




Computed tomography arthrography versus magnetic resonance imaging for diagnosis of osteochondral lesions of the talus

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Abstract

Introduction Osteochondral lesions of the talus (OLT) usually have non-specific clinical symptoms, and radiographs have a low sensitivity for detecting OLT. The purpose of this study is to compare the diagnostic value of CT arthrography (CTa) with that of MRI using arthroscopy as the reference standard for grading OLT.

Materials and methods We retrospectively reviewed patients who had OLT between 2015 and 2020. Patients with symptomatic OLT as a surgical indication, who were treated arthroscopically, and underwent both CTa and MRI before surgery were included. OLT was evaluated by both CTa and MRI using arthroscopy as the standard. We graded CTa, MRI, arthroscopic findings using Mintz classification.

Results Thirty-five patients were included. Accuracy rates of MRI and CTa for grading OLT, compared to those of arthroscopy, were 57.1% and 88.6%, respectively. Among 15 mismatched cases in MRI, 12 lesions (80%) were matched in CTa and arthroscopy. CTa had significantly higher diagnostic performance than MRI for the detection of grade III lesions ($p=0.041$). Using the receiver operating characteristics curves, the area under the curve values for lesion grading were 0.893 for CTa and 0.762 for MRI.

Conclusion CTa was statistically significantly better in detecting chondral flapping or subchondral exposure lesions for OLT than MRI on using arthroscopy as the reference standard. Because the stability of the OLT is essential in determining the treatment method, if an OLT is observed on MRI and is suspected to cause ankle pain, we recommend additional CTa examination to determine the more correct treatment strategies for OLT.

Level of evidence Diagnostic Level III.

Keywords Osteochondral lesion of the talus · CT arthrography · MRI · Arthroscopy

Introduction

Osteochondral lesions of the talus (OLT) are defects of the cartilage and subchondral bone in the talar dome. They commonly occur following trauma such as ankle sprain, resulting in ongoing residual pain and functional disability [15]. In many patients, clinical symptoms are non-specific, and X-rays generally have a low sensitivity for detecting OLT unless a definitive displacement is present [30].

Magnetic resonance imaging (MRI) provides a non-invasive evaluation of the cartilage surface, subchondral plate, and soft tissue injuries [18]. MRI is considered the gold standard for the assessment of chondral and osteochondral lesions in the ankle [23, 28]. Arthroscopy has the advantage of allowing simultaneous diagnosis and treatment. It helps to accurately identify the OLT, enables cartilage examination, and is considered the real reference standard for assessing

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the OLT. However, we observed differences between the OLT grades determined using MRI and arthroscopy. Further, other previous studies reported that MRI also has limited performance in the depiction of articular cartilage surfaces [16, 17] Because the treatment strategy is based on the stability of the osteochondral fragment, ankle articular depiction is important [21].

With the introduction of multi-detector row computed tomography (MDCT), CT arthrography (CTa), capable of isotropic data acquisition with high spatial resolution, enables excellent depiction of the articular cartilage [4, 27]. With these improvements, CTa is considered a valuable imaging modality in the assessment of articular cartilage of the knee, ankle, shoulder, and hip joints [12, 22, 29, 30].

There are few reports comparing CTa and MRI findings of OLT, but these comparisons have been performed with either CTa as the reference standard [21], simply based on cartilage thickness [8] or with the surgical report as the standard. There is a report containing only the results of sensitivity for detection of cartilage lesions [12]. Furthermore, no study has compared the diagnostic values of MRI, CTa, and arthroscopy for the grading of OLT.

This study aimed to retrospectively compare the diagnostic value of CTa and MRI using arthroscopy as the reference standard for grading OLT. We hypothesized that CTa is more accurate with arthroscopy than MRI for the grading of the articular cartilage lesion of the talus.

Materials and methods

Subjects

This retrospective study was approved by our hospital Institutional Review Board. This study was conducted in accordance with the World Medical Association Declaration of Helsinki. We reviewed the electronic medical records identifying 74 patients with OLT who underwent both MRI and CTa between May 2015 and June 2020. In 41 of these cases, the patients underwent arthroscopic treatment. The inclusion criteria were symptomatic OLT as the surgical indication, no response to conservative treatment for at least 3 months. Patients were excluded if surgery was performed between the scanning of MRI and CTa. Furthermore, patients with any prior surgery on the affected ankle ($n=5$), diabetes, immune diseases, or active infection were excluded. In case the MRI was performed at other hospitals, patients with poor-quality MRIs were excluded ($n=1$; 1.0 T MRI). Finally, 35 patients were included in our study.

MRI

For 12 patients, MRIs were performed using 3.0-T scanners (Magnetom Verio/Trio, Siemens Medical Solution, Erlangen, Germany or Ingenia CX, Philips Healthcare, Best, the Netherlands) at our institution. Twenty-three patients underwent MRIs at other hospitals, of which 12 MRIs were 3.0-T and 11 were 1.5-T. All MRIs included coronal and sagittal plane spine echo T1- and T2-weighted images and fat-suppressed fluid-sensitive images.

CT imaging

All patients underwent dual-layer spectral-detector CT (IQon – Spectral CT®, Philips Healthcare, Best, Netherlands) at our institution. Axial data acquisition was performed with 0.8-mm slices 3D data set. Both semi-coronal and sagittal reformatted images of 2 mm were reconstructed. After CT imaging, each patient was imaged with contrast. In this procedure, the ankle joint was entered with a 22-gauge, 2-inch-long spinal needle. A single examiner performed all the injections. The 20 ml of injectate consisted of 12 ml non-ionic iodine contrast (Ioxitalamate) mixed with 8 ml normal saline. The average total injected volume was 5 ml. CT images were obtained immediately after the injection.

Arthroscopic assessment

All patients underwent arthroscopic ankle surgery under general or spinal anesthesia with a thigh tourniquet. A standard ankle distractor was used to facilitate joint access and visualization. Standard anteromedial and anterolateral portals were established. Arthroscopy was performed with a 2.7-mm diameter, 30° angle arthroscope. Once the osteochondral lesion was identified, its grade was checked by probing. Arthroscopic staging was determined by 2 orthopedic operators (D.Y.L., D-.O.L). These operators were unaware of MRI and CTa staging.

Image analysis

All magnetic resonance and CTa images were transferred on the Picture Archiving Communication System workstations (INFINITT Healthcare Co., Seoul, South Korea) and were evaluated by 2 observers (H.W.K, D-.Y.K) with 10 and 8 years of experience in musculoskeletal imaging, respectively, who were not involved in the patient care, blinded to the outcome of the arthroscopic evaluation, and independently analyzed the MRI and CTa images in random order.

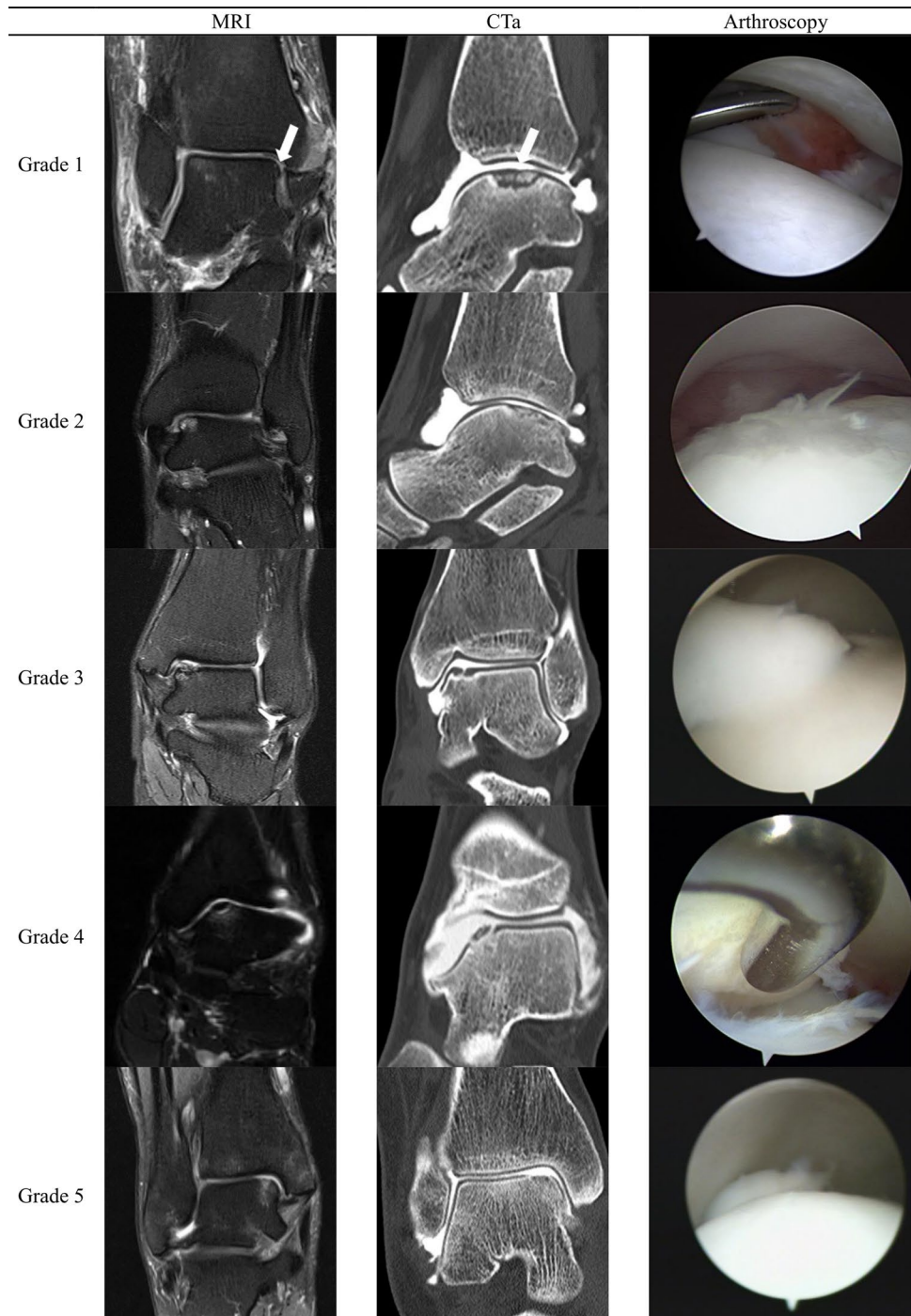
Based on CTa, MRI, and arthroscopy, OLTs were divided into 5 subtypes using the grading system

suggested by Mintz et al. [19]. In grade I, there was an abnormal signal but intact cartilage. Grade II lesions involved fibrillation or fissures in cartilage not extending to bone. In grade III lesions, a flap was present, or the bone was exposed. In grade IV lesions, a loose undisplaced fragment remained in the defect. Grade V lesions showed displaced fragments (Fig. 1).

Statistical analysis

The findings from MRI and CTa were compared with arthroscopic findings. Measurement data are expressed as mean \pm standard deviation. Using arthroscopy as the gold standard, sensitivity, specificity, positive and negative predictive value, and accuracy were determined for both CTa and MRI. Differences in the detection of grade III-V lesions were compared using McNemar's test.

Fig. 1 Representative images of Mintz classification obtained by magnetic resonance imaging (MRI), computed tomography arthrography (CTa) and arthroscopy



Performance of MRI and CTa were compared with regard to lesion grading using receiver operating characteristic (ROC) curve. Arthroscopic grading was used as the standard. Statistically significant differences between the area under the curve (AUC) of MRI and CTa were evaluated using the paired Wilcoxon test. Intra- and inter-observer reliability in grading appearances on CTa and MRI were determined using Cohen's kappa statistics. Observer reliability was categorized as poor (<0.20), fair (0.20 – 0.39), moderate (0.40 – 0.59), good (0.60 – 0.79), or excellent (>0.80). $P < 0.05$ was considered significant and all analyses were performed with SPSS version 23.0 (SPSS Institute, Chicago, IL, USA).

Source of funding

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Results

In the present study, the MRI, CTa, and arthroscopy were performed for all patients to visualize osteochondral lesions. The mean age of patients was 43.7 ± 13.0 years (range, 15–61 years), and 21 (60%) were males. There were 31 patients (89%) with a trauma history. The interval between CTa, MRI and ankle arthroscopy was not >3 months. Details of patients are summarized in Table 1.

Based on the Mintz classification, the results of different diagnostic techniques for each patient with osteochondral lesion are presented in Fig. 2. According to the arthroscopy data, grade III was the most common (20 patients, 57.1%), followed by grade V (9 patients, 25.7%). Accuracy rates of MRI and CTa for grading osteochondral lesions compared to those of arthroscopy were 57.1% and 88.6%, respectively. Using arthroscopy as the standard, MRI underestimated 14 lesions (40%) and overestimated 1 lesion (2.8%). CTa underestimated 4 lesions (11.4%) and overestimated no lesion. Among 15 lesions that were mismatched in MRI, 12 lesions (80%) were matched in CTa and arthroscopy.

For different diagnostic methods for grade III–V lesions, the sensitivity, specificity, positive and negative predictive values, and accuracy rates are given in Table 2. All the results for lesion grading were higher for CTa than for MRI. CTa had higher diagnostic performance than MRI for the detection of grade III lesions ($p < 0.05$). However, there was no statistical difference between CTa and MRI for grade IV

Table 1 Patient Demographics

Total patients (total ankles), <i>n</i>	35 (35)
Male/female, <i>n</i>	21/14
Age of diagnosis, y, mean \pm SD	43.7 ± 13.0
Right-/Left-sided lesion, <i>n</i>	12/23
Lesion location, medial/lateral/both, <i>n</i> of ankles	27/6/2
History of trauma, <i>n</i> of ankles	
Sprain	29
Ankle fracture	2
Unknown	4
CTa before to MRI, <i>n</i>	3
Days from MRI to Arthroscopy, mean \pm SD	51.6 ± 35.3
Days from CTa to Arthroscopy, mean \pm SD	30.8 ± 23.2

CTa computed tomography arthrography; MRI magnetic resonance imaging

and V lesions ($p = 0.617$ and $p = 0.480$, respectively). The AUC of CTa was higher than that of MRI but had no significant difference (0.893 vs. 0.762 , $p = 0.174$; Fig. 3).

Cohen's kappa analysis of all grades showed inter- and intra-observer reliability with arthroscopy. There was a fair agreement regarding MRIs between observers 1 and 2 with a kappa value of 0.308 and 0.251 , respectively, regarding CTa, the agreement was good with kappa values of 0.796 and 0.739 , respectively. Intra-observer agreements for MRI and CTa were excellent (0.953 and 0.943 , respectively).

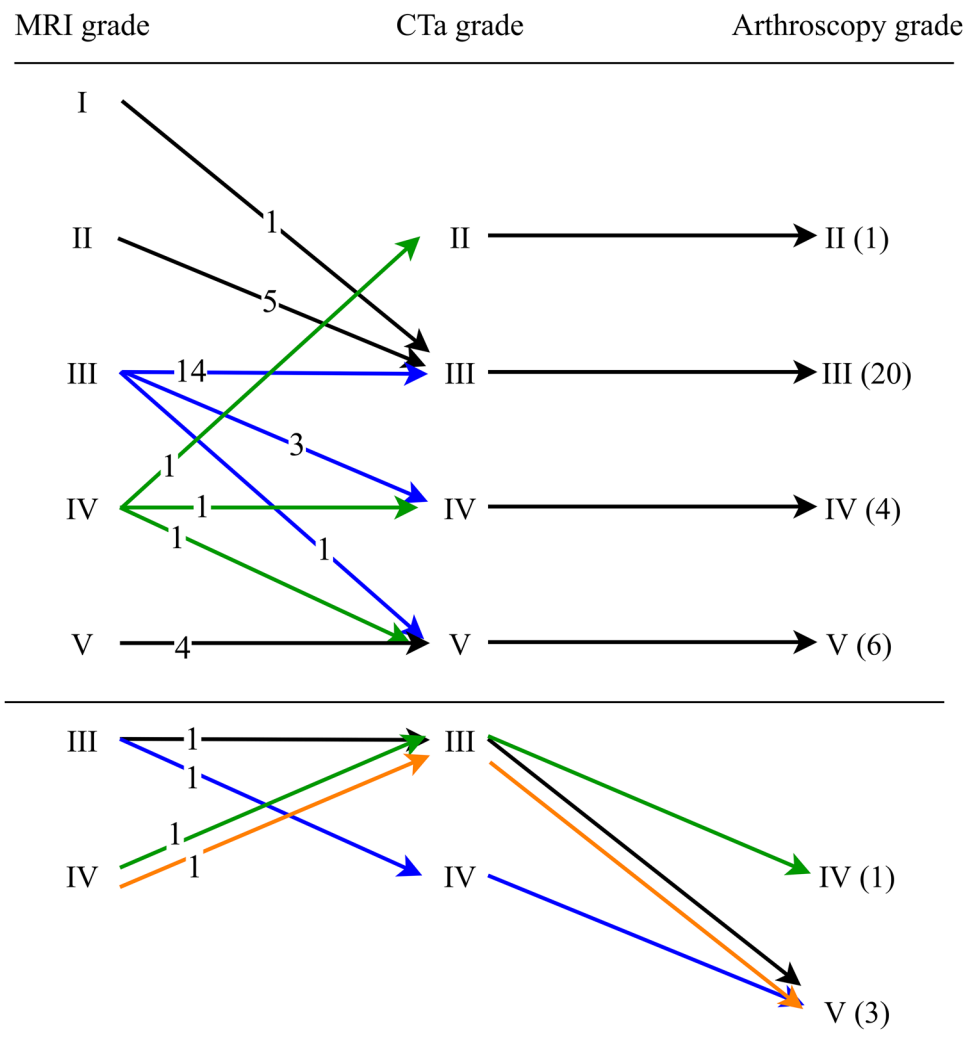
Discussion

The diagnostic values of CTa and MRI grading of OLT on using arthroscopy as the reference standard was assessed in the present study. CTa had a better diagnostic performance than MRI for grade III lesions. Intra-observer reliability for grading of OLT was superior for CTa than for MRI. The results of ROC curves showed a slightly better performance of CTa than that of MRI.

Although Kirschke et al. [14] compared MRI and CTa with intraoperative findings in the evaluation of depth and size of osteochondral defects, to the best of our knowledge, no published studies have compared the grading of OLT using Mintz classification by MRI and CTa and using arthroscopy as the reference standard.

Several grading systems based on the comparisons between MRI and arthroscopy have been reported for staging OLT [3, 5, 6, 19]. Mintz et al. [19] suggested a revised MRI-based staging system that had an accuracy of 83% for the staging of OLTs of the ankle. Other authors also reported similar results with an accuracy of 81% between MRI and arthroscopic staging using the Mintz classification [16]. This classification focus more on cartilage evaluation than do the Hepple [10] or Dipaola classifications [8]. We chose this

Fig. 2 A flow chart showing the grading of osteochondral lesions of the talus in patients varying by magnetic resonance imaging (MRI), computed tomography arthrography (CTa), and arthroscopy. The numbers on the line and in the parentheses indicate the number of patients



MRI, magnetic resonance imaging; CTa, computed tomography arthrography

Table 2 The calculated sensitivity, specificity, positive and negative predictive value, and accuracy of the different diagnostic methods for an OLT in Grade III, IV, and V

Arthroscopy	Grade III		Grade IV		Grade V	
	MRI	CTa	MRI	CTa	MRI	CTa
Sensitivity (%)	70 (53.4–83.7)	100 (85.7–100)	40 (7.7–77.3)	80 (34.6–98.2)	44.4 (19–44.4)	66.7 (38.2–66.7)
Specificity (%)	60 (37.9–78.3)	80 (60.9–80)	90 (84.6–96.2)	96.7 (89.1–99.7)	100 (91.2–100)	100 (90.1–100)
PPV (%)	70 (53.4–83.7)	87 (74.5–87)	40 (7.7–77.3)	80 (34.6–98.2)	100 (42.8–100)	100 (57.3–100)
NPV (%)	60 (37.9–78.3)	100 (76.1–100)	90 (84.6–96.2)	96.7 (89.1–99.7)	83.9 (76.5–83.9)	89.7 (80.8–89.7)
Accuracy (%)	65.7 (46.8–81.4)	91.4 (75.1–91.4)	82.9 (73.6–93.5)	94.3 (81.3–99.5)	85.7 (72.6–85.7)	91.4 (76.8–91.4)

Value (95% confidence intervals)
 OLT osteochondral lesion of talus; MRI magnetic resonance imaging; CTa computed tomography arthrography; PPV positive predictive values; NPV negative predictive values

classification to evaluate lesion stability in detail. However, MRI underestimated the lesion grade in 17% of the patients in the study by Mintz et al. [19]. The study by Lee et al. [16]

also showed that all the mismatched cases between MRI and arthroscopy (19%; 10/52 ankles) were underestimated by MRI. Using another MRI grading system by Anderson

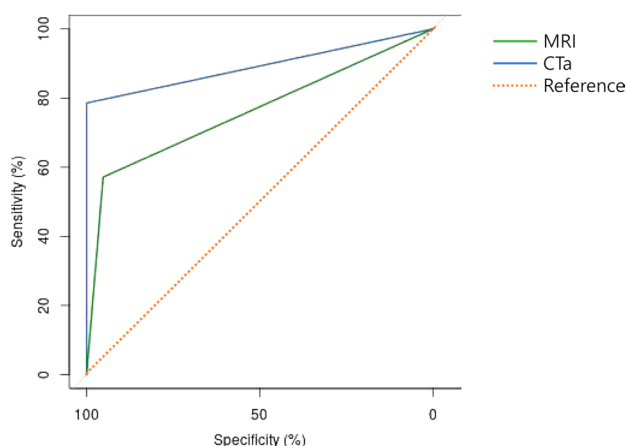


Fig. 3 The receiver operating characteristics curve for osteochondral lesion grading on magnetic resonance imaging (MRI) and computed tomography arthrography (CTa). Area under curve of CTa was higher than MRI (CTa, 0.893; MRI, 0.762), though the difference was not statistically significant ($p=0.174$)

[1], Bae et al. [2] reported a relatively low correlation rate of 65.9% between MRI and arthroscopy. Our study showed that the tendency of MRI to underestimate the lesion grade was similar to that reported in previous studies [16, 19]. MRI underestimated the lesion grade in 40% ($n=14$) of the patients in our study. And among these, 6 patients had symptomatic OLT and stable lesions (grade I or II) on MRI, which were grade III unstable lesions on arthroscopy.

The potential reason for this low correlation could be the following: the lesion interpretation with bone marrow edema or cyst is challenging when the overlying cartilage is intact. Rubin et al. [26] suggested that focal subchondral edema may provide a clue to detect overlying chondral lesion

injuries. In this study, MRI showed only signal changes or fibrillation in cartilage; therefore, we interpreted such lesions ($n=6$; 40% of mismatch cases) as grade II; however, these lesions were determined as grade III by arthroscopy. All these cases were also diagnosed as grade III on CTa, and the focal subchondral edema or cyst was observed (Fig. 4). Conversely, because of the large number of signal changes that can be caused by edema even after minor ankle injuries, Elias et al. [9] suggested that MRI leads to the overestimation of the extent of OLT. In our study, there was one false-positive case with subchondral edema and cyst with an osteochondral lesion on MRI. We interpreted that the osteochondral fragment would be unstable in a grade IV lesion; however, it was diagnosed as grade II through CTa and arthroscopy (Fig. 5). Therefore, it is necessary to carefully interpret focal subchondral edema or cysts with the overlying cartilage showing signal change or fibrillation on MRI.

CTa has been used for the detection of articular cartilage since the early eighties [24]. Schmid et al. [27] first compared magnetic resonance arthrography (MRa) and CTa with CTa as the standard of reference in the ankle joints and reported that CTa was more reliable for the detection of cartilage lesions. They reported an accuracy of 90–92% for CTa and 76–88% for MRa, and the interobserver agreement for CTa and MRa was 0.69 and 0.47, respectively [27]. Our study found that the accuracy of MRI and CTa for grade III–V lesions were 65.7–85.7% and 91.4–94.3%, respectively. The level of accuracy achieved in this study parallels that achieved by Schmid et al. [27].

In a clinical study of 79 patients [14], the depth and size of ankle osteochondral defects were assessed with both CTa and MRI. CTa and MRI detected 87.5% and 81.2% of cartilage defects and 84.6% and 46.2% of full-thickness defects,

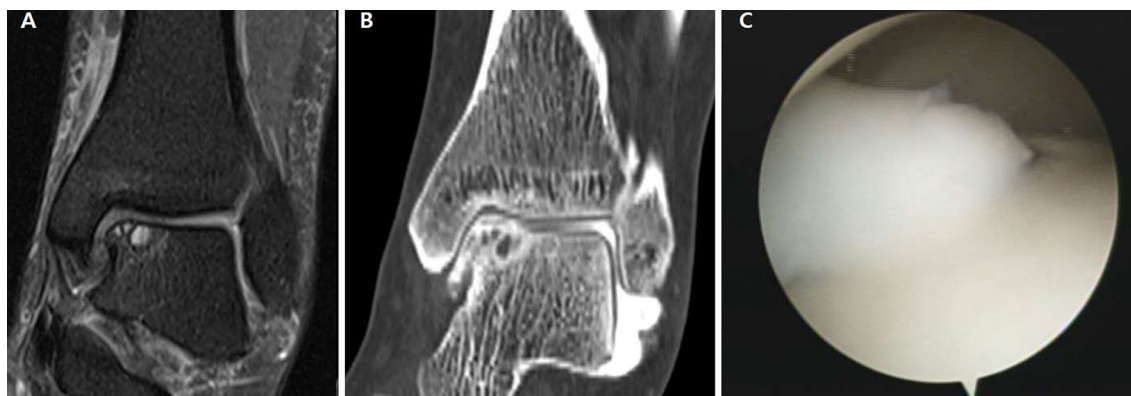


Fig. 4 Forty-seven-year-old female study patient showing challenges of lesion interpretation with subchondral cyst on magnetic resonance imaging (MRI). **A** Coronal proton density with fat saturation MRI shows only cartilage signal change with subchondral cyst at left medial talar dome (Mintz classification II). **B** Coronal computed

tomography arthrography shows chondral flap with subchondral cyst (Mintz classification III). **C** Arthroscopic image shows the flapping articular cartilage, but not detached on the medial talar dome (Mintz classification III)

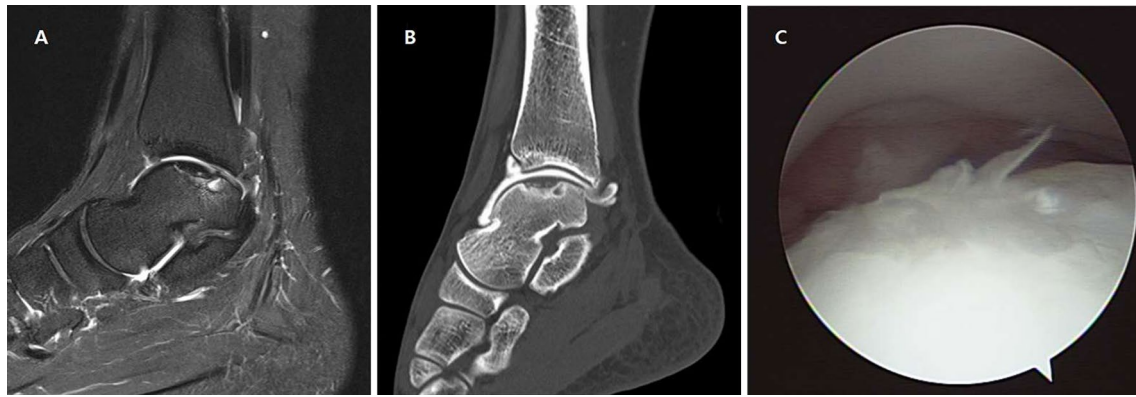


Fig. 5 Twenty-year-old male study patient showing challenges of lesion interpretation with bone marrow edema on magnetic resonance imaging (MRI). **A** Sagittal proton density with fat saturation MRI shows undisplaced osseous fragment with the high signal line below osteochondral lesion at left medial talar dome (Mintz classification

IV). **B** Sagittal computed tomography arthrography shows sclerotic change below osteochondral fragment with overlying cartilage intact, whereas there is subtle cartilage lesion (Mintz classification II). **C** Arthroscopic image shows the only cartilage fibrillation (Mintz classification II)

respectively. The authors concluded that the sensitivity of CTa was better than that of MRI for the detection of cartilage lesions [14]. In our study, 80% of mismatched cases in MRI for grading OLTs were matched in CTa. We think treatment strategies and surgical decisions for OLT might change based on CTa findings. In this study, although stable lesions were observed on MRI, surgical treatment was performed in 6 cases (17%) of patients with instability on CTa, and arthroscopic findings were also observed as unstable lesions. There may be opposite situations. If it is seen as an unstable lesion on MRI, but is confirmed to be stable on CTa, conservative treatment can be attempted further. This study did not illustrate this possibility further, because it included only those patients who underwent surgery. However, in 12% (9/74) of OLT cases that were unstable lesions based on MRI but not on CTa findings, we changed to the conservative treatment. These results will be reported in our later study.

The results of ROC curve analysis showed that the AUC of CTa was slightly higher than that of MRI (0.898 vs. 0.762), but there was no statistical difference ($p=0.174$). However, CTa showed a greater performance in flap lesions or subchondral bone exposure of grade III ($p=0.04$). This was probably because the unique high spatial resolution of CTa makes it easy to depict articular cartilage along each articular surface of the joint. Furthermore, the current surgical treatment paradigm of OLT is aimed at restoring the articular surface with repair tissue that is similar to the hyaline cartilage [11, 20, 23]. Therefore, the preoperative evaluation of articular cartilage in the ankle joint is important for assessing the location, size, depth, and stability of osteochondral lesions before deciding whether to perform surgical treatment and which type of surgical procedure to perform [11, 13, 20, 23]. However, because OLT is not clear

on X-ray, MRI, which can detect both intra and extra-articular injuries in ankle joints, is still considered the method of choice in patients with ankle pain [7, 25]. Therefore, if the cause of ankle pain is found to be an osteochondral lesion on MRI, it would be better to perform CTa, which is superior to cartilage delineation, to determine treatment strategies for OLT.

Some limitations may be considered in our study. First, this study is a retrospective case series, and there may have been a lack of statistical power due to the small cohort size. Because of the relatively small cases, it was difficult to evaluate some of the results for significance. Future larger studies will help to compare the performance of CTa and MRI. Second, we confirmed the quality of outside hospital MRI and excluded 1 patient who had poor-quality images, but outside hospitals' MRIs included 1.5-T and 3.0-T together. The higher performance of the 3.0-T compared to that of 1.5-T could have contributed to the better results. Third, because only the patients who underwent arthroscopic surgery were included, grade I and II cases could not be evaluated. Additionally, there may be a selection bias as patients who underwent conservative treatment were not included. Future studies should include patients treated conservatively as well as surgically. Finally, there is a problem in that additional radiation exposure and cost arise while additional CTa is taken.

In conclusion, CTa was statistically significantly better in detecting chondral flapping or subchondral exposure lesions for OLT than MRI on using arthroscopy as the reference standard. Furthermore, CTa had higher accuracy rates than MRI for grading OLT compared to those of arthroscopy. Because the stability of the OLT is very important in determining the treatment method, if an OLT is observed on MRI and is suspected to cause the ankle pain, we recommend

additional CTa examination to determine appropriate treatment strategies for the OLT.

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Data availability The dataset generated shall be available upon reasonable request to the corresponding author.

Declarations

Conflict of interest Each author certifies that there are no funding or commercial associations (consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article related to the author or any immediate family members.

Ethical review committee statement Ethical approval for this study was obtained from Seoul National University Hospital, Seoul, Republic of Korea (approval number H-1806–035-949).

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