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The comparison of direct magnetic resonance arthrography with volumetric interpolated breath-hold examination sequence and multidetector computed tomography arthrography techniques in detection of talar osteochondral lesions

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ABSTRACT

Objective: The aim of this study was to compare additive diagnostic values of magnetic resonance (MR) arthrography with volumetric interpolated breath-hold examination (VIBE) sequence and multidetector computed tomography (MDCT) arthrography for diagnosis and grading of talar osteochondral lesions.
Methods: MDCT arthrography and MR arthrography with three dimensional VIBE sequence were performed in 27 patients. Findings of MR arthrography and MDCT arthrography images were compared with arthroscopic findings. Sensitivity, specificity, and accuracy rates were calculated for both MR arthrography and MDCT arthrography imaging findings.
Results: For grade I osteochondral lesions; sensitivity, specificity and accuracy rates of MR arthrography were 95%, 73%, 90%, respectively; For grade I osteochondral lesions; sensitivity, specificity and accuracy rates of MDCT arthrography were 96%, 79%, 81%. For grade IV osteochondral lesions; sensitivity, specificity and accuracy rates of MDCT arthrography and MR arthrography were 100%. For grade II lesions, the sensitivity, specificity and accuracy rates of the MR arthrography were 80%, 76%, 77%, respectively; for grade III lesions, the sensitivity, specificity and accuracy rates of the MR arthrography were 78%, 68%, 75%. For grade II osteochondral lesions; the sensitivity, specificity and accuracy rates of the MDCT arthrography were 91%, 81%, 86%; for grade III osteochondral lesions; the sensitivity, specificity and accuracy rates of the MDCT arthrography were 90%, 83%, 89%; For grade II and III osteochondral lesions, MDCT arthrography had higher sensitivity, specificity and accuracy rates than MR arthrography. MDCT arthrography had higher diagnostic performance than MR arthrography for detection of grade II and III lesions ($p = 0.041$ and $p = 0.038$, respectively).
Conclusion: MDCT arthrography appears to be more reliable than MR arthrography with three dimensional VIBE sequence for accurate detection and grading of osteochondral lesions.
Level of evidence: Level III, Diagnostic Study.
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Introduction

Osteochondral lesions are usually posttraumatic or developmental injuries simultaneously involving the hyaline cartilage at an articular surface and its underlying subchondral bone. Common localizations of the osteochondral lesions are, in order of published frequency, the femoral condyles, capitellum of the elbow, talar dome and patella. The talar dome are affected in the third frequency.[1,2]

Osteochondral lesions at the talar dome frequently occur after traumatic injuries. They represent the most important joint-related risk factors for osteoarthritis at the ankle joint. Cartilage repair procedures have increasingly been applied at the ankle joint, aiming to decelerate progression to early osteoarthritis.[2,3] Thus, early diagnosis of osteochondral lesion is very important for determining of an available treatment strategy to optimize pain relief in the acute phase of injury and to preserve long-term joint

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function. Magnetic resonance (MR) imaging may be useful for preoperative assessment of osteochondral lesions in the ankle joint.

MR arthrography probably leads to better results in the detection of osteochondral lesions compared with standard MR imaging in the talar dome. The use of three dimensional volumetric interpolated breath-hold examination (VIBE) sequences produces thinner image slices and enables a higher in-plane resolution than conventional MR arthrography sequences. Thus, three dimensional VIBE sequence contribute to evaluating of the intraarticular structures such as the glenohumeral ligaments in shoulder MR arthrography examinations.[4–7]

With the rapid development of slip ring technology and multidetector computed tomography (MDCT), the availability to assess subtle osseous injuries with multi-planar reconstructions has dramatically improved. Thus, MDCT arthrography can also be used for cartilage imaging and the introduction of spiral CT has enabled thin, overlapping sections with excellent secondary sagittal and coronal reformations to be obtained, resulting in a revival of CT arthrography for the assessment of intraarticular lesions including articular cartilage.[8]

In our study, we aimed to compare the additive diagnostic values of the MR arthrography with three dimensional VIBE sequence and MDCT arthrography for the diagnosis and grading of osteochondral lesions in the talar dome. However; to the best of our knowledge, our study is the first original research evaluation of the talar osteochondral lesions using MDCT arthrography and MR arthrography with three dimensional VIBE sequence.

Material and methods

Patients

Between August 2016 and September 2017, a total of 32 patients with suspicious ankle osteochondral lesions according to the findings of the anamnesis, physical examinations and routine conventional ankle MR examinations were included in this prospective study. The exclusion criteria included cases with previous ankle surgery (n = 3 of 32 patients, 9.4%) and claustrophobia (n = 2 of 32 patients, 6.25%). The remaining twenty-seven consecutive patients (16 males, 59.2%; 11 females, 40.8%) with a mean age of 33.6 years (range 18–63 years) were included in this prospective study. Twenty-two of these patients had a history of ankle sprain with (n = 2 of 22 patients, 9.1%) and without (n = 20 of 22 patients, 90.9%) fracture. The remaining five patients presented with symptoms of osteoarthritis without prior trauma. All patients signed informed consent for application of both imaging and injection procedures and the study protocol was approved by the local institutional review board.

Injection technique

All injections were performed by a single radiologist on an outpatient basis, without sedation or premedication and using an ultrasonography (US) system (Aplio 500 Ultrasound System; Toshiba Medical Systems, Tokyo, Japan) equipped with a broadband 7.5–12 MHz linear array transducer. The injections were performed under US control using a 22 G needle via an anterior approach, medial to the anterior tibialis tendon as described by Cerezal (4). Diluted 1:1 mixture contrast medium (0.5 mmol/L gadoterate meglumine, Dotarem, Guerbet Pharma, France) at a concentration of 1:200 was injected (0.1 mL contrast medium diluted in 20 mL normal saline) and iopromide (300 mg iodine/ml) (Ultravist 300/100, Bayer Schering Pharma, Germany). A volume of 3.5–5 mL gadolinium based solution was injected until the joint capsule was distended appropriately. This procedure was performed by the same radiologist who had 5 years of experience in ankle joint injections.

MR and MDCT arthrography techniques

The MR and MDCT arthrography were both performed within 15–20 min after contrast injection. In 16 patients MR arthrography was performed prior to MDCT arthrography and in 11 patients after MDCT arthrography, depending on the availability of the scanners.

MR arthrography imaging examinations were performed using a 3T MR (Magnetom Skyra; Siemens Healthcare, Erlangen, Germany) within 10–15 min after the ankle joint injection. Our MR arthrography protocol includes spin echo (SE) T1weighted (TR/TE, 650/15 ms; echo train length, 8; section thickness, 3 mm; spacing, 0.3 mm; field of view, 130–200 mm; matrix, 256 × 256; three signals acquired) and fat-suppressed SE T1-weighted images. Arthrography images were performed in the axial, oblique coronal, and oblique sagittal planes with surface coils placed around the ankle joint. In our clinical practice, a fat-suppressed three dimensional VIBE sequence (TR/TE, 13.2/4.7 ms; flip angle, 11°; 130 × 150 mm FOV; matrix, 512 × 512; one slab of 112 slices with a slice thickness of 0.6 mm; one acquisition) was also added to the ankle MR arthrography imaging protocol. CT arthrography procedure was acquired with a 256-row multidetector CT system (Somatom Definition, Siemens Medical Solutions, Erlangen, Germany) within 10–15 min after the ankle joint injection using a bone algorithm and bone windowing (window 1800 HU; center 450 HU), slice thickness of 1 mm and a reconstruction interval of 2 mm.

Imaging analysis

All MR arthrography with three dimensional VIBE sequence and MDCT arthrography images were analyzed on high resolution monitors of a picture archiving and communication system (Syngo Via console, software ver. 2.0; Siemens Medical Solutions, Erlangen, Germany). Two staff radiologists with 10 and 5 years of experience in musculoskeletal imaging, respectively, who were blinded to the diagnosis of the patients, independently analyzed the MR arthrography with three dimensional VIBE sequence and MDCT arthrography images in random order.

Osteochondral lesions of the talus on the basis of MDCT arthrography and MR arthrography with three dimensional VIBE sequence were divided into four subtypes using the grading system suggested by Anderson et al.[9] In grade I, there was a small area of compression of the subchondral bone or subchondral edema. Grade II lesions involved a partially detached osteochondral fragment (flap) with cyst on CT and/or edema on MR imaging. In grade III lesions, a completely detached osteochondral fragment remained in the defect. Grade IV lesions also showed a free osteochondral fragment (loose body). All MR with three dimensional VIBE sequence and MDCT arthrography images were evaluated in a randomized fashion for assessment of interobserver agreement. Sensitivity, specificity and accuracy were calculated for both MR and CT arthrography images.

Statistical analysis

The findings of the MR with three dimensional VIBE sequence and MDCT arthrography images were compared with arthroscopic findings. Sensitivity, specificity and accuracy were calculated for both MR and CT arthrography and for both readers using the review panel as the standard of reference. The McNemar test was performed to determine whether the diagnostic performance between MR arthrography with three dimensional VIBE sequence and MDCT arthrography differed significantly. We calculated interobserver

agreements for all observers. An inter-observer reliability analysis using the Kappa statistic was performed to determine the consistency among observers. The degree of agreement is based on kappa values and was as follows: < 0, none; 0–0.20, slight; 0.21–0.40, fair; 0.41–0.60, moderate; 0.61–0.80, substantial; and 0.81–1.00, almost perfect. The P values < 0.05 were considered to be statistically significant.

Results

The twenty-seven patients (16 males, 59.2%; 11 females, 40.8%) with a mean age of 33.6 years (range 18–63 years) were included in this prospective study. A total of 27 talar osteochondral lesions were evaluated in all 27 patients. Fourteen of 27 osteochondral lesions (51.8%) had right talar osteochondral lesions and the remaining 13 of 27 osteochondral lesions (48.2%) also had left talar osteochondral lesions. MDCT arthrography and MR arthrography with three dimensional VIBE sequence protocols were successfully performed in 27 patients. Arthroscopy was also performed in 22 of the 27 cases (81.4%).

For grade I osteochondral lesions; the sensitivity, specificity and accuracy rates of the MR arthrography with three dimensional VIBE sequence were 95%, 73%, 90%, respectively (Fig. 1A); for grade II lesions, the sensitivity, specificity and accuracy rates of the MR arthrography with three dimensional VIBE sequence were 80%, 76%, 77%, respectively (Fig. 2A); for stage III lesions, the sensitivity, specificity and accuracy rates of the MR arthrography with three dimensional VIBE sequence were 78%, 68%, 75% respectively (Fig. 3B); and for stage IV lesions, the sensitivity, specificity and accuracy rates of the MR arthrography with three dimensional VIBE sequence were 100%, 100%, 100%, respectively (Fig. 4A and B). Table 1 summarized all the findings.

For grade I osteochondral lesions; the sensitivity, specificity and accuracy rates of the MDCT arthrography were 96%, 79%, 81%, respectively (Fig. 1B); for grade II osteochondral lesions; the sensitivity, specificity and accuracy rates of the MDCT arthrography were 91%, 81%, 86%, respectively (Fig. 2B); for grade III osteochondral lesions; the sensitivity, specificity and accuracy rates of the MDCT arthrography were 90%, 83%, 89%, respectively (Fig. 3A); for grade IV osteochondral lesions; the sensitivity, specificity and accuracy rates of the CT arthrography were 100%, 100%, 100%, respectively (Fig. 4C and D). Table 2 summarized all the findings.

MDCT arthrography had higher diagnostic performance than MR arthrography with three dimensional VIBE sequence for detection of the grade II and III lesions ($p = 0.041$ and $p = 0.038$, respectively). There was no any statistical difference between MR arthrography with three dimensional VIBE sequence and MDCT arthrography techniques for grade I and IV lesions ($p = 0.442$ and $p = 0.365$, respectively). Between observer 1 and 2, the highest interobserver agreement for MR arthrography with three dimensional VIBE sequence and MDCT arthrography was 0.94 and 0.96, respectively in detection of grade IV osteochondral lesions. The lowest interobserver agreements for MR arthrography with three dimensional VIBE sequence and MDCT arthrography also were 0.59 and 0.66, respectively in detection of grade III osteochondral lesions (Tables 1 and 2).

Fig. 1. Coronal fat suppressed VIBE sequence-weighted (A) and coronal MDCT arthrography (B) images show a grade I osteochondral lesion at talar dome in a 23-year-old woman (white arrows).

Discussion

This study describes diagnostic availability for MDCT and MR arthrography imaging techniques in detection and grading of the osteochondral lesions in the talus. Our results present that MDCT arthrography had higher diagnostic performance than MR arthrography for detection of the talar osteochondral lesions in particular, for grade II and III lesions.

Detection of osteochondral lesions in the ankle joint is clinically relevant. In the past 25 years, CT and MR imaging have come to play a greater role in the diagnosis and grading of osteochondral lesions and conventional radiographs are now generally considered to be insensitive for the evaluation of suspected chondral injury, unless there is a significant subjacent osseous component. With the development of slip ring technology and numerous sequential detector rows in CT or multidetector CT, the ability to evaluate subtle osseous injuries with multi-planar reconstructions has improved dramatically.[8–12] We believe that high-resolution MDCT plays a valuable role in the delineation of subchondral lesions that may present with instability of osteochondral fragments at the articular surface by detecting the presence of detachment, fragmentation, and displacement; we recommend MDCT arthrography in the setting of such lesions visible on MR imaging but equivocal for instability. Concordantly, we determined the high diagnostic performance for MDCT arthrography in detection of talar osteochondral lesions.

Vande Berg et al[8] performed a study using dual-detector spiral CT, higher detectability rates of grade IIA (substance loss less than half of cartilage thickness and IIB (substance loss more than half of the cartilage thickness) cartilage lesions in the knee joint were found with CT arthrography. Our study showed comparably high sensitivities for MDCT arthrography in the ankle joint using a 256-row computed tomography device.

Schmid et al[13] compared MR arthrography and CT arthrography for the evaluation of cartilage lesions in the ankle joint. They found that accuracy of MR arthrography in the talus/tibia/fibula (88%/88%/94%) was slightly inferior to CT arthrography (90%/94%/92%). They also emphasized that CT arthrography appeared to be more reliable than MR arthrography for the detection of cartilage lesions in the ankle joint. Our diagnostic accuracy rates for detection of the talar osteochondral lesions were also parallel with their results.

MR arthrography usually plays an important role to determine whether the OCL is detached by demonstrating contrast material insinuating between the fragment and the parent bone. In addition, MR arthrography have a potential role for detection of intraarticular bodies because of capsular distension.[2,4,5] The usage of three dimensional VIBE sequences produces thinner image slices with the thickness of 0.6 mm, which enhances effectiveness of the imaging. Volume acquisition enables multiplanar image reconstruction and volume rendering. It also provides good contrast between the joint and surrounding soft tissues in MR arthrography examinations.[6,14] Ogul et al[7] evaluated the tibiotalar joint capacity and

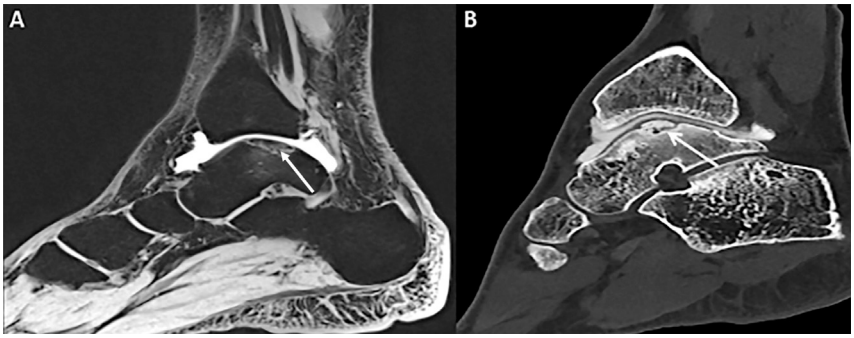

Fig. 2. Sagittal fat suppressed VIBE sequence-weighted (A) and sagittal MDCT arthrography (B) images show a grade II talar osteochondral lesion in a 34-year-old man (white arrows).

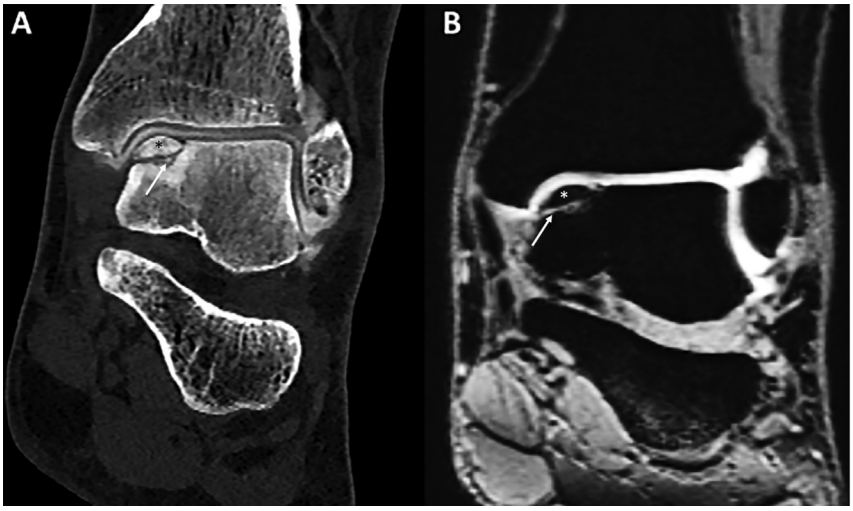

Fig. 3. Coronal MDCT arthrography (A) and coronal fat suppressed VIBE sequence-weighted (B) images show a grade III osteochondral lesion at talar dome in a 43-year-old woman (white and black asterisks). Intraarticular contrast material was seen around the completely detached osteochondral fragment (white arrows).

the localization, frequency and amount of extravasation in patients with extraarticular contrast material leakage into adjacent synovial compartments on ankle MR arthrography images. They also included the three dimensional VIBE sequence in their MR arthrography protocol and presented the connections between the ankle and neighboring synovial compartments can decrease the diagnostic value of ankle MR arthrography examinations due to inadequate joint distention. They emphasized that large injection volumes should be preferred for ankle MR arthrography of patients with grade IV osteochondral lesions. We have successfully performed the three dimensional VIBE sequence on MR arthrography examinations to detect the talar osteochondral lesions in our study.

Additionally, the three dimensional VIBE sequence is very sensitive to susceptibility artifacts caused by inadvertently injected intraarticular air bubbles. It is also a sensitive technique that will reveal the hemosiderin particles in the synovium and joint space, as well as intraarticular air bubbles. Could mimic intraarticular loose bodies, chondrocalcinosis of hyaline cartilage, and inflammatory adhesions of the joint capsule. Knowledge of this artifacts would help in avoiding misdiagnosis.[6,15,16] In our study, we detected that three dimensional VIBE sequence had a low diagnostic performance in differentiation between the grade II and III talar osteochondral lesions on MR arthrography images. This issue may be due to the above-mentioned high sensitivity of the three dimensional VIBE sequence.

In treatment for osteochondral lesions of the ankle, stable lesions are generally treated conservatively with non-weight-bearing cast immobilization followed by progressive weight-bearing over 3–4 months. Unstable lesions are more likely to be managed surgically with arthroscopic or open approaches. After treatment, not only is the subjective functional outcome of importance, but also has objective assessment of repair tissue become of interest.[3] Postoperative imaging examinations play important role to assess the outcome following surgical procedures. MDCT has been shown to be accurate in the follow-up of talar osteochondral lesions. MDCT arthrography imaging could also be performed during the postoperative follow-up to evaluate the cartilage morphology. MR imaging techniques including proton density-weighted fast spin-echo and 3D fat-suppressedT1-weighted gradient-echo sequences could be performed to evaluate the components of osteochondral lesions after treatment.[17–19]

Our study has some limitations. First, the patient cohort was relatively small. Therefore, we did not any power analysis for both MR and MDCT arthrography techniques. Future studies with larger sample are necessary to confirm our results. Second, we did not consider patient size or weight differences; however, those factors probably play a minor role because the talus anatomy is usually quite similar in an adult cohort. Third, arthroscopic correlation was not performed in all patients.

In conclusion, MDCT arthrography appears to be more reliable than MR arthrography with three dimensional VIBE sequence in the assessment of hyaline cartilage in the ankle joint. MDCT arthrography and MR arthrography with three dimensional VIBE sequence

Fig. 4. Sagittal fat suppressed VIBE sequence-weighted (A, B) and sagittal MDCT arthrography (C, D) images show a grade IV osteochondral lesion at talar dome in a 43-year-old woman (white and black asterisks). Intraarticular loose body formation (B, D) was also seen at the posterior recess of the ankle joint (white arrows).

Table 1
The sensitivity, specificity and accuracy rates and Kappa values for MR arthrography with three dimensional VIBE sequence.

	Sensitivity	Specificity	Accuracy	Kappa values for observer 1 and 2
Grade I lesions	% 95	% 73	% 90	0.74
Grade II lesions	% 80	% 76	% 77	0.63
Grade III lesions	% 78	% 68	% 75	0.59
Grade IV lesions	% 100	% 100	% 100	0.94

Table 2
The sensitivity, specificity and accuracy rates and Kappa values for MDCT arthrography.

	Sensitivity	Specificity	Accuracy	Kappa values for observer 1 and 2
Grade I lesions	% 96	% 79	% 91	0.78
Grade II lesions	% 91	% 81	% 86	0.70
Grade III lesions	% 90	% 83	% 89	0.66
Grade IV lesions	% 100	% 100	% 100	0.96

had good diagnostic performance for detection of the ankle osteochondral lesions. But, MDCT arthrography appears to be more reliable than MR arthrography with three dimensional VIBE sequence for the accurate detection and staging of osteochondral lesions and imaging of the chondral injury. MDCT imaging is more cost-effective technique and provides 16-cm z-axis coverage in a single 0.28-s rotation time. This approach minimizes dose requirements. Concordantly, we recommend the using MDCT arthrography in routine daily practice for assessment of the ankle osteochondral lesions.

Conflicts of interest

The authors declare that they have no conflict of interest.

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