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Comma sign of subscapularis tear: diagnostic performance and magnetic resonance imaging appearance

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Background: The main aim of this study was to evaluate the performance of magnetic resonance imaging (MRI) and interobserver agreement in the identification of the comma sign. The second objective was to look for a correlation between the comma sign and the detachment of the superficial fascia of the subscapularis.
Materials and methods: Two radiologists, blinded to the arthroscopic findings, retrospectively assessed the magnetic resonance images of 110 shoulders and were asked to assess the presence of the comma sign and the intact subscapularis fascia. The inter-reader agreement and the MRI performance values for detection of the comma sign were calculated. In addition, the association between the intact superficial subscapularis fascia and the comma sign was evaluated.
Results: The agreement between the 2 radiologists was perfect. The following values were obtained: sensitivity, 90.9%; specificity, 98.8%; positive predictive value, 95.2%; negative predictive value, 97.7%; and accuracy, 97.2%. No association between the comma sign and subscapularis fascia lesions was found.
Conclusion: MRI appears to be a reliable method for preoperative assessment of the comma sign. The comma sign appears not to be formed by the detached subscapularis fascia.
Level of evidence: Level III; Diagnostic Study

Keywords: Comma sign; MRI; shoulder; subscapularis; coracohumeral ligament; superior glenohumeral ligament

The comma sign is a well-known arthroscopic landmark in the identification and repair of the torn subscapularis (SSC) tendon stump.[3,6-9,19-21] Lo and Burkhart[14] first described this sign in 2003, defining the comma structure as tissue composed of the superior glenohumeral ligament (SGHL) and coracohumeral ligament (CHL), both detached from the humeral head but still

The Ethical Committee of Campolongo Hospital approved this retrospective study.

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adherent to the superolateral corner of the torn and retracted SSC tendon. This interpretation is in accordance with the most frequently cited anatomic research studies,[5,12,17,23] which have shown that the anterior portion of the CHL both envelops the SSC and merges with its superficial fascia[1,2] (Fig. 1). Despite the importance and diffuse arthroscopic knowledge of this sign, it seems not to be known by radiologists. To our knowledge, no research regarding the role of imaging in the identification of the comma sign has been carried out to date.

On the other hand, the presence of residual superficial SSC fascia is a frequent finding on magnetic resonance imaging (MRI) and during open surgery. If we consider the

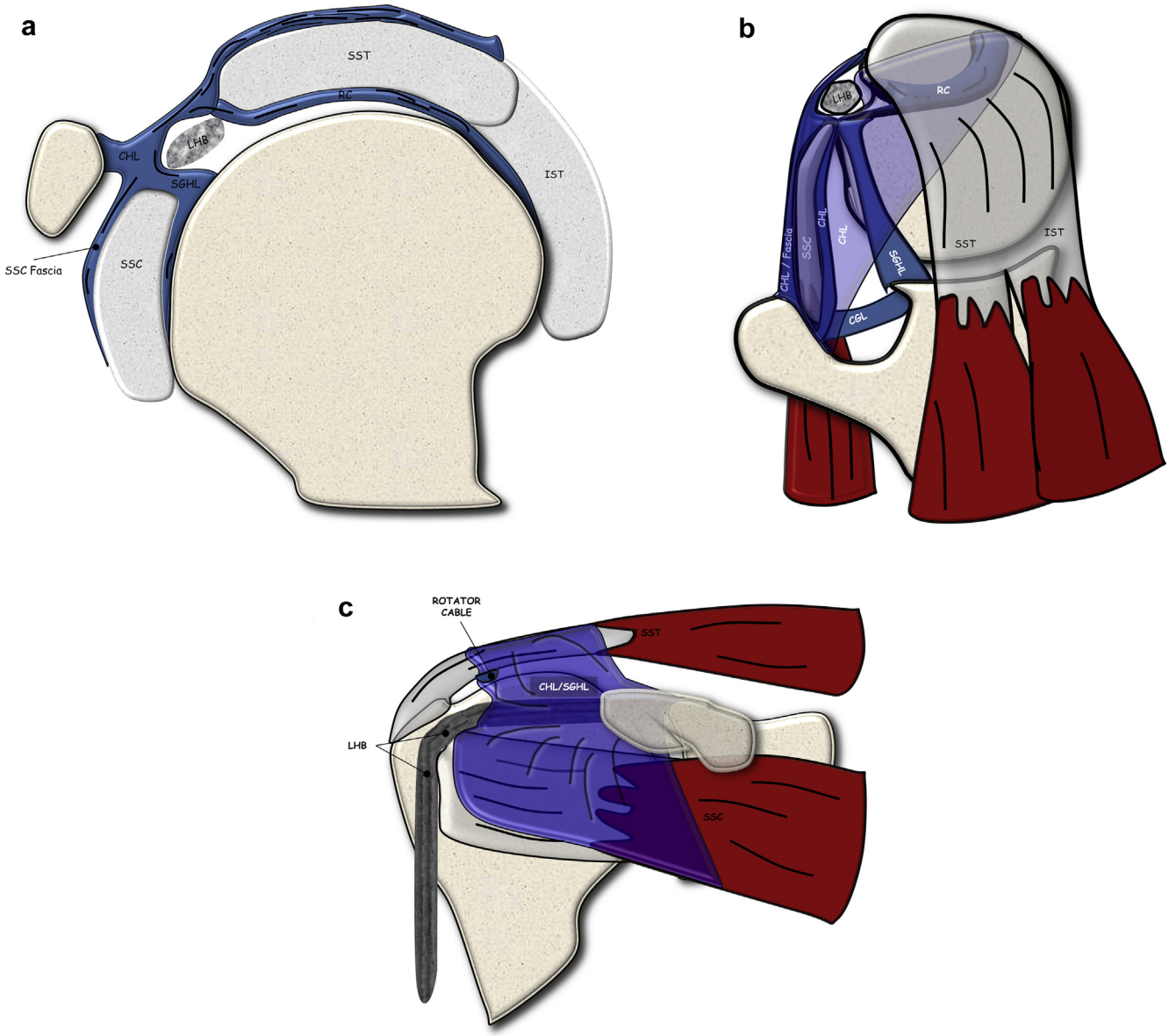

Figure 1 Illustration of coracohumeral ligament *(CHL)* anatomy in sagittal (**a**), axial (**b**), and coronal (**c**) planes. The CHL originates from the base of the coracoid process. The anterior part of the CHL envelops the cranial part of the subscapularis *(SSC)* and anchors the muscle to the coracoid process; the superficial layer of the anterior portion continues seamlessly with the SSC fascia, which attaches to the greater tuberosity. Similarly, the posterior part of the CHL envelops the anterior edge of the supraspinatus *(SST)* tendon; the deeper layer of the posterior part fuses with the rotator cable *(RC)*. Medially, the CHL and superior glenohumeral ligament *(SGHL)* are considered 2 parts of the same ligament that runs laterally and attaches to the SSC tendinous slip and the greater and lesser tuberosities.[17] At the most lateral rotator interval, the CHL-SGHL forms the long head of the biceps tendon *(LHB)* reflection pulley. The coracoglenoid ligament *(CGL)* is an expansion of the pectoralis minor tendon that partially merges with the superficial part of the CHL-SGHL.[17,23] *IST*, infraspinatus.

CHL and superficial SSC fascia to be merged and consider that comma tissue is formed by the CHL,[2] it is reasonable that the comma sign will only be present if the SSC has become detached.

The main aim of this study was to retrospectively evaluate the performance of MRI in the identification of the comma sign using arthroscopy as a reference standard. In addition, the relationship between the comma sign and the intact SSC fascia was evaluated.

Materials and methods

In this retrospective study, the need for patients' informed consent was waived. This article has been drafted following the STARD (Standards for Reporting of Diagnostic Accuracy Studies) checklist.

Study population

The 120 patients most recently admitted to our institution to undergo shoulder arthroscopy for cuff pathology were enrolled in the study. Of these 120 patients, 40 showed SSC full-thickness tears (Lafosse type II or higher). A further inclusion criterion was the availability of images from a magnetic resonance (MR) examination performed ≤3 months prior to surgery. Of the 120 patients, 10 were excluded (previous surgery, n = 1; insufficient quality of MR images, n = 7; or MRI performed >1 month before surgery, n = 2). Thus, the final study population included 110 patients (Fig. 2): 53 women and 57 men. The mean age was 57 years, with an age range of 36-75 years (standard deviation, 8.401001 years).

MR examinations were performed either at our institution or elsewhere. For all examinations, the following sequences were available: at least one proton density–weighted or intermediate-weighted sequence with fat saturation and one T1-weighted or proton density–weightedsequence in the coronal plane, T2-weighted sequence or T2-weighted sequence with fat saturation in the axial plane, and T1- or T2-weighted sequence in the sagittal plane, with a slice thickness ≤ 4 mm, matrix ≥ 256 × 256, and field of view ≤ 180 mm.

Arthroscopic procedure

All procedures were performed by surgeons with 22, 13, and 5 years' shoulder surgery experience (A.R., G.N., and F.A., respectively), with patients in the beach-chair position, after administration of an interscalene nerve block with or without

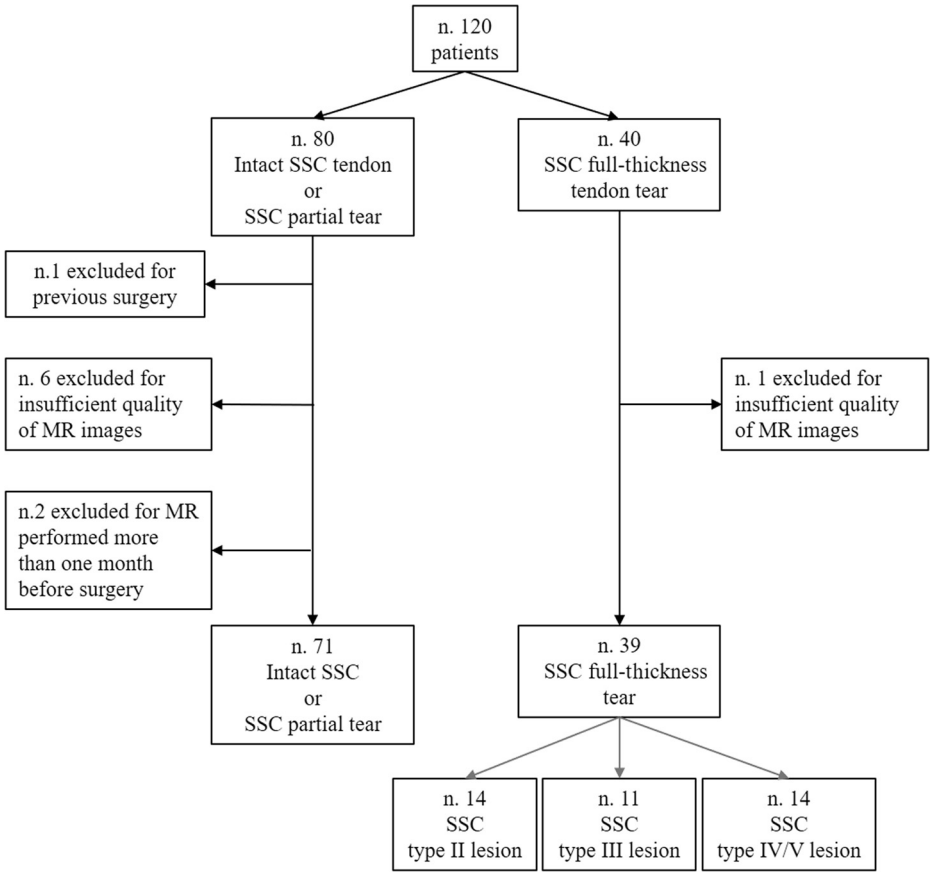

Figure 2 Flowchart of patient inclusion. *SSC*, subscapularis; *MR*, magnetic resonance.

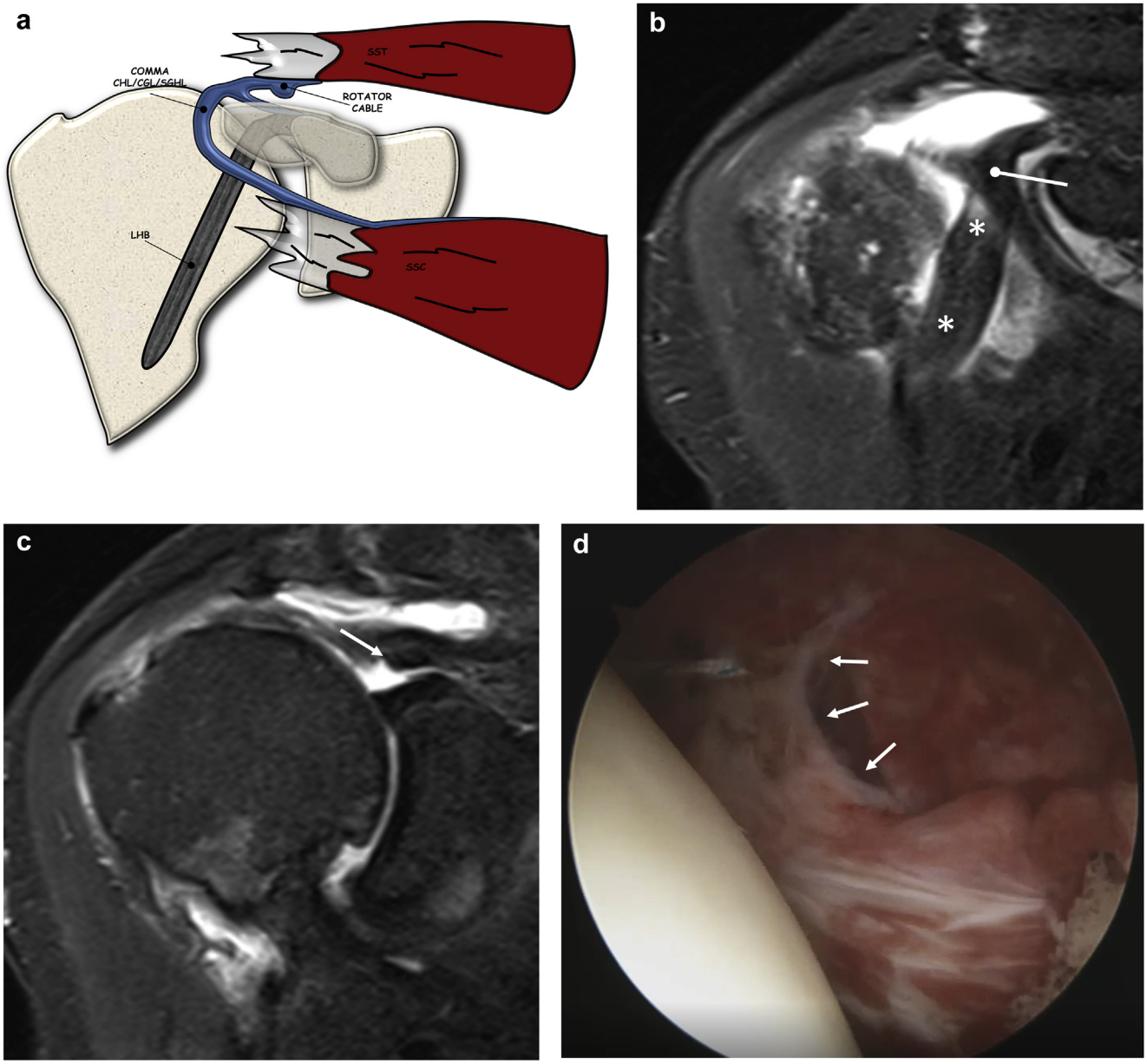

Figure 3 Illustration (**a**), 2 STIR (short tau inversion recovery) coronal magnetic resonance images (**b, c**), and arthroscopic image (**d**) in a 58-year-old man showing the comma sign. The supraspinatus *(SST)* and subscapularis *(SSC)* are torn and retracted. The comma structure *(dot)* is detected lateral to the coracoid process, running from the superior edge of the SSC to the superior capsule and the rotator cable *(RC) (arrows)*. In **a** and **b**, the long head of the biceps tendon *(LHB) (*)* appears medially dislocated. The arthroscopic image (**d**) was acquired after LHB tenotomy. *CHL*, coracohumeral ligament; *CGL*, coracoglenoid ligament; *SGHL*, superior glenohumeral ligament.

intravenous sedation. The operative arm was draped in a traction pulley device. The procedure began with diagnostic arthroscopy through a standard posterior viewing portal. After routine intra-articular examination, an anterior portal was made just lateral to the coracoid tip and below the coracoacromial ligament in the rotator interval. An anterolateral portal was created 2-3 cm anterior and slightly medial to the anterolateral corner of the acromion. In a chronic SSC tear, a torn tendon edge was usually difficult to recognize in the intra-articular view. To identify the leading edge of a retracted SSC tendon, the comma sign was searched for. These structures were torn from the lesser tuberosity; however, they typically remained attached to the superolateral portion of the SSC tendon as an anatomic landmark.

All procedures were partially recorded on digital support and stored. The presence and type of SSC tendon tear (according to the Lafosse classification[13]) and the presence of the comma sign (according to Lo and Burkhart[14]), in addition to any other rotator cuff lesions, were reported in the patient's medical record.

MR image analysis

Two radiologists (M.Z. and F.D.P., with 14 and 17 years' experience in musculoskeletal imaging, respectively), blinded to the arthroscopic assessment findings, independently evaluated the MR images and were asked to assess the presence of the comma sign. The criteria for the presence of the comma structure were as follows:

- In the coronal plane, a comma-shaped fibrous structure located lateral to the coracoid process, running from the superior part of the SSC tendon to the superior glenohumeral capsule (Fig. 3)

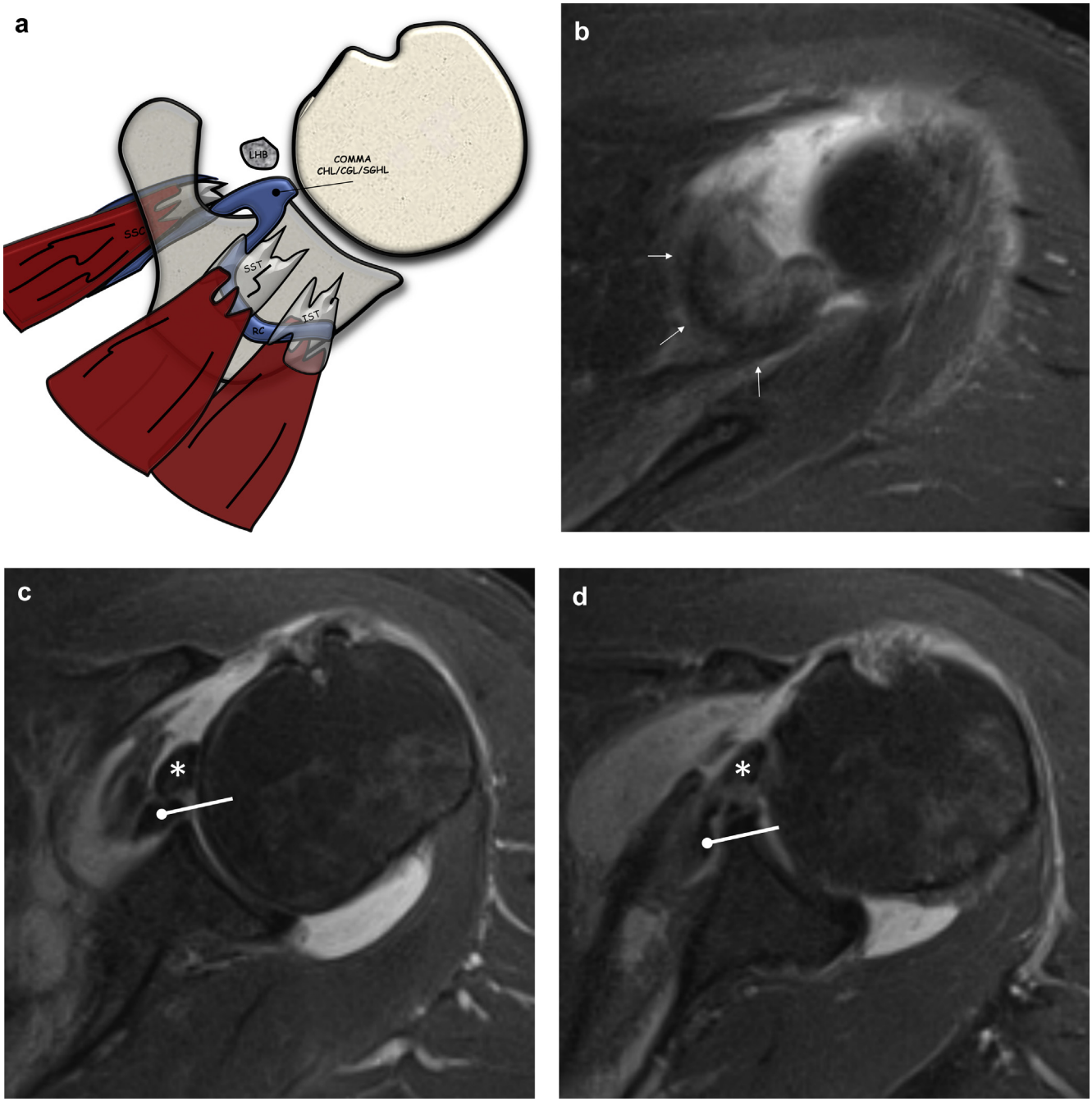

Figure 4 Illustration (**a**) and 3 proton density–weighted axial images with fat saturation (**b-d**) in a 61-year-old woman showing an arthroscopically proved comma sign. The comma structure *(dot)* runs from the rotator cable *(RC)* (*arrows* in **b**) to the deeper portion of the superior edge of the subscapularis *(SSC)* stump. The long head of the biceps tendon *(LHB)* *(*)* appears medially dislocated, anterior to the comma tissue. *CHL*, coracohumeral ligament; *CGL*, coracoglenoid ligament; *SGHL*, superior glenohumeral ligament; *SST*, supraspinatus; *IST*, infraspinatus.

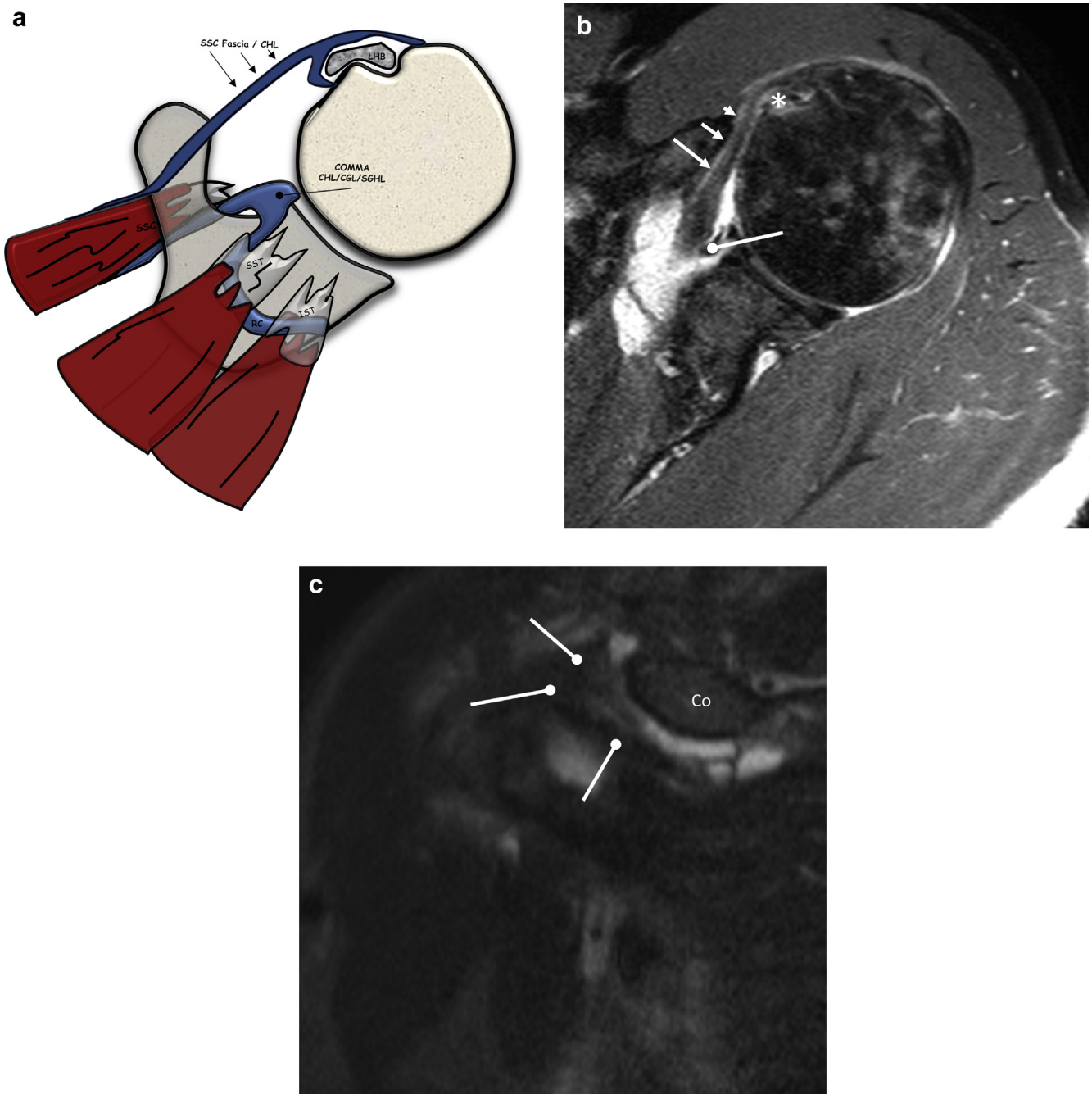

Figure 5 Illustration (**a**), axial proton density–weighted magnetic resonance image with fat saturation (**b**), and coronal STIR (short tau inversion recovery) magnetic resonance image (**c**) in a 62-year-old man with an arthroscopically confirmed comma sign, showing the presence of the comma sign *(dots)* and an intact superficial layer of the anterior coracohumeral ligament *(CHL)* and subscapularis *(SSC)* fascia (*arrows* in **a** and **b**). The comma sign appears to be formed by the deeper portion of anterior part of CHL only, and not by the superficial layer. The long head of the biceps tendon *(LHB) (*)* appears medially subluxated. *SGHL*, superior glenohumeral ligament; *SST*, supraspinatus; *IST*, infraspinatus; *RC*, rotator cable; *Co*, coracoid.

- In the axial and/or sagittal plane, a fibrous structure connecting the superior border of the torn SSC tendon and superior capsule or deep portion where the SST tendon was retracted (Fig. 4)

In addition, in cases of retracted SSC tears in the axial plane, the presence of superficial SSC fascia that was still anchored to the great tuberosity was reported (Fig. 5).

Table I Diagnostic performance of magnetic resonance imaging in identification of comma sign with arthroscopy as reference standard in series of 110 patients

	Intact SSC, n	SSC type I lesion, n	SSC type II lesion, n	SSC type III lesion, n	SSC type IV or V lesion, n
True positive	0	0	3	7	10
False positive	0	0	0	0	1
False negative	0	0	0	1	1
True negative	60	11	11	3	2

SSC, subscapularis tendon.
The patients were divided into groups according to the Lafosse SSC lesion classification.[13]

Statistical analysis

The Cohen κ value was used to evaluate the agreement between the 2 radiologists in the identification of the comma sign. With arthroscopy as the reference standard, the sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of MRI in the identification of the comma sign were calculated.[18] In addition, the Fisher exact test (with a significance level of .05) was used to evaluate the association between intact superficial SSC fascia on MRI and the comma sign on arthroscopy, as well as the association between the type of SSC lesion and the presence of the comma sign on arthroscopy.

Results

The agreement between the 2 radiologists was perfect for detection of the comma sign ($\kappa = 1$). Full data of the diagnostic performance of MR, with arthroscopy as the reference standard, are reported in Table I. The following values were obtained: sensitivity, 90.9%; specificity, 98.8%; positive predictive value, 95.2%; negative predictive value, 97.7%; and accuracy, 97.2%.

Intact superficial fascia was found in 6 cases of SSC tear, 5 of which were associated with the comma sign. No significant association between the comma sign and intact superficial SSC fascia was found. A significant association was found between Lafosse type IV or V SSC tears and the comma sign ($P < .00001$, Fisher exact test), as well as between Lafosse type III SSC tears and the comma sign ($P = .0229$, Fisher exact test).

Discussion

Our data showed excellent interobserver agreement and high accuracy of MRI in the identification of the comma sign. The comma tissue is an arthroscopic structure of fundamental importance when delimiting the superolateral edge of the SSC tendon. Arthroscopic recognition of the comma tissue allows accurate identification of the retracted SSC tendon and its distinction from the conjoined tendon and coracoacromial ligament.[4,14] During arthroscopic SSC repair, the vertical fibers of the comma tissue act as a "rip stop" to avoid cut-through of the sutures in the SSC tendon and postoperative structural failure.[4] Moreover, in cases of combined tears of the retracted supraspinatus and SSC, reduction of the comma tissue to the upper border of the remnant SSC results in concomitant reduction of the supraspinatus tendon, allowing anatomic repair of anterosuperior rotator cuff tears.[7]

In view of this arthroscopic background, preoperative knowledge of the presence of the comma sign would prove useful for the orthopedic surgeon. Consequentially, we decided to evaluate the accuracy of MRI in identifying this sign. In our study, unexpectedly, the 2 radiologists made the same mistakes in the same cases (1 false-positive and 2 false-negative cases) in MRI identification of the comma. In the first MRI false-negative case, a hypertrophic middle glenohumeral ligament was found; we believe this to be a confounding structure. In the second MRI false-negative case, the dislocated long head of the biceps tendon was present but leaning against the comma structure, thus taking on the appearance of a single structure on the coronal image; the superiority of the arthroscopic view, owing to long head of the biceps tenotomy, might be explained by this (Fig. 6). Although we assessed MRI accuracy in this study using both the coronal and axial planes (as is the case in current clinical practice), the fastest and easiest visualization of the comma sign appears to be on the coronal plane whereas the axial plane may be more accurate.

To our knowledge, Jung et al[11] have published the only existing imaging assessment for the comma structure to date, called the "bridging sign." They found that this sign is a highly specific finding for MRI diagnosis of combined full-thickness tears of the SSC tendon and the anterior portion of the supraspinatus tendon, associated with more chronic and severe rotator cuff tears. We believe that the comma sign is not always present in case of lesions that involve both tendons. In our series, we found 2 cases with SSC and CHL or SGHL lesions without full-thickness tears

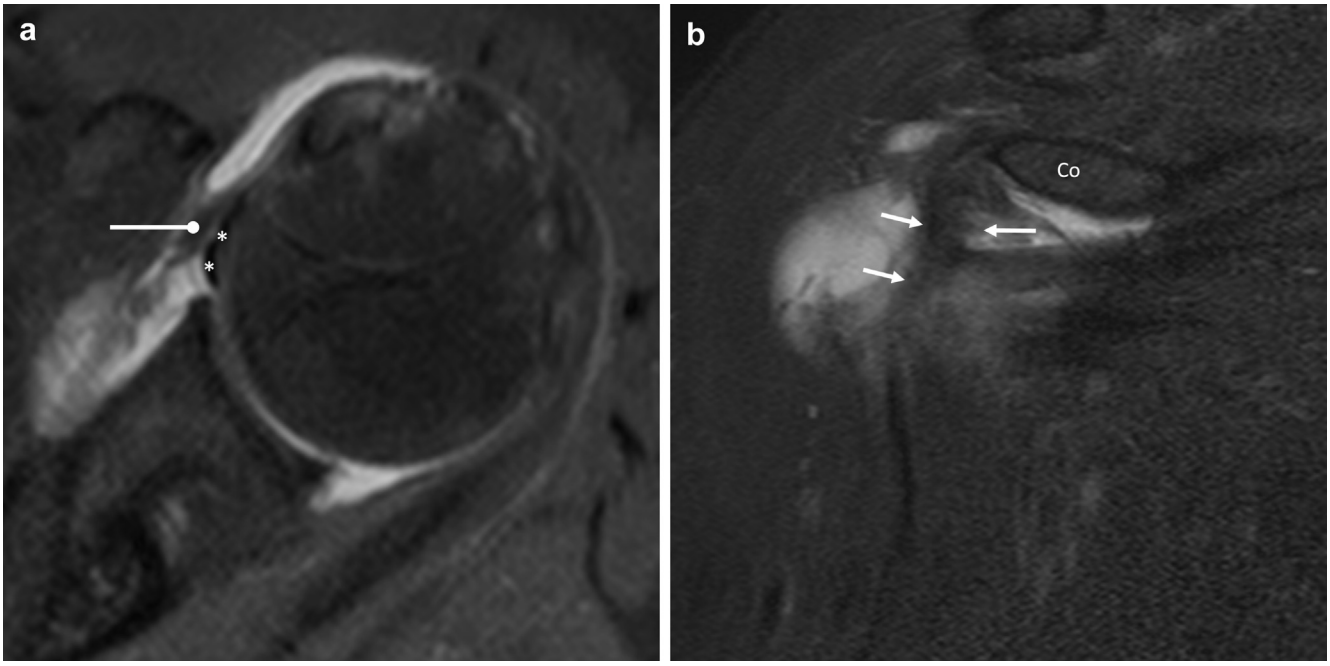

Figure 6 (**a, b**) False-negative comma sign on magnetic resonance imaging: axial proton density–weighted magnetic resonance image with fat saturation (**a**) and coronal STIR (short tau inversion recovery) magnetic resonance image (**b**) in a 69-year-old woman with an arthroscopically proved comma sign. In the axial plane, few fibers *(dot)* are visible close to the long head of the biceps tendon *(*)* (**a**), but the coronal image does not allow the 2 structures *(arrows)* to be distinguished (**b**). Both radiologists incorrectly interpreted this examination finding as negative for the comma sign. *Co*, coracoid.

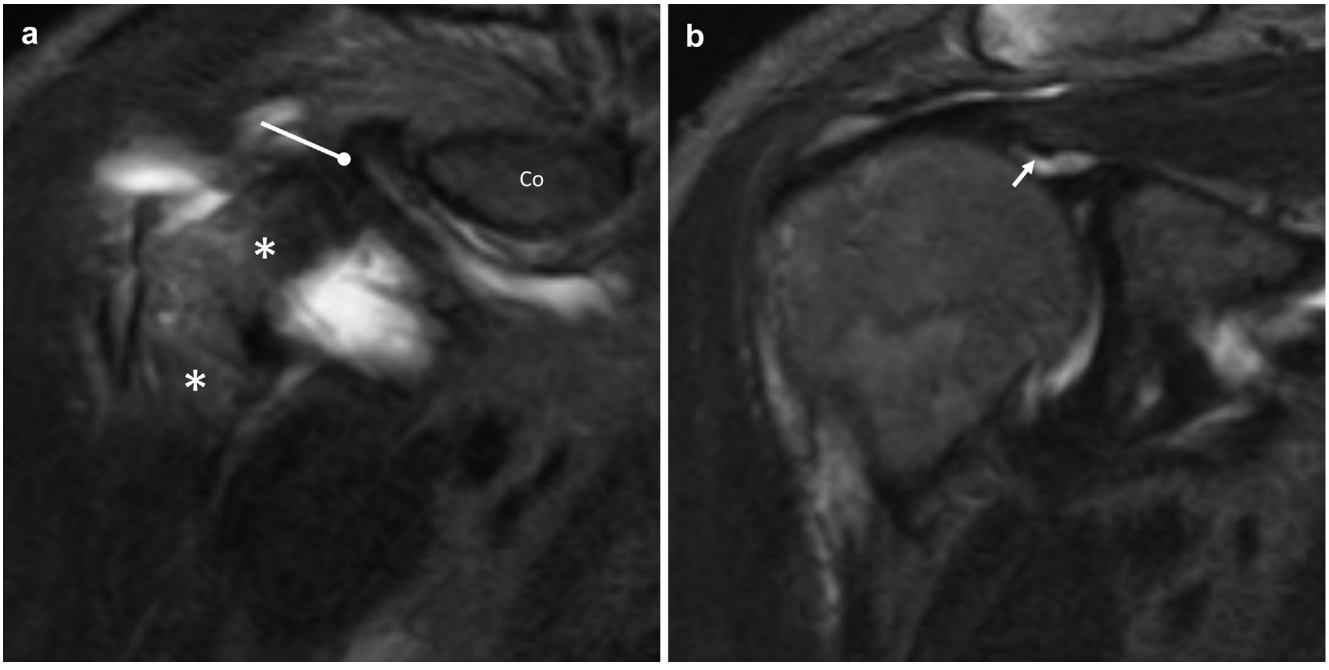

Figure 7 (**a, b**) Two coronal STIR (short tau inversion recovery) magnetic resonance images in a 55-year-old woman show the comma sign (*white dot*). The supraspinatus tendon does not show a full-thickness tear. A thickened rotator cable (*arrow*) is noted. Arthroscopy revealed an articular partial-thickness tear of the supraspinatus. The long head of the biceps tendon *(*)* appears medially subluxated. *Co*, coracoid.

of the SST tendon in which the comma sign was detected, although of a less curved morphology (Fig. 7).

What is more, although not a specific objective of our study, the identification and presence of the comma sign did not change MRI accuracy in the diagnosis of SSC lesions for either of the 2 operators. Identification of the retracted SSC is probably easier with MRI than with arthroscopy.

The anatomic origin of the comma sign is still under debate. Although some articles have stated that the comma tissue is likely of tendinous origin,[7,15] most anatomic studies have corroborated the idea that the comma structure is part of the CHL, SGHL, and superior capsule. In particular, Arai and Matsuda[1] have shown that the anterior end of the rotator cable is the lateral-most portion of the rotator interval and forms the comma sign. Our MR images fully confirm this interpretation. The continuity of the comma tissue, torn CHL and/or SGHL, and rotator cable is clearly visible in both the coronal and axial planes in all our MRI series (Figs. 1 and 4).

The hypothesis that the comma tissue may also be formed by the torn and retracted superficial SSC fascia (consequentially, the superficial layer of the anterior part of the CHL) found no confirmation. These 2 structures were identified as independent in our MRI series.

The residual superficial SSC tissue has no clear-cut anatomic reading in the literature. An overlying scar[16] and fascia[10,22] are merely 2 possible interpretations of this structure.

On the basis of the anatomic literature,[2] in addition to our MR image series, we agree that the residual superficial SSC tissue is represented by the intact superficial fascia merged with the superficial layer of the CHL, which is still attached to the greater tuberosity, differently from the comma tissue, which would appear to consist of the detached deeper portion of the anterior CHL (Fig. 5). This could explain the coexistence of the comma sign and superficial SSC fascia and/or CHL.

MRI acknowledgment of the superficial SSC fascia is crucial in distinguishing it from the SSC tendon.[21] In our daily professional experience, most radiologist errors regarding SSC lesions relate to the presence of this residual tissue that mimics the intact SSC tendon.

Several limitations of this study should be considered. First, this was a retrospective study, and not all secondary data were available for review during the retrospective analysis. In addition, MR examinations were performed at different hospitals with different scanners and various magnetic fields. However, adequate sequences were always available for review. Furthermore, the comma sign is an arthroscopic landmark and therefore arthroscopy was used as the reference standard, but open surgery may have provided advanced anatomic data, especially regarding the superficial SSC fascia. Finally, a prospective study subsequent to radiologists being made aware of the comma sign would be interesting in determining the learning curve and/or the level of additional assistance the comma sign might provide.

Conclusion

MRI shows high diagnostic performance in the identification of the comma sign and shows perfect inter-reader agreement. The comma sign is not formed by the superficial layer of the anterior part of the CHL or SSC fascia but rather, most likely, only the deeper layer.

Disclaimer

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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