, Chan KK, Lieu JG, Kim BS, Steinbach LS. MR and CT arthrography of the shoulder. Semin Musculoskelet Radiol 2012;16:3–14.
[23] Adams CR, Brady PC, Koo SS, Narbona P, Arrigoni P, Karnes GJ, et al. A systematic approach for diagnosing subscapularis tendon tears with preoperative magnetic resonance imaging scans. Arthroscopy 2012;28:1592–600.
[24] Seo JB, Kim SJ, Ham HJ, Kwak KY, Yoo J. New predictors for subscapularis tear: Coraco-lesser tuberosity angle, lesser tuberosity angle, and lesser tuberosity height. OrthopTraumatol Surg Res 2020;106:45–51.
[25] 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;12:427–30.
[26] 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 2011;5:90–4.
[27] Ward JRN, Lotfi N, Dias RG, McBride TJ. Diagnostic difficulties in the radiological assessment of subscapularis tears. J Orthop 2018;15:99–101.
[28] Malavolta EA, Assunção JH, Guglielmetti CL, de Souza FF, Gracitelli ME, Bordalo-Rodrigues M, et al. Accuracy of preoperative MRI in the diagnosis of subscapularis tears. Arch Orthop Trauma Surg 2016;136:1425–30.
[29] 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 2019;139:659–67.
[30] Kappe T, Sgroi M, Reichel H, Daexle M. Diagnostic performance of clinical tests for subscapularis tendon tears. Knee Surg Sports Traumatol Arthrosc 2018;26:176–81.