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Direct Coronal View of the Shoulder with Arthrographic CT[1]

Direct coronal oblique views of the shoulder were obtained with arthrographic computed tomography (CT) in 35 shoulders with surgical correlation. There were 18 complete cuff tears, four partial ones, two type 3 superior labral, anterior, and posterior (SLAP) lesions, and one type 4 SLAP lesion. The coronal sections were obtained after double-contrast shoulder arthrography and axial CT sections had already been obtained. The patient was seated directly on the slope of the gantry, and the shoulder to be studied was positioned in the center of the gantry. The maximal time needed for this procedure was 5 minutes. Rotator cuff tears were detected with a sensitivity of 95% and a specificity of 100%. The size of the tears as determined on the coronal sections was strongly correlated with surgical measurement (r = .939). All SLAP lesions were detected. The authors' experience shows that obtaining coronal oblique sections is an effective way to improve arthrographic CT.

Index terms: Shoulder, arthrography, 41.1211, 41.122 • Shoulder, injuries, 41.481

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Figure 1. To obtain coronal oblique CT sections, the patient is seated directly on the slope of the gantry. The contralateral hand grips the table and the patient's feet press against the base of the table to stabilize the patient.

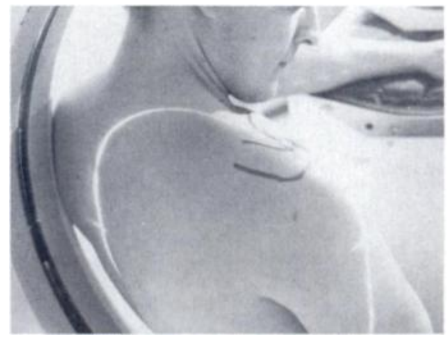


Figure 2. By palpating the acromion and using laser light for guidance, the patient's shoulder is positioned in the center of the gantry. From a strict coronal position, an approximate 30° rotation of the entire body is then obtained. During the procedure, the patient must flex the neck and maintain extension of the ipsilateral elbow to avoid beam-hardening artifact.

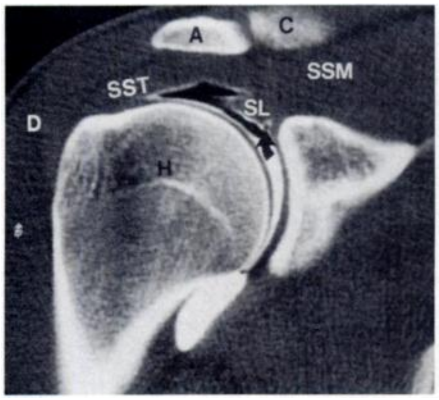
Many studies have demonstrated the ability of arthrographic computed tomography (CT) (1,2) and magnetic resonance (MR) imaging (3,4) to depict rotator cuff tears. In comparing these two techniques for evaluation of the rotator cuff, MR imaging seems to be more effective. The accuracy of MR imaging is probably due to its multiplanar capability and to the high degree of contrast provided between different soft tissues (5–7). Several reports, however, have suggested that MR imaging lacks specificity in certain types of cuff abnormalities. There seem to be no clear-cut criteria to differentiate degeneration from partial tears and partial tears from full-thickness tears (3,8). Moreover, there are still institutions without adequate MR imaging technology to study shoulder pathologic conditions, and some authors have demonstrated that arthrographic CT remains the examination of choice to detect labral tears (9). Arthrographic CT is still a useful technique, although rotator cuffs are often difficult to study with standard positioning of the patient.

To improve arthrographic CT of the rotator cuff and the superior labrum, we obtain direct coronal oblique views of the shoulder. Here we describe this technique and our early experience with this procedure.

MATERIALS AND METHODS

The case material consisted of 35 patients who underwent arthrographic CT in coronal oblique projections and subsequently underwent arthroscopy or open surgery. Findings were compared with those seen at surgery (open or arthroscopic), which were considered the standard for analysis. There were 25 men and 10 women ranging in age from 18 to 67 years, with a mean age of 51 years. Twenty-five

Abbreviations: COS = coronal oblique section, SLAP = superior labral anterior posterior.



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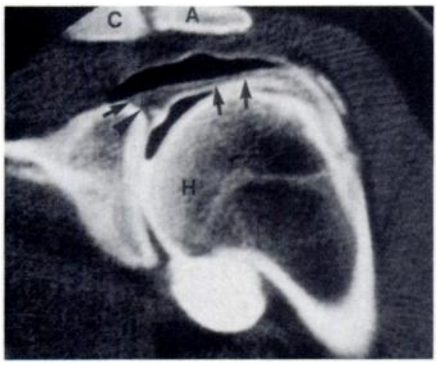

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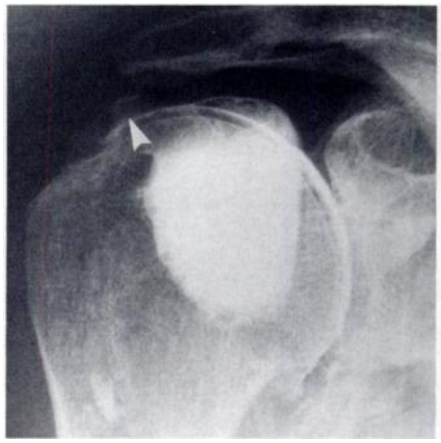
Figures 3, 4. *A* = acromion, *C* = clavicle, *D* = deltoid, *H* = humerus. **(3)** COS of the intact rotator cuff in the right shoulder of a 25-year-old man. The supraspinatus tendon (*SST*) and supraspinatus muscle (*SSM*) are well displayed. The superior labrum and proximal portion of the long head of the biceps are combined (*SL*). There is a small cleft at the central part of the superior labrum (arrow). **(4)** COS of the intact rotator cuff in the left shoulder of a 38-year-old woman. The biceps tendon (arrows) is well displayed. The small cleft of the superior labrum (arrowhead) should not be mistaken for a tear.



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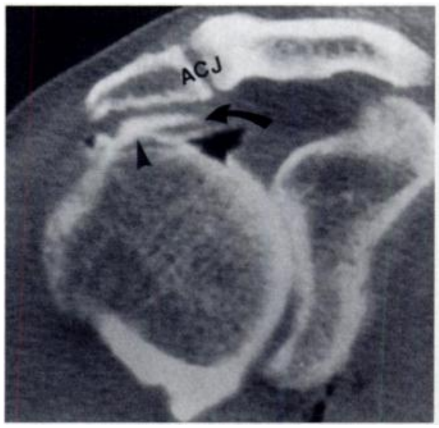

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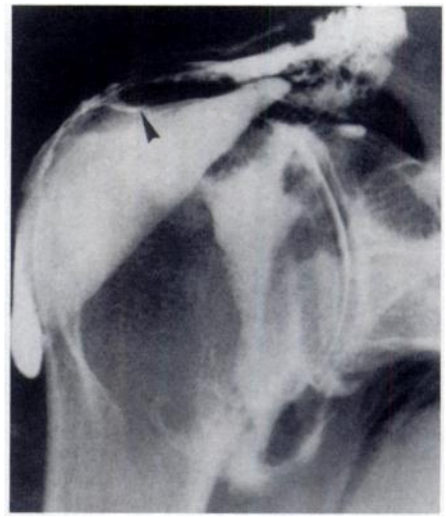
Figure 5. Partial tear in the articular surface of the supraspinatus tendon in the right shoulder of a 51-year-old woman. **(a)** Arthrogram shows contrast medium in the supraspinatus tendon (arrowhead). **(b)** COS shows the tear at the articular surface of the supraspinatus tendon (arrowhead) and within the tendon (arrow). *ACJ* = acromioclavicular joint.



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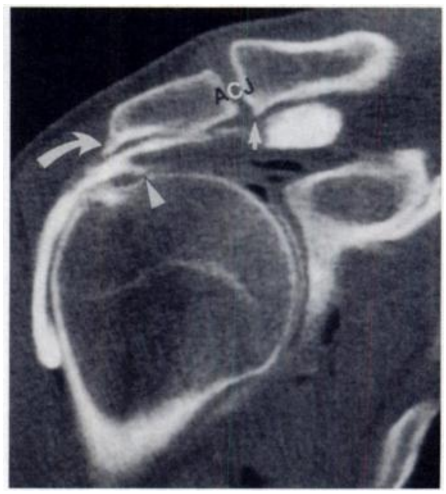


b.

Figure 6. Small, full-thickness tear of the right shoulder of a 40-year-old man. **(a)** Arthrogram shows a small complete tear (arrowhead). **(b)** COS shows a small complete tear of the supraspinatus tendon (arrowhead), thinning of the tendon, acromial spur (curved arrow), and degeneration of the acromioclavicular joint (*ACJ*) with a small inferior spur (straight arrow).

patients underwent studies with a CT 9800 Q imager (GE Medical Systems, Milwaukee, Wis) and 10, with a CT Pace Plus imager (GE Medical Systems).

At surgery, 18 patients were found to have a complete cuff tear, four had a partial tear of the articular surface of the supraspinatus tendon, two had an impingement syndrome without any rotator cuff tear, three had calcific tendinitis of the supraspinatus, five had chronic shoulder instability, two had a type 3 superior labral, anterior, and posterior (SLAP) lesion, and one had an avulsion of the tendon of the long head of the biceps brachii (type 4 SLAP lesion).

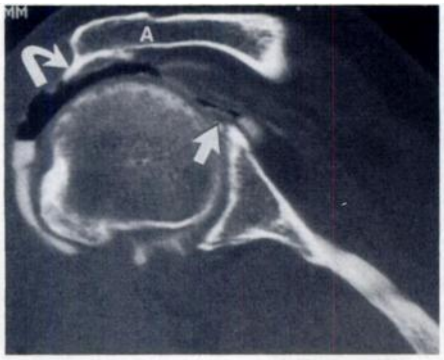
All patients underwent conventional double-contrast arthrography followed by axial CT. We used as contrast material 4–6 mL of Hexabrix 32 (sodium ioxaglate and meglumine ioxaglate; Guerbet, Aulnay-sous-Bois, France) and 8–15 cm^3 of air. After injection of contrast media, the shoulder was exercised and radiographs were obtained with the patient in supine and erect positions, with the arm in internal and external rotation. CT was then performed immediately, with the arm in the neutral position and the contralateral arm placed above the head. Patients were asked to hold their breath for each scan. Consecutive 5-mm-thick sections were obtained in 25 cases and 2-mm-thick sections in 10 cases. Then sagittal views were obtained with the Beltran technique in all cases.

Coronal oblique sections (COSs) were then obtained in the following manner: The patient was seated directly on the slope of the gantry, with the contralateral shoulder against the gantry. The contralateral hand gripped the table and the patient's feet pressed against the support of the table to stabilize the patient. The shoulder was then positioned in the center of the gantry, with the arm in slight abduction and slight external rotation (Fig 1). By palpating the acromion and using laser light for guidance, an axial rotation of about 30° was obtained to produce images in a plane parallel to the supraspinatus muscle and tendon courses (Fig 2). The patient had to flex the neck and maintain extension of the ipsilateral elbow to avoid beam-hardening artifact.

The parameters were 120 kV, 160 mA, and 2-second imaging time with the CT Pace Plus imager and 120 kV, 170 mA, and 2-second imaging time with the 9800 Q imager. A 15- or 25-cm field of view and a 5-mm section thickness were used. Data were stored in case an off-center reconstruction was necessary. A high-resolution algorithm (bone algorithm) was used.

Two or three sections were necessary in 18 cases because the patient was placed too far anterior or posterior. The patient was moved manually to correct his or her position. The maximal time needed for this procedure was 5 minutes.

We studied the rotator cuff and the superior labrum by using the COS. Rotator cuff tears were interpreted as complete when the subacromial bursa was filled



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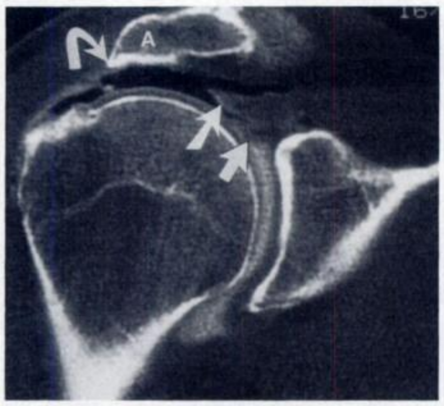
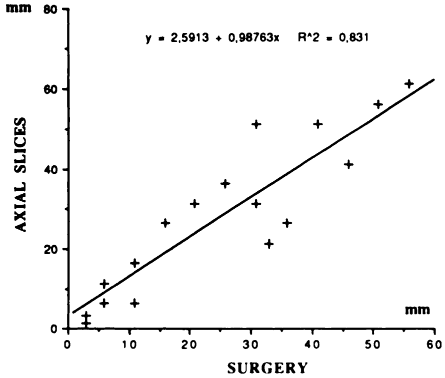


b.

Figure 7. Large rotator cuff tear in the right shoulder of a 60-year-old man. (a) COS obtained with poor positioning of the patient. The rotator cuff tear (straight arrow) is detected but cannot be measured accurately. Large acromial spur (curved arrow) and sclerosis of the acromion (*A*) are also seen. (b) COS obtained with correct positioning of the patient shows retraction of the tendon edge (straight arrow at left) and the spur of the acromion (*A*) (curved arrow). The superior labrum is indicated by the straight arrow at right.



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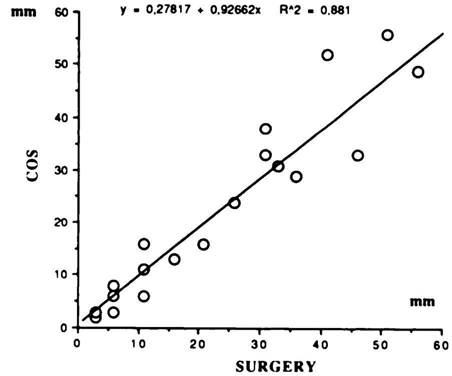


9.

Figures 8, 9. (8) Comparison, by means of linear regression analysis, of the size of the rotator cuff tears measured on axial sections with that found at surgery (r = .91). (9) Comparison, by means of linear regression analysis, of the size of the rotator cuff tears measured on the COS with that found at surgery (r = .93).

with contrast medium and as partial when contrast medium was passing through the cuff but not into the bursa. The rotator cuff tears were measured on the COSs and axial sections. With linear regression, these measurements were compared with those obtained by means of surgery. To determine whether the measurements obtained with the COSs were more precise than those obtained with the axial sections, a t test was performed with the Fisher transformation to verify the equality of the correlation coefficients (10).

The location of the calcifications was noted. Subacromial spurs and degeneration of the acromioclavicular joint were also noted. A cleft completely through the superior labrum was considered diagnostic of a labral tear.

RESULTS

The supraspinatus muscle and its tendon were well seen on the COS (Fig 3). The bone structures, especially the acromion, were well displayed.

Measurements of the Rotator Cuff Tears Determined with Surgery, COS, and Axial Section

	Measurement (mm) Obtained with		
Patient	Surgery	COS	Axial Section
1	2	1	2
2	2	2	0
3	5	2	5
4	5	5	5
5	5	7	10
6	10	5	5
7	10	10	15
8	10	15	15
9	15	12	25
10	20	15	30
11	25	23	35
12	30	37	50
13	30	32	30
14	32	30	20
15	35	28	25
16	40	51	50
17	45	32	40
18	45	32	40
19	50	55	55
20	55	48	60

The acromioclavicular joint was seen in 24 cases, while the acromion was solely visible in 11 cases.

The superior labrum had a sharp triangular shape, with a small cleft at its central part, and was usually surrounded by air (Figs 3, 4). The biceps tendon was apparent in 18 cases (Fig 4).

In two cases of complete rotator cuff tear, the COS could not be obtained in a good position. Therefore, in one case the tear could not be observed, and in the other case it could not be measured accurately. All the other rotator cuff tears were detected with the COS (sensitivity, 95% [21 of 22]). No false-positive results were noted (specificity, 100%). Partial and complete tears were differentiated accurately (Figs 5–7). One partial tear that was not apparent on the axial section was detected on the COS.

The measurements of the rotator cuff tears determined with the COS and axial section were separately compared with those surgically obtained (Table). The measurements obtained with the axial section and surgery were strongly correlated (r = .91, P < .0001) (Fig 8), as were the measurements obtained with the COS and surgery (r = .93, P < .0001) (Fig 9). The test for equality of the two correlation coefficients showed no statistically significant difference.

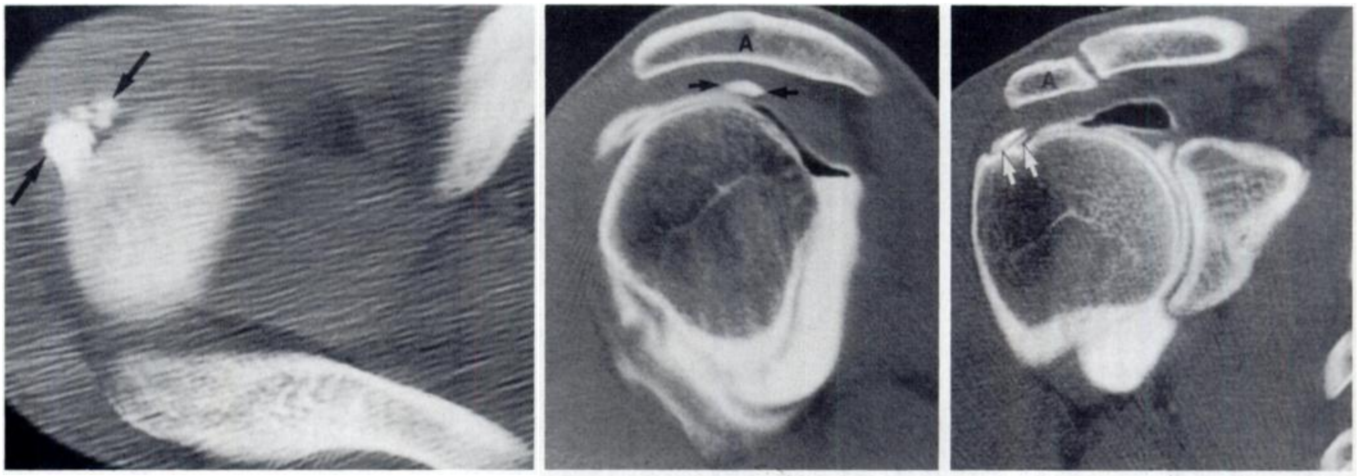
Calcifications of the supraspinatus tendon were well depicted and their location well determined. In one of the three patients who had calcific tendinitis, calcific deposits were close to the bursal surface of the tendon, and in the other two, calcifications were close to the undersurface of the tendon (Fig 10).

Acromial spurs were present in 21 cases at surgery and were depicted on plain radiographs and the COS in 19 cases. In two cases, the COS showed degeneration with substantial osteophytes of the acromioclavicular joint that were understated on the plain radiographs.

All the SLAP lesions were diagnosed with the COS (Figs 11, 12).

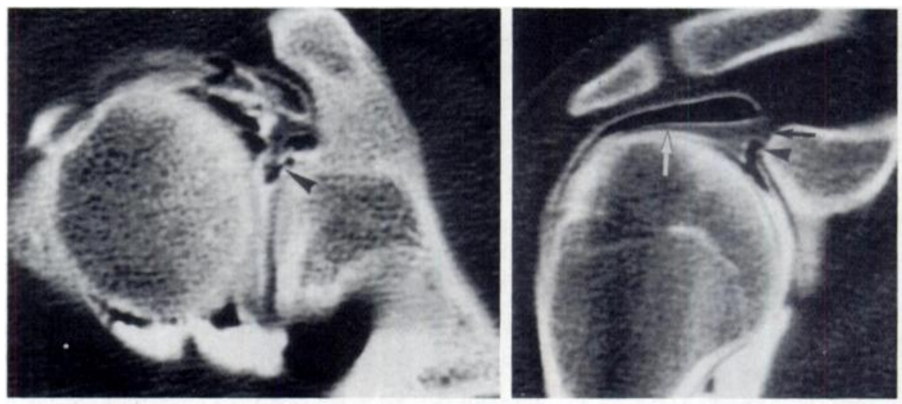
DISCUSSION

It is important to differentiate full-thickness from partial-thickness tears because treatment is different. Partial-thickness tears, unlike full-thickness tears, are frequently managed with conservative treatment or arthroscopic surgery. Moreover, the size of the tear and musculotendinous retraction are important findings for surgical planning.



a. b. c.

Figure 10. (a) Axial section, (b) direct sagittal scan of the shoulder, and (c) COS show calcific deposits in the supraspinatus tendon (arrows) close to the undersurface of the tendon. *A* = acromion.



a. b.

Figure 11. Type 3 SLAP lesion in the right shoulder of a 19-year-old man. (a) Axial section shows an anterosuperior labral tear (arrowhead). (b) COS shows a cleft completely through the superior labrum (arrowhead). The biceps tendon is intact (arrows).

Ultrasonography (US) and arthrography are the techniques most commonly used to study the rotator cuff. Shoulder US provides noninvasive, accurate, and low-cost imaging of the rotator cuff (11,12). US differentiation of edema, scarring, partial-thickness defects, and small full-thickness tears, however, is difficult to establish (11,13).

Arthrography is very sensitive in the detection of rotator cuff tears, but its accuracy in predicting the size of tears is just over 50% (14). Arthrographic CT is also very sensitive (1), although axial sections do not provide good visualization of the supraspinatus tendon. Thus, the location and size of the tear might be difficult to establish. Direct sagittal CT of the shoulder as described by Beltran et al depicts rotator cuff tears (2) and, in some cases, permits their anteroposterior measurement.

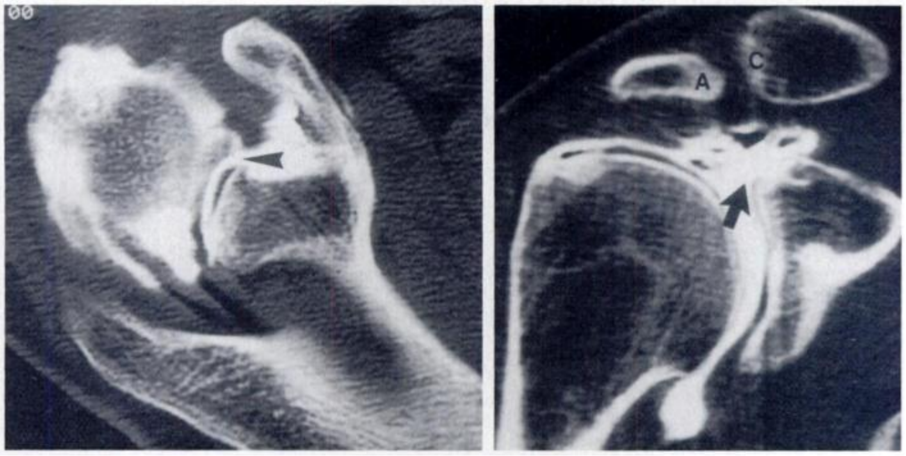
All these techniques have been partially replaced by MR imaging. This noninvasive technique is considered by some authors to be the most sensitive in detecting rotator cuff tears (5,6), although Flannigan et al noted a 35% false-negative rate (15) and Hodler et al found it difficult to correctly diagnose partial tears (8). MR imaging can be used consistently to predict the size of the tear (7). Moreover, MR imaging allows evaluation of tendinitis (4) and can depict the subacromial spur formation and acromioclavicular degenerative joint disease associated with chronic impingement (5). This accuracy is probably due to the ability to show coronal oblique and sagittal oblique views and to the high degree of contrast between the different soft tissues. MR imaging technique requires a good coil, off-centering software, and small fields of view. In some institutions, not all these conditions can be satisfied, and arthrography with CT remains the standard of reference for shoulder exploration.

Our study proves that COS imaging, when applied in studying the rotator cuff, is accurate in detecting rotator cuff tears and calcifications and in depicting the subacromial spurs and osteophytes of the acromioclavicular joint. Differentiation between partial and complete tears is easy.

The size of the tears can be measured accurately with the COS, but these measurements are not significantly different from those obtained with axial sections. Tears are sometimes difficult to measure on axial sections, however, because of the oblique course of the supraspinatus tendon. Several sections are necessary to visualize the edges of the tendon, since they are not all visible on a single section. In these cases, direct measurement and good localization of the tears are obtained with the COS. Moreover, the COS enables us to appreciate the relationship between the supraspinatus tendon and the acromion or between the tendon and the acromioclavicular joint. Neither routine arthrographic CT nor COS imaging, however, are able to depict edema, isolated midsubstance tears, and superior surface tears.

The COS involves little cost for the patient and the radiologist, as it is obtained in addition to the routine CT arthrogram in less than 5 minutes. Thus it provides adequate exploration of the cuff for a lower price than that of MR imaging.

Tears of the superior glenoid labrum result from injuries that place excessive stress on the tendon of the long head of the biceps brachii muscle (16,17). CT arthrography is considered



a. b.

Figure 12. Avulsion of the tendon of the long head of the biceps brachii in the right shoulder of a 49-year-old man (type 4 SLAP lesion). **(a)** Axial section shows a tear of the anterosuperior labrum (arrowhead). **(b)** COS shows an avulsion of the superior labrum and biceps tendon (arrow). *A* = acromion, *C* = clavicle.

very good for detecting labral tears (9,18,19), and Hunter et al could classify SLAP lesions with this technique (20). The superior labrum, however, is not well visualized on axial images and is better demonstrated with coronal images (21,22). Using the COS, we detected three SLAP lesions (Figs 11, 12). Currently, use of the COS to diagnose SLAP lesions is being investigated in a prospective study.

In summary, MR imaging is a thorough technique to study the rotator cuff especially because of its multiplanar capability. Should MR imaging performances not be in accordance with the required technical standards, however, arthrography with CT remains the standard of reference to explore the shoulder. In such cases COS imaging, as an additional tool, is a fast and reliable way to study the rotator cuff and to accurately measure rotator cuff tears. Moreover, the COS provides excellent visualization of subacromial spurs and acromioclavicular joint degeneration. ■

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