CHAPTER 8

Osteochondritis dissecans of the talar dome: Evaluation of bone viability with dynamic gadolinium-enhanced MR imaging in comparison with dynamic bone scintigraphy.

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Abstract

Objective. To determine the viability of osteochondritis dissecans (OD) in the talar dome with dynamic (dyn) contrast-enhanced MR imaging using dynamic (dyn) scintigraphy as the standard of reference.

Materials and methods. Dyn MR images and bone scintigraphy scans of 9 consecutive patients, evaluated between January 1998 to December 2000, were reviewed. MR imaging was performed using a fast gradient echo technique with acquisition of a single slice section positioned over the area of OD. Three-phase bone scintigraphy with administration of 600 MBq $^{99}$Tc HDP and dyn image acquisition for 3 minutes and after 3 hours post injection was performed. Signal intensity (SI) and radioactivity curves were compared between the two techniques.

Results. Eight of the nine cases showed good correlation between the findings of dyn MR and dyn scintigraphy. In seven of the eight patients there was contrast enhancement and radioactivity uptake in the central area of the OD lesion consistent with good vascularization of the lesion. No enhancement or activity was seen in one patient. In the other case dyn MR imaging showed no central enhancement of the OD lesion, while three-phase bone scintigraphy depicted uptake in the OD lesions.

Conclusion. The findings suggest that dyn MR imaging in comparison with dyn scintigraphy better determines the viability of OD lesions. It is our belief that due to the relative poor spatial resolution of scintigraphy central necrosis is not visualised. An additional advantage of dyn MR imaging is that the procedure is easily performed following conventional MR imaging without exposing the patient to ionizing radiation.

Introduction

Osteochondritis dissecans (OD) of the talar dome is a relatively common complication occurring in 6% of patients who have sustained an inversion injury [1]. There are no known specific clinical signs or symptoms indicating the presence of OD; however, persistent pain, despite treatment, is suggestive of this entity [2]. It has been demonstrated that repeated trauma may lead to progression of OD which, in turn, may result in progressive disability [3,4,5]. Although the exact cause of OD is unknown, it is thought that in mild cases microfractures, hemorrhage and edema occur [4,5]. When this subsides, the disease is reversible. However, in more severe instances, the subchondral fractures together with the vascular insufficiency, can eventually lead to avascular necrosis of the
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Bone fragment [4,6]. If healing does not occur, the fragment becomes necrotic and encased along its articular surface by hyaline cartilage and its trabecular surface by fibrocartilage, which is impenetrable to capillary ingrowth [7,8]. Healing of the OD requires ingrowth of capillaries into a stable fragment. Lesions with viable bone are likely to heal spontaneously with conservative treatment, while with necrosis the bone may collapse, leading to degenerative changes in the ankle joint [4,9].

Current treatment of OD is aimed at prevention of a necrotic section in order to maintain the integrity of the joint. Such treatment includes drilling (with fixation) of the subchondral bone in an attempt to facilitate revascularization of the compromised subchondral tissues, or excision of the unstable fragment [10]. Currently, in order to determine the status of the subchondral bone, diagnostic arthroscopy is performed whereby the articular cartilage is inspected. The OD lesion is considered to be stable when the overlying cartilage is firm on palpation [10]. When the cartilage is unstable and gives way, this suggests the presence of a loose fragment which in turn, would be indicative of necrosis of the bone fragment [6]. However, arthroscopic palpation is relatively insensitive in diagnosing necrosis of the underlying bone, and drilling of the OD is usually done empirically even when the findings of palpation are normal [10].

OD, particularly at an early stage, is difficult to visualize by conventional radiography [11,12]. Static bone scintigraphy with technetium $^{99m}$Tc HDP is more sensitive at detecting the disease; however, the specificity in determining the presence of OD is low [11,13]. In addition, it provides no information in assessing the viability of the lesion [14,15]. Dyn bone scintigraphy studies have shown to be accurate in assessing disease activity since it gives quantitative information of blood flow and this method is most commonly used to determine bone viability [9,14-17].

Conventional MR imaging has been shown to be a sensitive diagnostic tool for detecting OD of the talar dome [18]. In addition, with this technique the various stages of this disease can be determined [2,4,18]. However, despite extensive investigation evaluating the signal intensity (SI) appearances of the affected bone using conventional MR imaging, it has not been possible to determine the viability of the bone fragment in the OD lesion [19]. Studies have shown that dyn gadolinium-DTPA (Gd-DTPA) -enhanced MR imaging is more sensitive than unenhanced or non-dyn enhanced MR imaging in detecting osteonecrosis in the femoral head, knee and navicular bone [13,14,20,21]. Ceval et al., who investigated the navicular bone, found that lack of enhancement of bone marrow in the early phase of the study indicated lack of blood perfusion and the findings corresponded to variable degrees of ischemia [13]. The purpose of our study was to determine the ability of dyn contrast-enhanced MR imaging in assessing the vascularization of OD of the talar dome using the findings of dyn $^{99m}$Tc bone scintigraphy as the standard of reference.
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Materials and methods

Dyn contrast-enhanced MR imaging of the ankle was performed in all patients who had OD of the talar dome between January 1998 and December 2000. The diagnosis of OD was based on the commonly used MR criteria using non-dyn imaging [2,5,12]. All patients had persistent pain and a history of acute or recurrent inversion injury of the ankle occurring between 4 weeks and 1.5 years before MR imaging. There were 9 patients (9 ankles), seven males and two females with ages ranging from 13 to 41 years (mean age, 25 years). Bone scintigraphy of the affected ankles was performed in all patients, and intervals between dyn scintigraphy and dyn MR imaging ranged between 2 days and 5 weeks. Radiography of the ankles was also obtained in all cases.

MR imaging was performed at 0.5 Tesla (Philips, Best, the Netherlands) with the ankle placed in an extremity coil. Conventional sagittal and/or coronal T1- and T2-weighted images were obtained prior to dyn imaging, using the following parameters: T1-weighted spin-echo (SE) with repetition time/echo time (TR/TE) 600 ms/23 ms, T2-weighted SE (TR/TE 2000 ms/100 ms) and short tau inversion recovery (STIR) 3600 ms/20 ms; inversion time = 150 ms. The precontrast T1- and T2-weighted images were used to determine the position of the image plane that included the most representative part of the lesion. Dyn imaging was performed using a fast T1-weighted, magnetization-prepared, gradient-echo (MP-GRE) sequence with the following parameters: TR/TE/flip angle 15 ms/6.8 ms/ 30°, 741 msec preparatory pulse delay time (centric phase encoding), one signal acquired per data line, 128 or 256 x 256 matrix size, 160-450 mm field of view. The images were obtained as a single slice section and the image plane was chosen such that an artery, either the anterior or posterior tibial artery, was included to determine the time of arrival of the contrast bolus [22]. The temporal resolution was one image/3 seconds. Images were acquired at initiation of an intravenous bolus injection [2-3 cc/sec manual injection of 15 cc Gd-DTPA (Magnevist, Schering, Berlin, dose 0.1 mmol/ml] in the right antecubital vein followed by a saline flush, and imaging was continued until 5 min after beginning of the dyn examination.

Once obtained, the contrast-enhanced dyn images were subtracted from the first MP-GRE image of the dyn series that was obtained before arrival of the contrast material bolus. Regions of interest (ROI) were drawn in the central portion of the OD lesion and one in the normal bone marrow for comparison. Time intensity curves (TICs) of the two areas were then generated covering the first 5 minutes after injection of the contrast agent. Two observers in consensus did selection of the ROIs. Using each TIC the slope
and the time to maximum enhancement were determined. Using the TICs it was determined whether the central area demonstrated enhancement.

As surgery consisting of drilling of the lesions was performed in 5 of the 9 patients, the results of these findings was not used as the standard of reference since histologic examination were not performed [13]. We therefore used the results of three-phase bone scintigraphy as the standard of reference. Dyn scintigraphy was performed by injecting 600 MBq of $^{99m}$Tc HDP [17]. The patient was placed under a large field-of-view camera with a 15% window, 140 keV setting and high-resolution collimator [17]. Blood flow and blood pool data were obtained from AP and lateral views of the hindfoot in the first 3 minutes.

Dyn scintigraphic activity was classified as symmetric, increased or decreased as compared with the unaffected side [9,15-17]. Increased activity was considered indicative of increased local metabolic activity and regional blood flow to the bone. This increased scan activity was interpreted as a positive predictive sign for viability [15-17]. Curves with minimal or decreased extraction of the farmacon were indicative of delayed or absence healing [15]. Using the dyn phase of the three-phase bone scan, a ROI was drawn in the most central area and around the lesion. TICs of the two areas of both feet were then generated covering the first 3 minutes after $^{99m}$Tc HDP injection. Static bone scintigraphy was obtained 3 hours after injection of the nuclear farmacon.

Results

Analysis of the MR images
The results of enhancement of OD lesions by dyn MR and dyn scintigraphy are shown in table 1. In 8 of the 9 cases the flow curves showed a good correlation between the findings of dyn MR and dyn scintigraphy. In 7 of the 8 patients the increased enhancement or increased uptake in the central OD lesion was equal (Fig. 1). There was no enhancement or uptake, with both techniques, in one patient. In only one of the 9 cases the findings between the two techniques did not correlate. The dyn scintigraphy demonstrated increased radioactivity of the OD lesion while dyn MR detected a central area of diminished enhancement (Fig. 2).

The static bone scans showed activity in all of the patients.
Table 1. Demonstration of enhancement of the central bone area at 2 minutes after injection.

<table>
<thead>
<tr>
<th>Patient no.</th>
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<th>Scintigraphy</th>
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<tr>
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Figure 1. 37-year-old man with kissing contusion after inversion injury.
A, Anteroposterior radiograph of the right ankle.
B, STIR images of the right ankle, showing increased SI in the OD lesions of the lateral talar dome (arrow) and the lateral tibia plafond (small arrows) (“kissing lesion”).
C, Dyn bone scintigraphy with increased flow at lateral side of the talar dome (arrow) and tibia plafond (arrowheads).
D, TICs of dyn MR images with increased enhancement in the talar OD lesion indicating increased vascularisation. The ROI was sampled in the centre of the OD lesion (+) and the talus marrow (•).
E, TICs of dyn bone scintigraphy with increased activity indicating increased vascularisation of OD lesion. The ROI was sampled in the centre of the OD lesion (+). Left ankle for comparison (•).
Discussion

The treatment goal in OD lesions after trauma is to promote healing and prevent localized osteonecrosis or detachment of the fragment [16,17]. Since there is increased risk of ischemia of the OD lesion, it is important that early treatment is given to prevent deformity of the subchondral bone and overlying cartilage with resulting osteoarthritis [9,23]. Several authors have emphasized the importance of determining the viability of tissues of OD lesions when forming a treatment plan [16,17]. Only dyn bone scintigraphy has been reported to accurately identify preoperatively those patients whose lesions are unlikely to heal [15-17].

The talus is an unique bone in the foot. There are no direct tendon or muscle attachments to it. It is covered by cartilage for more than 60%, because of this blood supply to the talus is limited, as there are only a few areas for entry of arteries into the bone. The talar dome is supplied by small end-arteries extending from these vessels, so blood supply to the dome is vulnerable and can easily be compromised after trauma [24]. As a result, when injured, there is an increased risk for developing osteonecrotic areas in the talar dome [6,25].

Static bone scintigraphy depicts the focal distribution of the bone-seeking agent and is not a direct assessment of the dynamic processes of the disease [16]. In our series all of the static images showed a hot spot.

Dyn bone scintigraphy with technetium $^{99m}$Tc HDP has been shown to be a reliable method diagnosing OD of the talar dome. The ability of this technique to visualize bone perfusion provides a highly sensitive and specific means of early recognition of ischemia.
Figure 2. 25-year-old man with persistent ankle pain after ankle sprain.

A, Anteroposterior radiograph of the right ankle, with lucency in the medial talar dome (arrow).

B, Sagittal STIR image showing an OD lesion with decreased SI (arrow) and increased SI in the surrounding talar marrow (arrowheads).

C, Dyn bone scintigraphy with increased flow at right talar OD lesion (arrow).

D, TICs of dyn MR image indicating decreased vascularisation in OD lesion. The ROI was sampled in the centre of the OD lesion (1), artery (2) and tibia (3).

E, TICs of dyn bone scintigraphy with increased flow indicating increased vascularisation of the OD lesion. ROI was sampled in the centre of the OD lesion (+). Left ankle for comparison (•).
Using the flow phase of the test, an assessment can be obtained of the vascularity of the lesion \([15, 16, 24, 27]\). Studies have also shown that the degree of osseous uptake reflects accurately the metabolic status of the bone which seems to be related to the potential for healing of the fragment \([15, 16, 24]\).

Using MR imaging, the bone marrow normally enhances following intravenous injection of Gd-DTPA. In normal bone tissue early, rapid enhancement occurs in the first two minutes after injection, followed by a slow decrease during the next 2 to 5 min \([13]\). In conventional T1-weighted post-contrast-enhanced images, obtained in the late vascular phase (between 4-9 min after injection), the contrast agent is already diffusely distributed in the interstitium of bone marrow and maximal marrow enhancement is already passed \([14, 28]\). Therefore, in order to optimally depict viability of the bone or ischemia, it is important that images are obtained in the early vascular phase \([14]\).

Recent introduction of fast, contrast-enhanced MR imaging techniques have permitted studies of the arterial blood flow of the tissues. These have shown that lack of arterial enhancement of the bone marrow is correlated with lack of blood perfusion and thus to ischemia \([13, 29]\).

In our study we found decreased enhancement of the central area of the OD lesion in two of the 9 patients who had sustained injury to the ankle. However, this was confirmed by dyn bone scintigraphy in only one. In the other one, no central area of decreased uptake was visualized by bone scintigraphy. A potential explanation for this discrepancy could be that the superior spatial and contrast resolution of MR allowed better visualization of the small region of decreased blood flow and thus ischemia in the OD lesion. Although dyn bone scintigraphy is frequently used as the “gold standard” for determining ischemia in case of an OD lesion, the findings of our study suggest that this modality may not be accurate enough for detecting small areas of necrosis due to the inferior image resolution in comparison with dyn MR imaging. However, a disadvantage of dyn MR imaging is that with this technique only one (sometimes three) slice sections are obtained for evaluation and as a result, sampling errors may occur when the OD lesion is partially included in the image \([22, 28]\).

Although we believe that MR imaging is very sensitive in detecting vascularisation of an OD lesion, our study is limited by the fact that only a small group of patients was evaluated and that follow-up was available in only a fraction of them. Another problem is that with dyn MR imaging it is difficult to differentiate between reactive synovitis, regenerating osteochondral tissue and fibrosis \([29]\). However, the same is true for bone scintigraphy. Furthermore, a limitation of our study was that no histologic material was available to proof the necrotic character of the non-enhancing area in the OD lesion.
However, when surgery is performed, biopsies are not routinely obtained. In addition, it is well recognized that the findings from random biopsies cannot be used to determine the histologic status of the entire specimen because focal areas of normal appearing bone may exist adjacent to regions of necrosis making it impossible to accurately determine whether ischemia is present [13].

In conclusion, in this series of patients with OD of the talar dome we found ischemia in two cases using dyn MR imaging while this was found in only one case with dyn scintigraphy. In all likelihood the area of necrosis was not visualized with scintigraphy due to its relatively poor spatial resolution in comparison to MR imaging. Therefore, dyn MR imaging appears to be the preferred method for evaluating the viability of the OD lesions. Additional advantage of dyn MR imaging is that the procedure is easily performed following conventional MR imaging without any exposure of the patient to ionizing radiation.

References


