Shoulder joint instability evaluation by CT arthrography and MR arthrography

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Shoulder instability;
MRA;
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Abstract  Background and introduction: Our work aimed to compare and evaluate CT arthrography (CTA) and MR arthrography (MRA) techniques in diagnosing glenohumeral joint instabilities, also help the clinician to choose the ideal diagnostic modalities CTA & MRA either separately or combined to reach the early and accurate diagnosis of glenohumeral joint instability.

Patient and methods: The study included 96 patients: 72 males, 24 females. Their age ranged from 14 to 51 years (mean = 33), complaining of shoulder dislocation whether traumatic or non-traumatic with glenohumeral instability.

For every patient, intra-articular contrast injection was done followed by CT and MRI arthrography (CTA & MRA).

Results: Preliminary results showed the role of CTA & MRA in diagnosing the causes of instability. Correlation between CTA and MRA may have a role in more accurate diagnosis of glenohumeral instability.

Conclusion: The combination of CT arthrography and MR arthrography is a promisable one in defining the type of instability.

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1. Aim of work

Our work aimed to compare and evaluate CT arthrography to MR arthrography techniques in diagnosing glenohumeral joint instabilities, also help the clinician to choose the ideal diagnostic modalities CTA & MRA either separately or combined to reach the early and accurate diagnosis of glenohumeral joint instability. Also our aim was to evaluate the usage of both CT and MR arthrography of the shoulder as a one-shot examination.

2. Patients and methods

96 patients, 72 males and 24 females, aged from 14 to 51 years (mean = 33), complaining of shoulder dislocation whether traumatic or non-traumatic, were referred to the Nile scan diagnostic centre from the outpatient orthopaedic clinic of different university, governmental and private sector hospitals.

2.1. Fluoroscopic guided injection of contrast

– Direct MR arthrography was done using fluoroscopic guided (anterior approach) using Omni Diagnost Multipurpose X-ray system (PHILIPS) which comprises a table with

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an over-table tube user interface, an automatic serial changer and a large image intensifier.

- The best position for doing fluoroscopically guided arthrography is through anterior approach with patient supine and the shoulder is mildly rotated externally.

- Technique
  - Prepare the shoulder in a sterile fashion.
  - Given local anaesthesia.
  - Lead marker is placed under fluoroscopic guidance just lateral to the junction between middle and lower third of the medial cortex of scanned humeral head.
  - The needle tip (22-gauge) is inserted in an anteroposterior direction perpendicular to the fluoroscopic beam until it reaches the scanned head of the humerus.
  - The needle is angled obliquely towards the glenoid.
  - Start injection of the contrast (the mixture used is composed of 0.1 ml gadopentetate dimeglumine, 5 ml non-ionic contrast, 3 ml xylocaine and completed to 20 ml with sterile saline). To be sure that contrast material being placed intra-articular, you must see column of contrast agent between the glenoid and the humerus.
  - The patient should be scanned with MRI during max. 30 min of injection.

2.2. Magnetic resonance arthrography

- Devices MR 1.5-Tesla (Achieva philips Medical Systems).
- Patient position: The patients should be supine with the head directed towards the scanner bore. The preferred positioning of the patient’s arm is neutral to slightly externally rotate.
- Surface coils (flexible coils) are those that wrap around and conform to the anatomic area of interest.
- Imaging planes and pulse sequences.
  - Preliminary Scout Localizer in axial, sagittal, coronal.
  - Coronal T1 (TSE, TR 664, TE 18, FOV 14, SL 4, MT-ARIX 205/512, NSA 3).
  - Coronal T2 (TSE, TR 2411, TE 100, FOV 14, SL 4, MTARIX 201/512, NSA 2).
  - Coronal STIR (TSE, TR 2411, TE 15, FOV 14, SL 4, MTARIX 201/512, NSA 2).
  - Coronal PD (TSE, TR 1400, TE 16, FOV 18, SL 4, MTARIX 201/512, NSA 3).

Table 1 Comparative study of the radiological diagnoses in 96 patients with glenohumeral instability By MRA versus CTA.

<table>
<thead>
<tr>
<th>Lesions detected</th>
<th>Total lesions</th>
<th>Frequency &amp; percentage by CTA only</th>
<th>Frequency &amp; percentage by MRA only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bankart</td>
<td>16</td>
<td>12 75%</td>
<td>16 100%</td>
</tr>
<tr>
<td>Osseous Bankart</td>
<td>14</td>
<td>14 100%</td>
<td>10 71%</td>
</tr>
<tr>
<td>Perthes</td>
<td>28</td>
<td>16 57%</td>
<td>28 100%</td>
</tr>
<tr>
<td>ALPSA</td>
<td>16</td>
<td>10 62%</td>
<td>16 100%</td>
</tr>
<tr>
<td>GLAD</td>
<td>8</td>
<td>6 75%</td>
<td>8 100%</td>
</tr>
<tr>
<td>HAGL</td>
<td>4</td>
<td>2 50%</td>
<td>4 100%</td>
</tr>
<tr>
<td>GAGL</td>
<td>4</td>
<td>4 100%</td>
<td>4 100%</td>
</tr>
<tr>
<td>SLAP</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hill Sachs</td>
<td>60</td>
<td>60 100%</td>
<td>46 76%</td>
</tr>
<tr>
<td>Reversed Bankart</td>
<td>6</td>
<td>4 66%</td>
<td>6 100%</td>
</tr>
<tr>
<td>Reversed osseous</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Bankart</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Reversed Hill Sachs</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rotator Cuff tendon</td>
<td>42</td>
<td>14 33%</td>
<td>42 100%</td>
</tr>
</tbody>
</table>

Fig. 1 Right shoulder joint arthrography coronal T1WI (A), coronal T2WI (B), coronal T1WI fat sat (C) and coronal CT (D). The MR images showed a focal cortical and subcortical small area of abnormal MR signal being low on T1 & T2 and bright on STIR. The CT image showed a focal small cortical depression at the supero-lateral aspect of the humeral head representing HILL Sachs lesion (red arrows). The axillary pouch showed partial interruption of its humeral attachment (HAGL lesion) which was not clearly identified in CTA (blue arrow).

Chart 1 Comparative study of the radiological diagnoses in 96 patients with glenohumeral instability By MRA versus CTA.
– Axial GR (TSE, TR 551, TE 18, FOV 17, SL 4, MTARIX 179/512, NSA 3).
– Sagittal T2 (TSE, TR 3342, TE 100, FOV 16, SL 4, MTARIX 205/512, NSA 3).

2.3. CT arthrography

- Device used is multi-detector computed tomography 16 detector Toshiba Asteon.
- The patients are in a supine position with the arm lateral to chest wall at the side of the injection while the opposite arm is above the head. Antero-posterior and lateral scanogram was performed.
- The patients were scanned from the level just above the acromion process till the level of the proximal end of the humeral shaft.
- The images were obtained in the axial plane with post processing coronal oblique and sagittal oblique reconstruction in a plane like those performed in the MR scanner.
- The coronal oblique images were done in a direction parallel to the tendon of supraspinatus from before backward, while the sagittal oblique images were done perpendicular to the obtained coronal oblique images.

3. Results

The frequency of the different pathological lesions detected in glenohumeral joint instability in this study either by MRA or by CTA is tabulated in Table 1. Also Table 1 shows the frequency and percentage of the suspected lesions detected by CT arthrography alone and MR arthrography alone with respect to the total lesions (see Figs. 1, 3, 4, 7, 8, 14 and 18).

– In our study a comparative analysis was performed between CTA and MRA findings as regards the frequencies and percentage of lesions detected in the 96 patients and the results are tabulated in Table 1 and we use Charts 1 and 2 for more clear presentation of the results.
– The cartilaginous Bankart lesion (Figs. 5 and 20) was detected in 16 patients out of the 96 patients involved in this study. MRA detects all these 16 cases by a percentage of 100% while CTA can clearly identify 12 cases only out of the 16 patients by a lower sensitivity of 75%.
– As regards the osseous Bankart lesion (Figs. 16 and 20) it was found in 14 cases out of the presented 96 patients in this

![Chart 2](chart2.png)

**Chart 2** Comparative study of the accuracy of radiological diagnoses in 96 patients with glenohumeral instability By MRA versus CTA.

![Fig. 2](fig2.png)

**Fig. 2** Right shoulder joint arthrography axial T1WI (A) and axial T1WI fat sat (B) as well as axial ABER T1WI (C) showed small Hill Sachs lesion (red arrows) at the superolateral aspect of the humeral head and torn medially displaced antero-inferior glenoid labrum seen delineated with the intra articular injected contrast. Axial ABER in addition showed the intact scapular periosteum diagnosing ALPSA lesion (blue arrows) as well as the intact anterior capsule and anterior band of the IGHL (yellow arrow). The serial axial CT arthrography (D–F) confirms the Hill Sachs lesion (red arrow) as well as the torn medially displaced antero-inferior labrum (blue arrow) with apparently intact scapular periosteum.
Fig. 3  Right shoulder joint arthrography coronal T1WI (A) and coronal T2WI (B) showed detached axillary pouch from its glenoid attachment (GAGL lesion) and leakage of contrast into the axilla (red arrow). Coronal CT (image C) cannot delineate the torn axillary pouch but showed the contrast leakage into axilla.

Fig. 4  Right shoulder joint arthrography axial T1WI (A) and T1WI fat sat (B) showed small cortical and subcortical area of abnormal low signal on T1WI and bright signal on fat sat representing small Hill Sachs lesion. The Axial CT (C) at the same level showed tiny cortical depression at the superolateral aspect of the humeral head (red arrows).

Fig. 5  Right shoulder joint arthrography axial CT (A), axial T1WI (B) and axial T1WI fat sat (C). The CT image as well as the axial MR images showed small depression fracture at the superolateral aspect of the humeral head representing Hill Sachs lesion (blue arrow). The antero-inferior glenoid labrum was seen torn with interrupted scapular periosteum which was more clear in the MR scan representing cartilaginous Bankart lesion (red arrow).

Fig. 6  Right shoulder joint arthrography coronal CT (A), coronal TWI (B) and coronal T1WI fat sat (C). A well defined cortical depression (Hill Sachs lesion) was seen at the superolateral aspect of the humeral head clearly identified in the CT image while in the MR images it appears as a focal cortical area of abnormal MR signal with surrounding reactive marrow oedema in the fat sat images (blue arrow). Lateral and down ward slopping of the acromion process was seen effacing the underlying peritendinous fat plane and slightly indenting the supraspinatus tendon. The subacromial segment of the supraspinatus showed a focal bright signal on fat sat images not reaching its acromial or glenoid aspect. Such supraspinatus tendinopathy cannot be diagnosed in CT images.
research. MRA had the capability to identify 10 cases only out of the 14 bony Bankart lesions with a percentage of 71% while CTA success was in detecting all cases of the 14 bony Bankart lesions by an accuracy of 100%.

– In our study Perthes lesion (Figs. 15 and 19) was the most prevalent labral injury and detected in 28 cases out of the 96 patients included in our study. MRA showed very high sensitivity in detecting all the 28 lesions with 100% sensitivity while CTA showed less capability detecting only 16 cases out of the 28 lesions by an accuracy of 57%.

– The ALPSA lesions (Figs. 2, 9 and 13) were detected in 16 cases out of the 96 patients included in this study. MRA showed great potency in detecting all lesions (100%) while CTA detected only 46 lesions out of the 60 Hill Sachs lesions by an accuracy of 76%.

– Reversed Bankart lesions (Figs. 17 and 21) were seen in 6 cases out of the 96 patients included in this study. The CTA detected only 4 cases (66%) while MRA detected all cases (100%).

– Rotator cuff tendon injuries (Figs. 6, 10–12 and 16) were found in 42 cases out of the 96 patients shared in the current research. CTA detected only 14 cases with clear tear (33%) while MRA showed all injuries of the rotator cuff (100%).

4. Discussion

Glenohumeral joint instability is a common disorder of the shoulder. Glenohumeral is the most labile joint in human body for instability, because it has gained the extra-mobility at the expense of stability. Instability occurs in different manners and symptoms. Pain may be the only symptom; however, some patients may have been expressed with a frank dislocation.

The glenohumeral instability is abnormal painful movement of the humeral head of the humerus out of its glenoid fossa. There are two types of instabilities the dislocation which mean that the humeral head is disassociated from the glenoid fossa and needs orthopaedic reduction and subluxation means the humeral head translates to the edge of the glenoid, beyond well known physiologic boundaries, and mostly followed by self reduction (1).

Radiology assessment of shoulder has the most important role and includes conventional radiography, ultrasonography, conventional magnetic resonance and magnetic resonance (MR) arthrography. CT and CT arthrography may also be used successfully especially with the advent of MDCT as it offers excellent three plane resolution when absolute or relative contraindication to MRI or MRA is considered (2).

In our study, we apply direct intra-articular injection of contrast to distend the joint capsule using fluoroscopically guided anterior approach as applied with Choi et al. (1). Most of these articles had shown superior sensitivity and accuracy of direct MR arthrography over conventional MR imaging, particularly for labral lesions.

However the arthroscopy is a golden method for diagnosis of glenohumeral instability and the best way to showing of many different structural abnormalities varying from the Bankart lesion to rotator cuff damage and other lesions. But
it has many disadvantages because its results varied according to the skills of operator and being one of invasive procedure. So now we depend on MR Arthrography (MRA) & CT arthrography as diagnostic investigations for instability. Many authors proved MR-Arthrography has highest sensitivity and specificity, radiological method of assessment, and the glenohumeral joint, but there may be limitations described, most of which were general MRI such as metallic substances within body as cochlear implant or pace-makers as well as claustrophobia. CT-Arthrography in practice of work is needed more than MR-Arthrography, and orthopaedic surgeons have high confidence with computed tomography images, wide distribution of CT scanners and the possibility of CT to assess whether there is any bone loss at glenoid.

In the current study a comparative analysis was performed between CTA and MRA findings as regards the frequencies and percentage of lesions detected in the 96 patients. The cartilaginous Bankart lesion was detected in 16 patients out of the 96 patients involved in this study. MRA detects all these 16 cases by a percentage of 100% while CTA can clearly identify 12 cases only out of the 16 patients by a lower sensitivity of 75%. This showed that MRA is more reliable than CTA in assessment of cartilaginous Bankart lesion.

As regards the osseous Bankart lesion, it was found in 14 cases out of the presented 96 patients in this research. MRA had the capability to identify 10 cases only out of the 14 bony Bankart lesions with a percentage of 71% while CTA success was in detecting all cases of the 14 bony Bankart lesions by
Fig. 12  Left shoulder joint arthrography axial T1WI (A), axial T1WI fat sat (B) and axial CT (C). Both MR and CT images clearly identify full thickness tear of subscapularis tendon with free distal end of the tendon (red arrow). Consequent anterior subluxation of the humeral head was noted.

Fig. 13  Left shoulder joint arthrography axial CT (A and C), axial T1WI fat sat (B and D), axial T1WI ABER (E). Images (A and B) showed medially displaced antero-inferior labral tear (ALPSA) delineated by the intra articular injected contrast being more clear in the CT image (red arrows). Anterior capsular tear as well as torn anterior band of the IGHL was noted in images (C and D) and more clearly identified in axial ABER (blue arrows).

Fig. 14  Left shoulder joint arthrography coronal CT (A), coronal T1WI (B) and coronal T1WI fat sat (C). A well defined complete tear was seen involving the glenoid attachment of the axillary pouch of the IGHL with downward sagging of the axillary pouch. The intra articular injected contrast delineating a well defined gap (blue arrows) near the glenoid attachment of the axillary pouch being more clearly identified in the axial T1WI fat sat representing GAGL lesion. The tendon of supraspinatus appear thickened and showed intrinsic bright signal on T1WI & fat sat.
an accuracy of 100%. Such a result clarifies the higher sensitivity of CTA in diagnosing underlying bony Bankart lesion than MRA.

Richard and his colleagues (6) mentioned that CT-Arthrography by two different experienced radiologists has high sensitivity results (91.6% for first reader and 88.8% for second one) in detection of anterior located labral tears. Also in comparing with previous CT-Arthrography studies done by Zwar et al., Mulligan et al. and Soh et al. (7–9) there was very great difference, with a sensitivity ranging from 72% to 93%. Therefore, it was difficult to make a good comparison with their results.

Instead, Richard et al. (6) results are comparable with those of previous Kassarjian et al. (10) to assess the diagnostic accuracy of MR arthrography.

Khedr et al. (11) studied Bankart lesion as the most common abnormality. It involves interruption of the antero-inferior glenoid labrum which may appear irregular in outline or entirely be absent with stripping of the capsule from the scapular periosteum (4). Direct CT arthrography has lower sensitivity (84.2%) of glenoid lesions in comparison with MR arthrography (94.7%).

This was in agreement with other studies (2). Anterior glenoid margin fracture was seen in seven patients. 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.

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 makes recurrent episodes of dislocations more common (12). So preoperative assessment of glenoid bone loss must be known to prevent post operative recurrence (13).

In our study Perthes lesion was the most prevalent labral injury and detected in 28 cases out of the 96 patients included in our study. MRA showed very high sensitivity in detecting all the 28 lesions with 100% sensitivity while CTA showed less capability detecting only 16 cases out of the 28 lesions by an accuracy of 57%.

Our study results come in hand with Kassarjian et al. (10) who mentioned that CT-Arthrography has shown a low sensitivity in characterization of the Perthes lesion. The intact

Fig. 15 Right shoulder arthrography axial CT (A and B), axial T1WI (C), Axial ABER T1WI fat sat (D). A well defined small Hill Sachs lesion was seen at the supero-lateral aspect of the humeral head (red arrows). Torn antero-inferior glenoid labrum was noted with intact scapular periosteum best demonstrated in the MR images than in the CT images (blue arrows) representing Perthes lesion.

Fig. 16 Right shoulder joint arthrography axial & coronal CT (A and D), axial & coronal T1WI (B and E), axial and coronal T1WI fat sat (C and F). A well defined fissure fracture line was seen involving the antero-inferior bony glenoid margin (image A) and seen as a low signal line on T1WI & fat sat representing bony Bankart’s lesion (blue arrows). Lateral and downward slopping of the acromion process was seen effacing the underlying peritendinous fat plane and gently indenting the supraspinatus tendon (red arrows).
capsule and the nondisplaced labrum create difficulties in diagnosis of these structural abnormalities. Many authors have already suggested that it needs specific positions as the arm in external rotation or in external abduction rotation (ABER) position is mandatory to see the labrum displacement. Also in our study results we agreed with Khedr et al. (11) work on Perthes lesions which were confirmed in 3 cases. CT arthrography has lower sensitivity (33.3%) compared to MR arthrography (66.6%). This was because on scanning 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 makes contrast media not to enter through the tear (14).

The ALPSA lesions were detected in 16 cases out of the 96 patients included in this study. MRA showed great potency in detecting all the lesions in 100% of cases while CTA clearly identifies 10 cases only out of the 16 lesions by a lower accuracy of 62%. This can be explained by intact capsule which makes a very good intra-articular contrast opacification, showing the medially dislocated labrum also periosteal reaction of the anterior aspect of the glenoid, could be an another specific indirect sign of ALPSA lesion (6).
In Khedr et al. (11) study, they have 7 cases of ALPSA lesions. CT arthrography has lower sensitivity (85.7%) compared to MR arthrography (100%); such results come in hand with our results in the current research. A medially displaced labroligamentous complex and absence of the labrum on the glenoid rim were reliable criteria for the diagnosis of ALPSA lesions (15).

GLAD lesions were seen in 8 patient out of the 96 in this study. MRA detect all this 8 cases (100%) while CTA can detect only 6 cases by a percentage of 75%.

Fig. 19  Left shoulder joint arthrography axial & coronal CT (A, D and G), axial & coronal T1WI (B, E and H), axial and coronal T1WI fat sat (C, F and I). Torn antero-inferior glenoid labrum with intact scapular periosteum (Perthes lesion) seen delineated by the intra articular injected contrast in both CT & MR (red arrows). A wedge shaped large Hill Sachs lesion was seen at the supero-lateral aspect of the humeral head (blue arrows).

Fig. 20  Right shoulder arthrography axial CT (A and B), coronal CT (C), axial T1WI (D), axial T1WI ABER (E), coronal T1WI fat sat (F). Detached antero-inferior glenoid labrum (blue arrows) with fractured underlying bony glenoid margin (red arrows) representing combined cartilaginous and bony Bankart’s lesion. The fractured bony glenoid was detected only in the CT images. The axial ABER showed the disturbed scapular periosteum. Tiny Hill Sachs lesion was noted in the coronal CT and coronal fat sat (yellow arrows).
In Khedr et al. (11) study GLAD lesions were confirmed in 5 cases. CT arthrography has higher sensitivity (80%) than MR arthrography (60%) because of its high spatial resolution; such results are in reversal to the results obtained in our research which showed the higher sensitivity of MRA than CTA.

GLAD lesions are usually stable, in contrast to other anteroinferior labroligamentous lesions, but were included in our work to show the differentiation between GLAD from unstable lesions is of therapeutic importance (15).

The distinction of Bankart lesion from ALPSA, Perthes or GLAD is not great important for management decision; however, some authors proved that a degeneration or absence of the antero-inferior capsulo-labral complex is an important criteria for management decision (16–18).

HAGL lesions were detected in 4 patients only with all cases detected by MRA (100%) and only two cases detected by CTA (50%). Similar results found in GAGL lesions were seen in 4 patients only; however, both CTA & MRA showed the same capability in detecting all lesions (100%).

Hill Sachs lesions of the humeral head were the commonest lesions (60) detected among the 96 patients included in this study. CTA showed the highest power in detecting all Hill Sachs lesions (100%) while MRA detected only 46 lesions out of the 60 Hill Sachs lesions by an accuracy of 76%.

Osseous injuries observed following anterior dislocation or subluxation as a result of impaction of the postero-superior aspect of the humeral head against the anterior or anteroinferior glenoid margin (18) were seen in 27 patients with Bankart lesions (11).

Reversed Bankart lesions were seen in 6 cases out of the 96 patients included in this study. The CTA detected only 4 cases (66%) while MRA detected all cases (100%) and such results are similar to those obtained in the cases of Bankart lesions.

Rotator cuff tendon injuries were found in 42 cases out of the 96 patients shared in the current research. CTA detected only 14 cases with clear tear (33) while MRA showed all injuries of the rotator cuff (100%). This may be attributed to high resolution and tissue characterization capability of MRA compared to CTA.

Leocovet et al. (2) mentioned that CT arthrography has high accuracy in the determination of whole thickness and articular surface partial tears of the supraspinatus and infraspinatus. Fatty degeneration and volume loss of the rotator cuff can be evaluated by CT imaging. But CT still has a low diagnostic value in the assessment of interstitial and bursal-sided tears compared to MRA due to its low soft tissue contrast (1).

5. Conclusion

Our results recommend that MR arthrography is more cost benefit valuable one than CT arthrography and should be increasingly used, especially when there is any uncertainty, or when the issue of labral or capsular tear is not obvious from the clinical investigation. Furthermore combination of CT arthrography and MR arthrography as a one shot examination is also recommended if possible in order to extend the diagnostic value in evaluation of the osseous lesion in addition to joint capsule itself, and the size of the ligament-labral injury.

Conflict of interest

The authors declare that there are no conflicts of interest.

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