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Case Report

Progression of knee osteonecrosis on MRI ☆☆☆

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ABSTRACT

Magnetic resonance imaging (MRI) is regarded as the most specific and sensitive of imaging modalities for the detection and progression of osteonecrosis (ON). We present MRI progression of ON in the knee in a 40-year-old female patient with Sjogren disease-related interstitial nephritis recently initiated on corticosteroids for deteriorating renal function. This case report correlates the degree of surrounding marrow edema with the patient's symptoms.

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Introduction

Osteonecrosis (ON), similar to ischemia/necrosis in other organs, is a result of disruption of blood supply to the bone. It can occur in the medullary cavity or in the cortex [4]. The common locations of ON are the femoral head, femoral and tibial metadiaphysis, proximal tibia, talus, and scaphoid [2].

Magnetic resonance imaging (MRI) is regarded as the most specific and sensitive of imaging modalities for ON [3] with currently published literature reporting between 97% and 100% accuracy [5–9]. MRI appearance can be variable due to the age and stage of ON [3]. The earliest manifestation of ON is often nonspecific focal marrow edema

(T1 isointense/hypointense, T2 hyperintense) in a location one would expect ON to occur. This then progresses to a characteristic serpentine rim which is both T1 and T2 hypointense allowing for diagnosis [3]. This serpentine rim represents the interface between viable and dead bone which is present in 90% of ON cases [1,3,4].

We present a series of 4 MRI knee examinations, in the same patient, performed at 3-month intervals which demonstrate the characteristic features of ON in different stages of evolution. In addition, the patient had 3 separate foci of ON in the knee (denoted as first, second, and third lesions for the purposes of this case report). This case also illustrates the relationship between marrow edema surrounding the focus of ON and the presence of clinical symptoms (Figs. 1–3).

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Fig. 1 – First lesion (anterior weight-bearing surface of the lateral femoral condyle). Selected PDFS images illustrate consecutive MRI studies at 1 month (A), 4 months (B), 7 months (C), and 11 months (D) of the first focus of osteonecrosis, first lesion (Arrow). (A) Multiple punctate hyperintense foci with surrounding marrow edema. (B) The lesion now appears as more confluent signal abnormality with a serpentine signal abnormality. There was an increase in the size of the lesion with proximal extension of signal abnormality into the metadiaphysis of the femur. The surrounding marrow edema had reduced. (C) Increased cystic change at the subcortical bone. There is early cortical bone and overlying cartilage irregularity (Chevron) which is suspicious for early cortical collapse and cartilage involvement. Increased marrow edema in this location when compared to the second MRI, possibly due to early cortical fracture/stress edema from cartilage damage rather than edema associated with bone infarction. (D) Further decrease in surrounding marrow edema. Cortical collapse of the articular surface (Asterisk) and the adjacent cartilage (Chevron) have slightly worsened.

Case report

A 40-year old female patient was referred by her rheumatologist for investigation of recent onset spontaneous severe left knee pain. Her medical history included chronic interstitial nephritis secondary to Sjogren's syndrome, hypothyroidism, coeliac disease, and transverse myelitis. Her serology was strongly positive for Antinuclear Antibodies, Anti-SSA (RO) and SSB (La) antibodies consistent with Sjogren's syndrome.

She was recently started on a trial of systemic corticosteroid therapy (oral Prednisolone 50 mg) for her deteriorating renal function. The corticosteroid therapy had been initiated 4 weeks prior to the onset of her knee pain. The pain was initially severe but present only while climbing stairs and

gradually completely settled over a period of months. Management of her knee pain was conservative with gentle walking and avoidance of strenuous physical activity. In this clinical context, corticosteroid-related disorders (ON and subchondral insufficiency fractures of the knee) were considered and an MRI of the knee was requested for workup and assessment.

The MRI studies of the left knee were performed on a 3T Siemens Magnetom MRI. Slices from the proton density with fat suppression sequences have been selected to illustrate 3 distinct foci of ON in the left knee.

The first MRI of the left knee was performed on June 17, 2019. Baseline MRI performed approximately 1 month after the onset of left knee pain. The initial MRI of the left knee demonstrates multiple punctate proton density (PD) hyperintense foci at the anterior weight-bearing surface

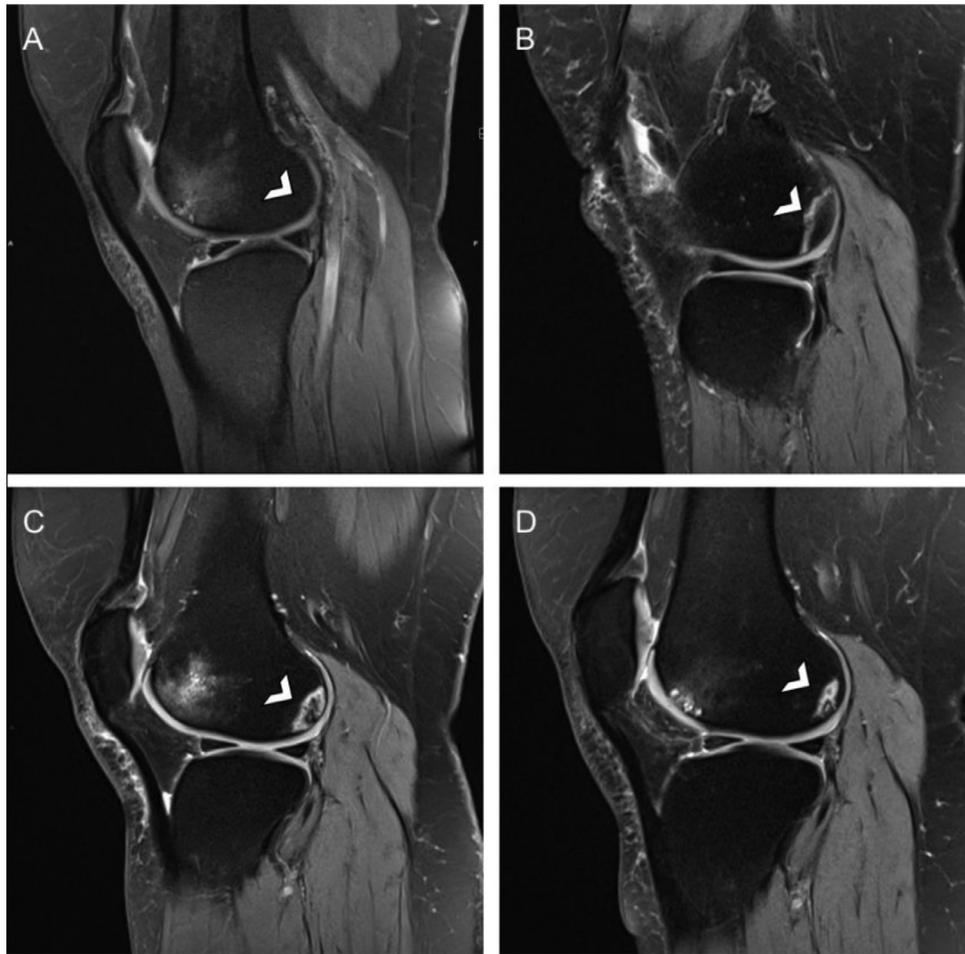


Fig. 2 – Second lesion (posterior weight-bearing surface of the lateral femoral condyle). Consecutive MRI studies at 1 month (A), 4 months (B), 7 months (C), and 11 months (D) after the onset of knee pain demonstrating the second focus of osteonecrosis, second lesion (Chevron). The second lesion was not present on the initial MRI performed 1 month after onset of symptoms. (A) No signal abnormality was present. (B) Second focus appears as a curvilinear focus at the posterior weight-bearing surface of the lateral femoral condyle with minor associated surrounding marrow edema. (C) The lesion appears more conspicuous with reduced surrounding edema. (D) Reduction in marrow edema and more well defined cystic change. No articular surface or cartilage collapse.

of the lateral femoral condyle in the subcortical bone with contact of the cortical surface (denoted as first lesion for the purposes of this case study). There was surrounding marrow edema. The overlying articular cartilage appeared normal. At this stage, the MRI findings were deemed to be nonspecific and a decision was made to monitor the knee clinically with a follow-up MRI requested in 6–8 weeks.

The second MRI of the left knee was performed on September 25, 2019. The second MRI in the series performed approximately 3 months after the initial study, demonstrated the previously noted punctate foci in the lateral femoral condyle (first lesion) as now appearing more conspicuous and increased in size. While on the previous study this region appeared as multiple tiny punctate PD hyperintense foci, the lesion now appeared as more confluent signal abnormality which now demonstrated the typical serpentine signal abnormality. There was an increase in the size of the lesion with proximal extension of signal abnormality into the metadiaphysis of the

femur. The surrounding marrow edema had reduced compared to prior MRI. In addition, there were now 2 new focal areas of signal abnormality, developed since the last study. The first new abnormality (denoted as second lesion) was a curvilinear focus at the posterior weight-bearing surface of the lateral femoral condyle. There was minor surrounding marrow edema. The second new abnormality (denoted as third lesion) was at the medial femoral condyle weight-bearing surface. Curiously, the 2 new lesions demonstrated a more characteristic appearance of “established” ON compared to the previous lesion; the serpentine band typical of ON. The patient’s symptoms had markedly improved by the second MRI. The possibility of a subchondral insufficiency fracture of the knee had been raised by the reporting radiologist at the time.

The third MRI in the series was performed on December 12, 2019. The patient’s knee pain continued to clinically improve by the third MRI study. The lateral femoral condyle lesion (first lesion) evident on the first MRI had further “matured,” now

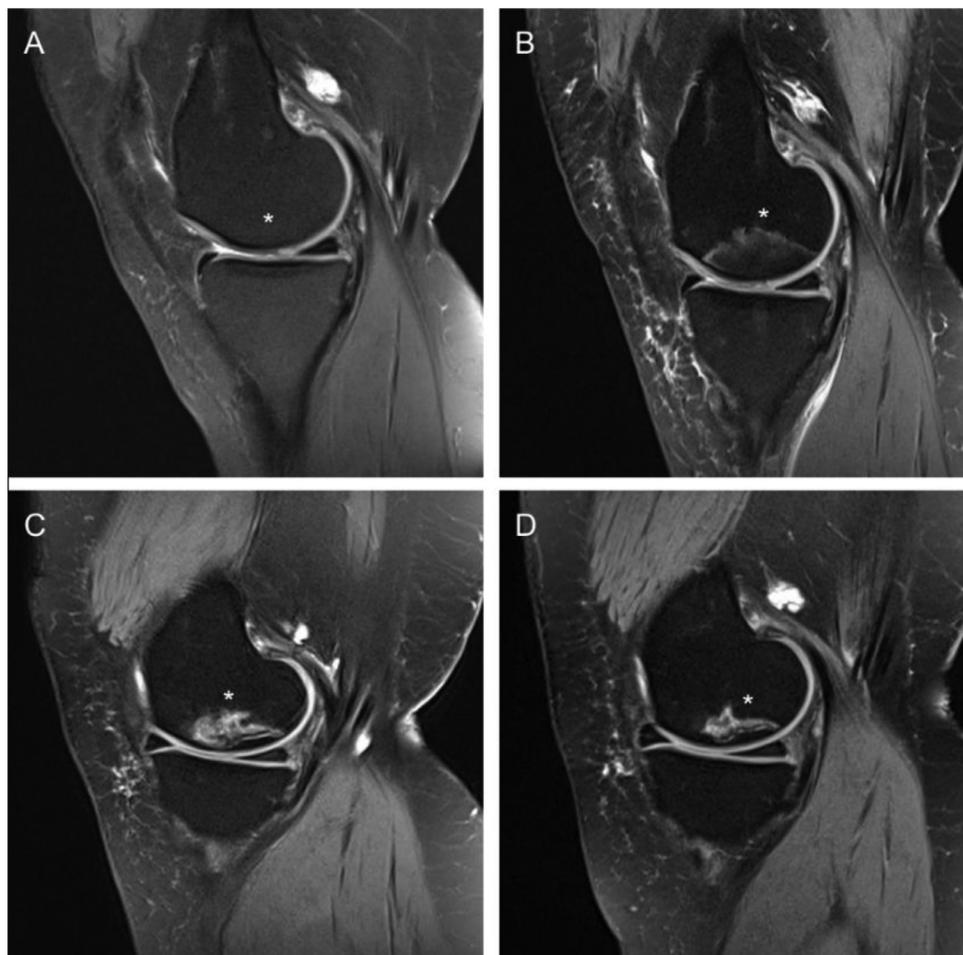


Fig. 3 – Third lesion (weight-bearing surface of the medial femoral condyle). Different pictures illustrate consecutive MRI studies at 1 month (A), 4 months (B), 7 months (C), and 11 months (D) after the onset of knee pain. (A) The third lesion was not present on the initial MRI performed 1 month after onset of symptoms. (B) The third focus of osteonecrosis (Asterisk) demonstrates a curvilinear focus at the weight-bearing surface of the medial femoral condyle with associated surrounding marrow edema. (C) The lesion appears more conspicuous with increased surrounding edema. (D) Reduction in marrow edema and more well defined cystic change. No articular surface or cartilage collapse.

with a more cystic appearance at the subcortical bone. There was early cortical bone and overlying cartilage irregularity, suspicious for early articular surface cortical collapse and cartilage involvement. There was increased marrow edema in this location when compared to the second MRI. It can be postulated that the edema might be due to early cortical fracture/stress edema from cartilage damage rather than edema associated with bone infarction. The more posterior lateral femoral condyle lesion (second lesion) now appeared more conspicuous with reduced surrounding edema. The third lesion at the medial femoral condyle (third lesion) now demonstrated the typical serpentine line. A “double line” sign (parallel adjacent high and low-intensity lines on the PD sequences). This finding is noted to be present in 80% of ON cases [3], although not required to be present to make a diagnosis. Surrounding marrow edema was also noted to have partially subsided.

The fourth and final MRI study of the left knee was performed on April 20, 2020. The patient’s pain had completely

settled by the time of the fourth and final MRI. The first lesion demonstrated further interval contraction and almost complete resolution of surrounding marrow edema. The cortical collapse of the articular surface and the adjacent cartilage had increased. The second and third lesions also demonstrated a reduction in marrow edema with more well defined cystic change. No articular surface or cartilage collapse, however, was seen in regard to these lesions.

Discussion

ON is a result of disruption of blood supply to the bone and can either be cortical or medullary [1–4]. ON is a common condition [1] with estimated symptomatic femoral head ON being 2–4.5 cases/year, and thus, resulting in 10,000–20,000 new cases annually in the United States [1]. The incidence is underestimated as a majority of patients would be asymp-

tomatic, for example, patients with ON occurring in the metadiaphyseal location [1].

Risk factors for ON include trauma, steroid therapy, sickle cell anemia, and alcoholism. ON can also be idiopathic. Clinical diagnosis of ON can be difficult due to a lack of or non-specificity of symptoms. Patients who are symptomatic typically experience pain and reduced range of movement [1]. In this patient, ON of the knee presented clinically as non-specific knee pain.

The pathogenesis of ON is varied and mechanisms would include vascular compromise, systemic steroid therapy, thromboembolic disease (nitrogen bubbles in Caisson disease), and vasculitis [4]. The pathogenesis of steroid-induced ON remains unclear. Postulated etiologies include hepatic adipose infiltration with subsequent fatty embolization, osteoporosis induced microfractures, vasculitis, and vascular coagulation with increased blood viscosity and increased bone marrow fatty infiltration [1]. Regardless of the cause, pathologic and imaging features of ON remain the same [4].

ON most commonly affects areas where yellow marrow (with its poor vascular supply) predominates, that is, the epiphysis and diaphysis of long bones. In fact, patients with ON of the femoral head have been shown on MRI to have more fatty than red marrow elements, at an earlier age, in the femoral neck and intertrochanteric region than did a control group, indicating decreased blood supply to the region, thus, may predispose to the development of ON [3].

There is a strong positive correlation between marrow edema surrounding the focus of ON and clinical symptoms in published literature [11,12,13] with improvement and subsequent resolution of symptoms, most notably pain, as the marrow edema subsides. This was evident in the case study.

Plain radiography is poorly sensitive in detecting early changes of ON [1]. ON on radiography becomes evident only in the late/advanced stages manifesting as serpiginous or patchy sclerotic foci. Multiple studies and reviews have demonstrated the specificity of radiographs in the advanced stages of the disease [10]. Computed tomography (CT) is a modality not commonly used in the detection and diagnosis of ON but may have value in detecting and characterizing subchondral fractures that are in association with the disease [10]. CT would more clearly depict the bony changes compared to MRI [10].

MRI is regarded as the gold standard for detecting the earliest stages of ON with multiple studies demonstrating >97% specificity and sensitivity [3,10] with published series reporting 97%–100% accuracy [5–9]. Early diagnosis of ON is critical as early treatment is associated with a more favorable prognosis. More advanced stages of ON would require more aggressive management such as arthroplasty [10]. The use of intravenous Gadolinium contrast can improve the early detection of ON. Furthermore, contrast-enhanced MRI sequences are useful in distinguishing viable and nonviable trabeculae and marrow [14]. However, in this patient, the use of intravenous contrast would be contraindicated due to poor renal function.

Subsequent symptoms and the long-term prognosis of ON are largely predicated on the development of collapse of the overlying articular surface [1]. This would account for why, in cases of metadiaphyseal ON, there is limited to no long term sequelae: bone collapse does not occur in these cases and necrosed bone is as strong as viable bone [1]. Management

of ON would include noninvasive and surgical management options and would be based on location, symptoms, and likelihood or presence of overlying articular collapse. Progression of the disease to secondary osteoarthritis would invariably require surgical management with joint arthroplasty [1].

In conclusion, we recommended MRI for early detection of ON with serial short-term follow-up MRI studies 2-3 monthly as a means to monitor progression and to detect complications such as subchondral fractures or cartilage damage.

Imaging, more specifically MRI, plays an important role in diagnosing, progressing, and staging ON. The case series presented here illustrates stepwise progression in chronicity for 3 femoral bone infarcts of varying age in the same patient, demonstrating the reliability of characteristic MRI findings at various temporal stages of ON. This case series also highlights the specificity of MRI in detecting ON relatively early which can mimic other disease processes on other imaging modalities such as conventional radiography and CT as well as clinically. Serial MRI may have a role in monitoring treatment effects and in assessing the need to alter treatment paradigms.

Patient consent

Written consent was obtained from the patient for the submission and publication of this manuscript including the use of the patient's diagnostic imaging.

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