**ORIGINAL ARTICLE**

**One-shot MR and MDCT arthrography of shoulder lesions with arthroscopic correlation**

Mohammad Koriem Mahmoud a,*, Yousef Mohamad Badran a, Hatem Galal Zaki b, Abeer Houssein Ali a

a The Department of Diagnostic Radiology, Faculty of Medicine, Assiut University, Egypt
b The Department of Orthopedic Surgery, Faculty of Medicine, Assiut University, Egypt

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**Abstract** Although MR imaging and MR arthrography are the first choice modalities for shoulder imaging, CT arthrography (CTA) may be used successfully to address many clinical questions. The advent of sub-millimeter multiple detector CT (MDCT) technology and subsequent excellent three-plane resolution has considerably increased the quality of CTA examinations and has propelled this technique to the forefront in a growing number of indications.

The combined use of iodinated contrast material for fluoroscopic confirmation of the articular position of the needle before injection of gadolinium chelates for MR arthrography offers the unique opportunity to compare CTA and MRA findings in carefully selected cases. On this basis, the aim of this study was to compare the diagnostic efficacy of multidetector CT arthrography (MDCTA) and magnetic resonance arthrography (MRA) of the shoulder by performing MDCTA and MRA as a one-shot examination using a mixture of iodinated and paramagnetic contrast agents, with arthrosopic correlation.

**Materials and methods:** The study included 31 patients with suspected shoulder pathology who underwent both MDCT Arthrography (MDCTA) and MR Arthrography (MRA) as a one-shot examination. MDCTA and MRA were evaluated separately and jointly (MDCTA-MRA) in different blinded sessions. Each imaging study was evaluated for the presence of bony (Hill-Sachs) or labral (Bankart or superior labrum anteroposterior [SLAP] lesions), and rotator cuff disorder (full- or partial-thickness tears). All patients subsequently underwent conventional arthroscopic surgery. Detailed arthroscopic findings were reported and compared with MDCTA and MRA findings.

* Corresponding author. Tel.: +20 1003331902; fax: +20 882343420. E-mail addresses: koriemomar@yahoo.com (M.K. Mahmoud), y_badran@yahoo.com (Y.M. Badran), Hatemgalal@yahoo.com (H.G. Zaki), abeeryaa@yahoo.com (A.H. Ali).
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We determined sensitivity, specificity and accuracy of both MDCTA and MRA for detecting various shoulder pathologies on the basis of the arthroscopic findings.

Results: Sensitivity, specificity and accuracy were comparable in each imaging study for Bankart, SLAP, Hill-Sachs lesions and full-thickness rotator cuff tears, but those of MDCTA were significantly lower than MRA for partial-thickness cuff tears.

Conclusion: We suggest that the sensitivity of diagnosing shoulder lesions is similar for MDCTA and MRA. MDCTA is effective for diagnosing and evaluating shoulder pathology.
A mixture of contrast agents was prepared using Gd-DTPA at 1:250 and iobitridol 350 at 1:5 in 20 ml of saline solution for a total mixture of 24 ml. Joint opacification was performed by an anterior approach. The needle, a 90-mm Chiba needle (20 gage) was directed to the glenohumeral joint space under fluoroscopic guidance and under sterile conditions. The volume of injected solution ranged from 10 to 24 ml, with an average of 20 ml. No side effects were observed.

Arthrographic films were traditionally obtained in the X-ray room after careful mobilization (in cases where injection was done under fluoroscopic guidance). The main residual usefulness of these films was the identification of adhesive capsulitis and synovial diseases.

5.2. Imaging protocol

MDCTA scans were performed using a 64 slice MDCT. Technical parameters were adjusted to optimize image quality and minimize patient irradiation. The scan parameters used were a tube voltage of 120 kV, a tube current of 150 mA, feed/rotation of 9 mm, collimation beam of 0.75 mm, effective pitch of 0.75, and FOV at an acquisition of 150 mm in the transverse plane and a matrix of 512 x 512 pixels.

Patients were positioned in the supine position with the examined arm in neutral position and the other arm raised overhead. If residual doubt was present and in patients with suspected anterior instability or postero-superior glenoid impingement, additional series in internal rotation or in ABER (abduction and external rotation) position were obtained, to study the anterior and posterior glenoid and the labrum, and deep surface of the supraspinatus tendon.

Scanning proceeded from the superior aspect of the acromio-clavicular joint to several centimeters inferior to the glenohumeral joint to include the axillary pouch of the joint; these landmarks were easily seen on the scout view. Scanning time with MDCT technology just accounted for several seconds.

For data analysis, oblique coronal, oblique sagittal and axial reconstructions were generated at a 3-dimensional (3D) workstation, with a 2-mm section thickness and no reconstruction interval for axial images, and a 2-mm or less reconstruction interval for the oblique coronal and sagittal images. Oblique coronal images were reconstructed parallel to the supraspinatus muscle and oblique sagittal images parallel to the joint surface of the glenoid with an identical section thickness and reconstruction interval.

Patients were then moved for an MR study, which was performed by a 1.5-T MRI system (Gyroscan NT, Philips Medical Systems), and positioned again in supine position with the examined arm in neutral position within a dedicated, phased array surface coil. Fat-suppressed T1-weighted spin-echo images were obtained in the transverse plane (400–700/10–20, with a 3-mm section thickness, 0.3 mm interval, 160 x 160 mm field of view, and 256 x 512 pixel matrix), in the oblique coronal plane, parallel to the supraspinatus muscle, and in the oblique sagittal plane, parallel to the joint surface of the glenoid. T2-weighted spin-echo images were obtained in the coronal plane and in the oblique sagittal plane (repetition time [TR] 2500–3500/time to echo [TE] 89–100), 3D-gradient echo images (3D WatSc, TR 20/TE 9–10, 20 flip angles) were obtained in the transverse plane.

All patients subsequently underwent shoulder arthroscopy, and care was taken to evaluate all the compartments of the shoulder. After the completion of surgery, the arthroscopic findings were incorporated on a standard form by the operator. The result for each modality was compared with the intra-operative arthroscopic assessment.

5.3. Image assessment

The MRA and the MDCTA were assessed independently by two musculoskeletal radiologists. They had access to only the clinical history. The images were interpreted separately with 1 week between the reading sessions. The MRA in the first session and the MDCTA in the second session were evaluated individually. Two radiologists assessed the type of shoulder pathology.

The types included classic and bony Bankart lesions, including Bankart variants (anterolabral-gamentous, periosteal sleeve avulsion (ALPSA), Perthes lesion), superior labrum antero-posterior (SLAP) lesions, Hill-Sachs lesions and rotator cuff lesions (partial or complete tears). Consensus was finally obtained in the case of initial disagreement.

The criteria for a classic Bankart lesion were a fragment of labrum attached to the anterior band of the inferior glenohumeral ligament with a ruptured scapular peristeum that was “floating” in the antero-inferior aspect of the glenohumeral joint. Combined evidence of an osseous lesion led to the diagnosis of a bony Bankart lesion rather than a classic Bankart lesion (8).

ALPSA were seen as a tear of the antero-inferior labrum without rupture of the anterior scapular peristeum, stripped and medially displaced inferior glenohumeral ligament, labrum and periosteum. A Perthes lesion was also defined as a labroligamentous avulsion, but with a medially stripped intact periosteum (9).

The criteria for a SLAP lesion were extension of a labral tear into the superior labrum with the lateral or superior portion (3,7). An antero-superior labral tear is a tear limited to the antero-superior aspect of the labrum, with or without associated lesions in the superior and middle portions of the glenohumeral joint (6,10). A tear of the glenoid labrum was diagnosed when the normal cross-sectional appearance was disrupted or when an abnormal signal intensity was noted. The signal intensity on MRA was compared to that of the nearby muscles or circumferential labrum (6).

The Hill-Sachs lesion is a defect or depression of the posterosuperior-lateral aspect of the humeral head related to a compression fracture of this contour against the antero-inferior portion of the glenoid rim during dislocation (3).

The diagnosis of complete rotator cuff tears was established by the observation of a contrast-filled gap in the rotator cuff tendons and extension of intra-articular contrast material through this tear into the sub-acromial-sub-deltoid space. Tears of the rotator cuff usually begin at the anterior aspect of the distal insertions of the SSp tendon on the greater tuberosity, and then typically extend posteriorly to involve the whole attachment of the SSp. The lesions of the articular surface of the tendons were defined by their location, extent, and depth. Three grades of partial thickness tears have been described at arthroscopy, according to the depth of the lesion (less than 3 mm: grade I; 3–6 mm: grade II; more than 6 mm: grade III) (3).

Finally, a radiologist and an orthopedist assigned a 0–3 score to the agreement between CTA and arthroscopy, MRA
and arthroscopy, and CTA-MRA and arthroscopy by consensus (0; no agreement, 1; low agreement, 2; high agreement, 3; total agreement).

6. Results

6.1. Comparative assessment of the two modalities (MRA and MDCTA)

At arthroscopy, 12 Bankart lesions (n = 8 classic Bankart lesions, n = 4 bony Bankart lesions), 8 SLAP lesions (2 cases had combined Bankart and SLAP lesions, Fig. 1) and 11 rotator cuff tears (n = 6 complete tears, n = 5 partial thickness tears) were visualized in the 31 shoulders. Seven cases with Bankart lesions had associated Hill-Sachs lesions (Table 1).

Eleven cases were correctly diagnosed as Bankart lesions by both MDCTA and MRA and each imaging modality missed the diagnosis of one arthroscopically proved Bankart lesion.

Also, two bony Bankart lesions were incorrectly diagnosed as classic Bankart by MRA while, correctly diagnosed by MDCTA (Fig. 3). All Hill-Sachs lesions were correctly diagnosed by both imaging modalities.

For the SLAP lesions, eight cases by MRA and seven cases by MDCTA matched the arthroscopic findings (Fig. 4).

For the 11 rotator cuff tears all cases of complete tears were correctly diagnosed by MRA and 5 cases were diagnosed by

![Fig. 1](image-url) Right shoulder of a 25 year old athlete man with a history of recurrent shoulder dislocation. (A–C) axial, coronal and sagittal oblique reformatted MDCTA images and (D–F) axial, coronal and sagittal oblique TWI fat suppressed MRA images: show detachment and globular shape of the anterior labrum (arrows in A and D) with a large bone defect of the postero-superior lateral aspect of the humeral head (curved arrows in A and D). Coronal reformatted MDCTA shows a normal superior labrum (arrow in B) while coronal MRA demonstrates abnormal irregular pooling of contrast material inside the superior labrum (arrow in E); consistent with type I Slap lesion. Both sagittal images show detachment of the antero-superior labrum; best seen on sagittal MRA image (arrows in C and F). Combined Bankart and Slap lesions are confirmed by arthroscopic correlation.

<table>
<thead>
<tr>
<th>Pathology</th>
<th>Operative findings (n = 31)</th>
<th>Modality</th>
<th>True positive</th>
<th>True negative</th>
<th>False positive</th>
<th>False negative</th>
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<td></td>
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<tr>
<td>Bankart lesion</td>
<td>12</td>
<td>MDCTA</td>
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<td>19</td>
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<tr>
<td></td>
<td></td>
<td>MRA</td>
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<td>19</td>
<td>0</td>
<td>1</td>
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<tr>
<td>SLAP lesion</td>
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<td>MDCTA</td>
<td>7</td>
<td>23</td>
<td>1</td>
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<td></td>
<td></td>
<td>MRA</td>
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<td>23</td>
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<td>Hill-Sachs (and bone lesions)</td>
<td>11</td>
<td>MDCTA</td>
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<td>20</td>
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<td>0</td>
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<tr>
<td></td>
<td></td>
<td>MRA</td>
<td>9</td>
<td>20</td>
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<td>2</td>
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<td>Cuff tear thickness (n = 11)</td>
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<tr>
<td>Full</td>
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<td>MDCTA</td>
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<tr>
<td></td>
<td></td>
<td>MRA</td>
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<td>26</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MRA</td>
<td>3</td>
<td>26</td>
<td>0</td>
<td>2</td>
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</table>
6.2. Statistical comparison

Diagnostic efficacy of labral lesions (SLAP and Bankart lesions) was excellent for both imaging studies. With Bankart lesions, sensitivity, specificity, predictive value (PPV), negative predictive value (NPV), and accuracy were the same for both MDCTA and MRA which were 91.6%, 100%, 100%, 95%, and 96.7% respectively.

With SLAP lesions, sensitivity, specificity, PPV, NPV and accuracy for MRA were all 100% and those for MDCTA were 87.5%, 95.8%, 87.5%, 95.8% and 89.3% respectively. The difference in the sensitivity between the two groups for detecting SLAP lesions was not significant. The agreement of MDCTA with arthroscopic identification of the Bankart lesion was almost perfect, which was better than for the SLAP lesion. Sensitivity and specificity of MDCTA and MRA for the Hill-
Sachs and bony lesions were comparable with slight superiority of MDCTA. The agreement of MDCTA and MRA with arthroscopic identification of the Hill-Sachs lesion was substantial. Sensitivity, specificity, and accuracy of MDCTA and MRA were excellent for full-thickness rotator cuff tears; however, those of the MDCTA group were poor for partial-thickness tears. The sensitivity and the PPV of MRA for partial-thickness cuff tears were 60% and 100%, whereas those of MDCTA were 20% and 33.3% respectively.

These data suggest that the diagnostic efficacy of MDCTA was statistically comparable with that of MRA, except for partial-thickness rotator cuff tears (Table 2).

7. Discussion

History taking, various physical examinations, plain radiographs, and ultrasound imaging are helpful in the diagnosis of patients with shoulder problems, and MRI has been widely used for the definitive diagnosis and preoperative assessment because of its inherent improved soft tissue contrast, oblique imaging plane capability, and excellent resolution using surface coils (11).

If MRI is combined with an intra-articular contrast media application, it distends the joint capsule, outlines the intra-articular structures, and fills tears and leaks through them into the extra-articular space so the diagnostic efficacy of MRA under certain clinical conditions is greater than that of MRI (12).

Hence, MRA has gained in popularity as a diagnostic tool in the assessment of intra-articular derangement and rotator cuff tear in the shoulder joint. However, it is still an expensive imaging tool, and metal in the vicinity of the lesion can interfere with the true signal (3).

CT shows high accuracy for detecting cortical defect and calcification of tendon and ligament. Spiral single-detector row CT did not have sufficient sensitivity for detecting shoulder pathology, especially labral lesions (6).

Since 16-slice MDCT was first commercialized, MDCTA has recently given rise to renewed concern about the cost effectiveness of imaging tools for the identification of shoulder pathologies. MDCTA has several advantages (13):

- One can get an isotropic sub-millimeter spatial resolution with improved longitudinal resolution.
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- The examination time is substantially reduced with decreased motion artifact, which renders it very useful for trauma or pediatric patients. In patients with anterior instability of the shoulder exhibiting severe anterior apprehension, it is easy to get the CT images in the abduction-external rotation position in a short time.
- Even patients with metallic devices or implants, who are poorly indicated for MRA, can undergo the procedure, and we can easily estimate the lesion in the vicinity of metal without artifacts.

Farber and Buckwalter also concluded that CTA is extremely useful in postoperative shoulder procedures because it has the ability to scan in the presence of metal without artifacts.

Although preoperative MDCTA may have some limitations in the evaluation of soft tissues and the rotator cuff, postoperative CTA can be effective in assessing the integrity of tendon and labrum repairs, even with a metallic anchor.

- The cost is relatively lower than MRA in most countries.
- MDCTA allows reconstruction images with 1 mm or thinner sectioning in any direction in the target lesion, whereas MRA can show only images with a fixed section thickness (7).

Because of these advances, MDCTA has also proven to be useful for diagnosing certain pathologies in various joints (14).

Our study demonstrates the possibility of performing a one-shot CTA-MRA of the shoulder using a mixture of diluted iodinated and paramagnetic contrast agents. The CTA-MRA exam did not create any particular problems in scheduling, performing, and reading the images (15).

We injected a mean of about 19 ml of the mixture of the two agents, with a range of 10–24 ml. MRA of the shoulder is usually performed with a maximum required volume of 15 ml for rotator cuff lesions and 20 ml for instability (16). In order to obtain a marked distension of the capsule with optimal visualization of normal and abnormal anatomical structures, we stopped the intra-articular injection only when the distention became uncomfortable, reaching in such a way a higher mean of injected volumes compared with the literature (15).

In this study contrast injection (arthrography) took about 15 min, MDCT about few seconds and MR imaging about 10–15 min. So a total time of 30–35 min (including time of patient transfer and positioning) could be enough for the whole MDCTA-MRA of the shoulder.

By performing one shot MDCTA-MRA, Our prospective study compared sensitivity, specificity, PPV, NPV, and accuracy of the two imaging modalities simultaneously in the same patient. Sensitivity, specificity, and accuracy compared with the arthroscopic results can demonstrate the diagnostic efficacy of each imaging study. Then we were able to compare the diagnostic efficacy of MDCTA and MRA by using these values.

This prospective study demonstrates that the diagnostic efficacy of MDCTA is comparable with the MRA for labral lesions, such as SLAP and Bankart lesions. Although, the sensitivity of MRA for SLAP lesions is slightly better than that of MDCTA imaging in our study, this difference is not statistically significant. These results are concordant with a previous study that evaluated patients with chronic shoulder instability by comparing 4-slice MDCT and 16-slice MDCTA with direct MRA and concluded that MRA was better than CTA (17).

Our study demonstrates that sensitivity, specificity, predictive values, and accuracy of MDCTA for full-thickness rotator cuff tears are as high as those in MRA. Therefore, even though preoperative MDCTA may have some limitations in the evaluation of soft tissues, such as rotator cuff tendinopathy or bursal side tear, the diagnostic value in the detection of full thickness tears appears comparable with MRA.

The study, however, revealed that the sensitivity and the agreement of MDCTA for partial-thickness cuff tears were very low. This may be attributed to the difficulty in the detection of bursal side cuff tear, hemorrhage, or edema in the rotator cuff tendon. The results might have been better if we had performed external rotation and internal rotation CTA, or if we had used double-contrast CTA with air in the subacromial space (18).

So, this study demonstrates that the diagnostic performance of MDCTA is comparable with MRA for labral lesions, including SLAP and Bankart lesions, Hill-Sachs lesions, and full-thickness rotator cuff tears. Therefore, MDCTA can serve as an alternative diagnostic modality to MRA in certain in-

### Table 2

<table>
<thead>
<tr>
<th>Imaging test</th>
<th>SLAP</th>
<th>Bankart</th>
<th>Hill-Sachs (and bone lesions)</th>
<th>Cuff tear thickness</th>
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<tr>
<td>MDCTA, %</td>
<td></td>
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<tr>
<td>Sensitivity</td>
<td>87.5</td>
<td>91.6</td>
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<td>Specificity</td>
<td>95.8</td>
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<tr>
<td>PPV</td>
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<td>Accuracy</td>
<td>89.3</td>
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<tr>
<td>MRA, %</td>
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<tr>
<td>Sensitivity</td>
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<td>NPV</td>
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<td>Accuracy</td>
<td>100</td>
<td>96.7</td>
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stances. MDCTA also seems to be valuable to confirm postoperative integrity after rotator cuff or labral repair using by metal anchors, with clear advantages in terms of both time and cost (19).

This study has several limitations, first, only a few number of shoulders were evaluated. We presumed that the sensitivity of CT for detecting calcifications and bone injuries was greater, while MR was more sensitive for diagnosing soft tissue abnormalities, as based on the optimal MR contrast resolution. Nevertheless, in this study, MDCTA was not superior to MRA for detecting the bony defects of bony Bankart and Hill-Sachs lesions. We expect a study focusing on a large number of bony lesions will show a higher detectability on MDCTA than that on MRA. Second, mixed contrast material was used in this study. The stability of the mixture of gadolinium chelates and iodinated contrast agents has already been reported on, and its clinical safety was certain for performing CTA and MRA of the ankle and wrist as a one-shot CTA-MRA examination (20). Nevertheless, a decrease in the signal intensity on MRA was seen due to the dilution of the gadolinium chelate mixed with the iodinated contrast agent. This might have reduced the sensitivity of MRA for Bankart variants in this study, as compared to previous studies (9).

8. Conclusion

Our study demonstrates that MDCTA and MRA show very close observations in numerous clinical indications of shoulder imaging. Definition of the respective indications of both techniques depends on many factors. The relative availability of these techniques and local experience should first be taken into account.

Besides this, MRA seems to be the method of choice for the pre-operative work-up of suspected rotator cuff pathology. If another imaging technique has previously been used to evaluate the cuff (for example ultrasonography), MDCTA provides precise answers to all pre-operative questions (location and extent of the tear, position of the retracted tendon, and muscle atrophy).

In glenohumeral instability, both MRA and MDCTA demonstrate the labro-ligamentous lesions. Still, MRA has the advantage toward MDCTA to directly visualize the affected structures with a better evaluation of extent and location and to detect associated capsule-ligamentous injuries. MRA appears superior for the study of the intra-articular portion of the ligaments, whereas MDCTA seems more reliable for the detection and delineation of bony lesions.

MDCTA also seems to be valuable to post-operative workup to confirm postoperative integrity after rotator cuff or labral repair using by metal anchors, with clear advantages in terms of both time and cost.

Moreover, MDCTA is a method of choice for the study of cartilage lesions, but this indication closely depends on the availability of validated surgical treatments.

MDCTA-MRA seems to give more information than MDCTA or MRA separately. The two techniques give different information due to a higher MDCT sensitivity for calcifications and bone injuries and an optimal MR contrast resolution for soft tissue abnormalities.

Finally, One-shot MDCTA-MRA appear to be a promising examination that should be performed in cases of suspected complex tears of both bone and soft-tissue injuries in both acute and late phases.

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