Comparative study of direct MR arthrography and CT arthrography with arthroscopic correlation in preoperative evaluation of anterior shoulder instability

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Abstract Purpose: To compare direct MR arthrography and CT arthrography for the preoperative planning of shoulder anterior instability.

Patients and methods: 47 patients were included in this study. 43 patients with clinical history of anterior GHI or recurrent shoulder pain had no clinical findings of rotator cuff abnormality. They experienced multiple anterior dislocations of the shoulder. No patient showed evidence of multidirectional instability or generalized ligamentous laxity. The remaining 4 patients complained of anterior shoulder instability after anchor repair. All the patients underwent direct CT and MR arthrography. The results of CTA and MRA were compared with results obtained from arthroscopy in each patient to detect the sensitivity and specificity of each modality.

Results: The sensitivity and specificity of CTA for bankart lesion are 89.4% and 96.4% respectively and of MRA 94.7% and 96.4%, for Perthes lesion the sensitivity and specificity of CTA are 33.3% and 100% respectively and of MRA 66.6% and 100%, for ALPSA the sensitivity and specificity of CTA are 85.7% and 97.5% respectively and of MRA 100% and 97.5%, for GLAD the sensitivity and specificity of CTA are 80% and 97.6% respectively and of MRA 60% and 97.6% respectively.
1. Introduction

Anterior glenohumeral instability is a common cause of morbidity in young patients, particularly athletes, and often requires surgical reconstruction to restore the shoulder function. The clinical spectrum of instability ranges from obvious recurrent dislocation to equivocal symptoms that may mimic other shoulder disorders. Imaging examinations are used to guide preoperative planning and the selection of appropriate therapy (1,2).

The surgical treatment of anterior shoulder instability largely depends on the severity of bone and soft-tissue injuries found on preoperative imaging (1,2). Because MR arthrography is considered the reference standard for shoulder imaging, the diagnostic performances of this imaging modality in the evaluation of the glenohumeral articular structures have been widely studied (3,4). On the other hand, the advent of high-resolution MDCT technology has markedly increased the quality of current CT examinations, which has propelled MDCT arthrography to the forefront in a growing number of indications in shoulder imaging (5). Thus, specific indications of MDCT arthrography are no longer limited to absolute or relative contraindications to MR arthrography, such as pacemakers and other MRI-incompatible implanted medical devices, claustrophobic patients, and metal hardware in close proximity to the joint (5,6).

Because the combined and safe use of iodinated contrast material and gadolinium chelates (for fluoroscopic confirmation of the articular position of the needle and MR arthrography, respectively) provides the opportunity to correlate MDCT arthrography and MR arthrography findings, recent reports suggest that MDCT arthrography may allow a valuable assessment of labroligamentous lesions related to shoulder instability (7,8). This imaging technique, with its excellent spatial resolution, contrast resolution, and multiplanar capabilities, has even been described as more reliable than MR arthrography for the detection of osseous and articular cartilage lesions (9,10).

The purpose of this study was to assess prospectively the diagnostic effectiveness of MDCT arthrography in the preoperative planning of anterior shoulder instability, in comparison with MR arthrography and arthroscopy.

2. Patients and methods

2.1. Patients

Forty-seven patients were prospectively enrolled between March 2010 and December 2012. Inclusion criteria were anterior shoulder instability with proposed arthroscopic treatment; MDCT arthrography and MR arthrography of the shoulder performed (with the time interval between the two examinations is 1 h) in our institution, according to a standardized protocol as part of the preoperative workup; and arthroscopy of the shoulder performed by the same orthopedic surgeon, with a prospective description of the intraarticular lesions related to anterior shoulder instability. Exclusion criterion was a time delay between imaging and arthroscopy longer than 1 month. Thirty-five patients were males and 12 were females. The age range was 21–48 years (mean age, 26 years). Patients were informed that their arthrographic and arthroscopic charts could be reviewed for scientific purposes and gave their informed consent. The institutional ethics committee approved the study.

2.2. Imaging technique

After administration of local anesthesia and intraarticular positioning of a 22-gauge needle by using an anterior approach, 10–12 mL of a mixture of iopamidol (300 mg iodine/mL), gadoteridol (4 mmol/L), and saline solution were injected under fluoroscopic guidance. MDCT arthrography was then performed, immediately followed by MR arthrography. MDCT arthrography was performed on a 64-MDCT helical unit (VCT 64, GE Healthcare). Patients were placed in the supine position, with the arm along the body, the shoulder in neutral position, and the thumb pointing upward. After acquisition of the coronal scout image, axial scanning was performed between the upper pole of the acromioclavicular joint and the lower margin of the axillary recess. Scanning was performed with the following parameters: 120 kV, 300–350 mA, slice thickness of 0.625 mm, FOV of 18 cm, bone reconstruc-

<table>
<thead>
<tr>
<th>Type of findings</th>
<th>The number</th>
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<tr>
<td>Classic Bankart lesion</td>
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<tr>
<td>Perthes lesion</td>
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<td>ALPSA</td>
<td>7</td>
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<td>GLAD</td>
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<tr>
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<td>Post operative Bankart</td>
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<td>Humeral head fracture</td>
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<td>Glenoid fracture</td>
<td>7</td>
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tion kernel, and reconstruction thickness of 1 mm. Oblique sagittal and oblique coronal reformatted images parallel and vertical, respectively, to the glenoid fossa were obtained. MR examinations were done for all patients using Magnitom Symphony 1.5 Tesla, Syngo, Siemens and dedicated phased array shoulder coil. Similar sequences were obtained in every patient. Transverse turbo spin-echo (SE) T1-weighted images (TR/TE, 1191/16; FOV, 180 mm; slice thickness, 3 mm; slice interval, 0.3 mm; matrix, $512 \times 512$), coronal and sagittal fat-suppressed SE T1-weighted images (TR/TE, 551/14; FOV, 180 mm; slice thickness, 3 mm; slice interval, 0.3 mm; matrix, $512 \times 512$), coronal fat-suppressed SE T2-weighted images (TR/TE, 3500/90; FOV, 180 mm; slice thickness, 4 mm; slice interval, 0.4 mm; matrix, $256 \times 512$), and 3D gradient-echo T1-weighted images (TR/TE, 9.2/4.6; FOV, 160 mm; slice thickness, 0.4 mm; matrix, $512 \times 512$) were obtained with the arm in neutral position.

### 2.3. Image analysis

MDCT arthrography and MR arthrography examinations were blinded and randomly evaluated in consensus by musculoskeletal radiologist with 5 and 9 years of experience. Readings between the CT and the MRI examinations were separated by a 4-week interval. The osseous abnormalities involving the humeral head and glenoid, glenoid cartilage lesions, and labroligamentous lesions were assessed independently on each imaging modality.

Criteria established in previous studies were applied for the classification of labroligamentous lesions: a Bankart lesion was diagnosed if contrast medium was interposed between the glenoid and the detached labroligamentous complex. Loss of the triangular shape and increased signal intensity of the anteroinferior labrum were additional criteria for Bankart lesions, but only complete detachment of the labroligamentous complex was assessed as a Bankart lesion (4). Criteria for a Perthes lesion were a nondisplaced tear of the anteroinferior labrum that was attached by a linear structure with decreased signal intensity believed to be the intact medial periosteum (4). The ALPSA lesion differs from the classic Bankart lesion because the avulsed anterior labroligamentous structure is displaced medially along with an intact anterior scapular periostuem. An ALPSA lesion was diagnosed if the anteroinferior labroligamentous complex was displaced medially on the glenoid neck and if the labrum was absent on the glenoid rim (4). Criteria for a GLAD lesion were a superficial tear of the anteroinferior labrum with an adjacent articular cartilage injury (7).

Post operative anchor repair was assessed for the position of each anchor track and was recorded according to the analogue clock notation system. Further, we assessed whether intraarticular contrast material had extravasated through the suture in each imaging plane (2).

### 2.3.1. Assessment of capsular insertion type

We assessed the type of capsular insertion by using the classification established in the previous study. A type I capsule arose from the labrum, a type II capsule arose from the scapular neck within 1 cm of the labral base, and a type III capsule arose from the scapular neck more than 1 cm medial to the labral base (7).

### Table 2 MDCT arthrography findings.

<table>
<thead>
<tr>
<th>MDCT arthrography</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
<th>Accuracy</th>
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<tr>
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### Table 3 MRI arthrography findings.

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<th>PPV (%)</th>
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<tr>
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<td>97.5</td>
<td>83.3</td>
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2.4. Arthroscopy

Arthroscopic examinations of the shoulder were performed by the same orthopedic surgeon specialized in shoulder and elbow surgery. Arthroscopy was performed less than 1 month after imaging examinations. During arthroscopy, MDCT arthrography and MR arthrography images on film hard copy were available to the surgeon. Arthroscopy was performed with general anesthesia, with the patient in the beach chair position and the affected arm placed at the side of the body with the elbow flexed and the forearm resting on an arm rest, with neutral rotation. Diagnostic arthroscopy was performed using a 4-mm arthroscope.

The osseous abnormalities involving the humeral head and glenoid, glenoid cartilage lesions, and labroligamentous lesions were evaluated.

Fig. 1 A 26 year old male with recurrent shoulder dislocation. CT transverse (A) and fat suppressed T2 weighted MRI (B) showed torn and displaced anterior labrum.

Fig. 2 A 31 year old male with recurrent shoulder dislocation. CT transverse (A and B) coronal (C), MRI transverse T1WIs (D) and fat suppressed T2 WIs (E and F) showed torn and displaced anterior labrum.
Because a number of variants of anteroinferior labroligamentous lesions have been reported, Bankart lesions were identified in keeping with published descriptions (12). The classical Bankart lesion is described as detachment of the anteroinferior labrum with its associated glenohumeral ligament complex. The Perthes lesion is a labroligamentous avulsion, as well, but with medially stripped intact periosteum. The anterior labral periosteal sleeve avulsion (ALPSA) lesion is a tear of the anteroinferior labrum without rupture of the anterior scapular periosteum, with medial displacement of the inferior glenohumeral ligament, labrum, and periosteum in a sleeve-like fashion on the glenoid neck. The glenolabral arthicular disruption (GLAD) lesion represents a superficial tear of the anterior labrum attached to a fragment of articular cartilage.

Fig. 3 A 23-year-old man with anterior shoulder instability. CT transverse (A) and coronal (B), MRI fat suppressed T2WI and T1 transverse (C) and coronal (D and E) show anterior labral periosteal sleeve avulsion lesion with medial displacement of inferior glenohumeral ligament, labrum, and periosteum on glenoid neck.

Fig. 4 A 27-year-old man with anterior shoulder instability. CT transverse (A), MRI transverse fat suppressed T2WI and T1WI (B) show anterior labral tear with adjacent focal articular cartilage defect.
without associated capsuloperiosteal stripping. (12). Post operative anchor repair was assessed for reattachment of the anterior capsule and was judged as tight when no pocket was found at the glenoid margin from the view of the posterior arthroscopic portal. Reattachment of the anterior capsule was judged as redundant when a pocket was observed at the glenoid margin from the view of the posterior arthroscopic portal(13).

2.5. Data analysis

We compared the direct CT and MRI arthrography findings with arthroscopy findings in each patient and determined the number of true-positive, true-negative, false-negative, and false-positive results of both arthrography techniques. Their sensitivity, specificity, PPV, NPV, and accuracy in the diagnosis of different capsulolabral abnormalities were calculated.

3. Results

3.1. Arthroscopic Findings

Arthroscopic examination, confirmed pathological findings in 43 out of 47 patients included in this study. The findings include 19 classic Bankart lesion, 3 perthes lesions, 7 ALPSA, 5 GLAD, 2 SLAP, 3 absent labrum, 4 post operative Bankart, 27 humeral head (Hill-Sachs) fractures and 7 glenoid rim (Bankart) fractures (Table 1). The sensitivity, specificity, PPV, NPV and accuracy of direct CT and MR arthrography were compared to arthroscopic findings (Tables 2 and 3).

4. Discussion

Gleno-humeral instability refers to symptomatic subluxation or dislocation of the humeral head in relation to glenoid fossa. Anterior inferior instability is the most common type to involve the gleno-humeral joint occurring in 95% of all patients (14). The remaining 5% of the patients have posterior (3%), inferior, superior or multidirectional instability (14).

Since different types of anterior labroligamentous lesions require different surgical procedures, preoperative discrimination of lesions is of importance (15). In addition, results of several investigations on arthroscopic procedures showed that a strong anterior band of the inferior glenohumeral ligament and arthroscopically good delineation of the anterior labrum and associated glenohumeral ligament complex were predictors for a favorable postoperative outcome; therefore, several authors have suggested the use of proper selection criteria to obtain optimal results after arthroscopic stabilization without accepting an increased risk for recurrence. Again, accurate
imaging is essential in the proper management of anteroinferior labroligamentous lesions (15).

Although MR arthrography is considered the reference standard for shoulder imaging, MDCT arthrography could also provide a valuable preoperative assessment, given its excellent spatial resolution, multiplanar capacity, and high contrast resolution (11). In addition, MDCT arthrography is less expensive than MR arthrography and has a limited examination time (15).

In the current study, arthroscopic examination confirmed pathological findings in 43 out of 47 patients included in this study. The findings include 19 Bankart lesion, 3 Perthes lesions, 7 ALPSA, 5 GLAD, 2 SLAP, 3 absent labrum, 4 postoperative Bankart, 27 humeral head (Hill-Sachs) fractures and 9 glenoid rim (Bankart) fractures.

In our study Bankart lesion was the most common abnormality (Figs. 1 and 2). It involves interruption of the anteroinferior glenoid labrum which may appear irregular in outline or entirely absent with stripping of the capsule from the scapular periosteum (16). Direct CT arthrography has lower sensitivity, NPV and accuracy in (84.2%, 90%, and 91.4%) the detection of glenoid lesions compared to MR arthrography (94.7%, 96.4%, and 95.7%). This was in agreement with other studies (11).

In our study, we have 7 cases of ALPSA lesions (Fig. 3). CT arthrography has lower sensitivity and similar specificity (85.7% and 97.5%) compared to MR arthrography (100%, 97.5%). A medially displaced labroligamentous complex and absence of the labrum on the glenoid rim were reliable criteria for the diagnosis of ALPSA lesions. Typical features of ALPSA lesions in patients with chronic instability were labral degeneration and scar tissue formation of the medially displaced anteroinferior complex (17).

In this work Perthes lesions were confirmed in 3 cases. CT arthrography has lower sensitivity but similar specificity (33.3% and 100%) compared to MR arthrography (66.6% and 100%). On imaging of the shoulder with the arm in a neutral position (as performed in the current study), the torn labrum may be held in its normal anatomic position by an intact scapular periosteum, which thereby prevents contrast media from entering the tear (9–18). It was supposed that especially in Perthes lesions the abduction external rotation position, which could not be implemented in our study because of technical reasons, would improve the detectability. In this position, traction is applied to the inferior glenohumeral ligament complex and the partially detached labrum is pulled away from the glenoid, which allows the defect to fill with contrast media. Results of previous studies have indicated an improvement in the overall detection of nondisplaced labral tears with use of the abduction external rotation position (18).

In our study GLAD lesions were confirmed in 5 cases (Fig. 4). CT arthrography has higher sensitivity (80%) than MR arthrography (60%) because of its high spatial resolution. In contrast with other anteroinferior labroligamentous lesions,
GLAD lesions are usually stable. They were included in our study because differentiation from unstable lesions is of therapeutic importance. Normal functioning of the anterior labroligamentous complex is usually preserved. GLAD lesions are treated with arthroscopic débridement of the labrum and chondral injury without the need for a stabilization procedure (10–19).

Absent or degenerated anterior inferior glenoid labrum was found in 3 cases (Fig. 5) in our study all were detected by CT arthrography having higher sensitivity and specificity than MR arthrography. It is very important for the preoperative diagnosis of absent or degenerated anterior inferior labrum; as the arthroscopic stabilization procedure could not be performed due to poor quality and quantity of tissue. The distinction of Bankart lesion from ALPSA, Perthes or GLAD may be useful but not necessary for a treatment decision, but, many several authors have suggested that a degeneration or absence of the antero-inferior capsulo-labral complex is an important criterion for treatment decision (6–20).

In our series, type II SLAP lesions were found in 2 patients (Fig. 6), both were correctly diagnosed by direct CT and MR arthrography. The contrast was extending between the detached superior labral bicipital complex and the superior glenoid rim. This was in accordance with Waldt, et al. (21). The superior labrum has a close anatomic relationship with the long head of bicipital tendon and both the superior and middle gleno-humeral ligaments. In the presence of superior labral detachment the origin of bicipital tendon, and superior and middle gleno-humeral ligaments may lose their anchor to the glenoid rim (22). Disruption of these structures places a greater magnitude of strain on the inferior gleno-humeral ligament which with repetitive stress loading can stretch gradually and become incompetent (22).

In the current study we have 4 cases of recurrent post operative Bankart lesions (Fig. 7) all were detected by direct CT arthrography and 2 of these cases were missed by direct MR arthrography caused by artifact from anchor fixation. One of these cases showed focal and the other 3 cases showed complete detachment of the capsulolabram complex from the glenoid rim. These were in agreement with previous studies (23,24).

In our study in patients with capsule-labral abnormality capsular insertion type one was found in 17 shoulders, type two was found in 16 shoulders (Fig. 2) and type three was found in 14 shoulders (Fig. 4). Boileau et al., reported that types of capsular insertions were not statistically significantly different between shoulders classified clinically as stable and unstable, therefore had no role in the evaluation of anterior glenohumeral instability (2).

Osseous injuries may be observed following anterior dislocation or subluxation as a result of impaction of the postero-superior aspect of the humeral head against the anterior or antero-inferior glenoid margin. The resulting defect or deformity of the superolateral aspect of the humeral head is called Hill sachs deformity (1). This was seen in 27 patients with Bankart lesion (Fig. 5). A fracture of
the anterior glenoid margin was detected in 7 patients (Figs. 8 and 9). CT and MR arthrography had similar accuracy in the detection of Hill sachs lesion, however CT arthrography was more accurate than MR arthrography in the detection of fractured anterior glenoid margin. This osseous defect along the anterior and inferior margin of the glenoid is produced by the anterior and inferior translation and impaction of the humeral head against this rim (11). A fragment of variable size is avulsed together with the labroligamentous complex. This bony defect may lead to reversal of the normal pear shape of the glenoid surface, which promotes recurrent dislocations (11). Defects representing more than 7 mm, or more than one third of the glenoid surface, are usually treated with fragment refixation, coracoid transfer, or even bone grafting (25). Failure to address such glenoid bone loss is one of the main risk factors for the recurrence of shoulder dislocation after surgery. Because one cannot predict the degree of glenoid bone loss on the basis of the number of dislocations alone, preoperative identification and quantification of glenoid defects are useful, because this information helps to predict the likelihood of further dislocation and to determine the need for bone augmentation surgery to restore shoulder stability (26,27).

The present study is not without limitations. First, although arthroscopy was the best reference standard available for this study, it is an operator-dependent method, second, the fact that the decision to perform arthroscopy was based not only on clinical findings but also on imaging findings introduced a verification bias. In addition, findings at arthroscopy could have been biased by the availability of CT and MR reports. Third, although the total number of arthroscopically proved anteroinferior lesions was high, the number of ALPSA, Perthes, SLAP, GLAD and postoperative lesions was small to allow further statistical analysis.

5. Conclusion

In most institutions, MR arthrography is considered the reference standard for shoulder imaging. Although it nicely revealed the labroligamentous injuries in our population, MR arthrography also showed some limitations in the assessment of cortical bone. On the other hand, MDCT arthrography provided excellent three-plane resolution and precise answers to all preoperative questions in our study. Thus, our data suggest that MDCT arthrography is a method of choice for the preoperative planning of anterior shoulder instability. Be-

Fig. 8 A 23-year-old man with anterior shoulder instability. CT transverse (A) and coronal (B), MRI transverse T1WIs (C and D) show glenoid rim fracture by CT (arrow), which was misdiagnosed on T1-weighted MRI as anterior labral periosteal sleeve avulsion lesion (arrow).
cause it appears particularly reliable for the detection of gelenoid rim fractures, which represent crucial findings in the preoperative planning, this imaging technique may beneficially affect patient management by means of selecting the proper surgical treatment.

Conflict of interest

The authors have no conflict of interest to declare.

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Fig. 9 A 34-year-old man with anterior shoulder instability. CT transverse (A and B), and coronal (C), MRI transverse (D), coronal (E and F) show gelenoid rim defect and intraarticular loose body (large arrow), and hill sachs (small arrow).


