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Fig. 1 Anteroposterior radiograph of the right knee.

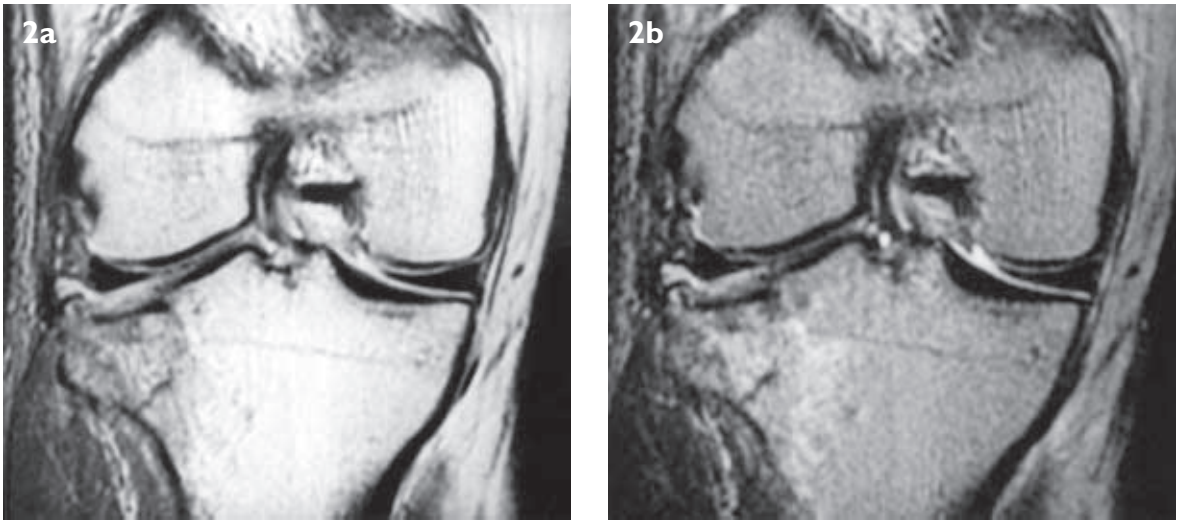

Fig. 2 Coronal (a) T1-weighted and (b) T2-weighted MR images of the right knee.

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CASE PRESENTATION

A 39-year-old man presented with pain over the right knee. This developed after a recent fall. Despite rest, the pain was persistent, and was worse on weight-bearing. There was no radiation. He did not have any other site of pain. What does the knee radiograph show (Fig. 1)? Magnetic resonance (MR) imaging was also performed (Fig. 2). What is the diagnosis?

Fig. 3 Axial T2-weighted MR image of the tibial condyle shows a hypointense curvilinear fracture line with adjacent hyperintense bone oedema.

Fig. 4 Sagittal T1-weighted MR image shows a diffuse area of hypointense signal in the lateral tibial condyle, consistent with bone bruising.

IMAGE INTERPRETATION

The anteroposterior radiograph of the right knee (Fig. 1) appears normal. The joint space is preserved and in particular, no fracture line is seen. MR images (Fig. 2) show a vertically-orientated curvilinear line extending across the lateral tibial condyle. Its superior end reaches the tibial articular surface, causing mild disruption. The fracture line itself is hypointense on both T1- and T2- weighted images, and is surrounded by patchy areas of low T1 and high T2 signal intensity, representative of bone marrow oedema or bruising. The collateral ligaments, cruciate ligaments and menisci are intact.

DIAGNOSIS

Occult tibial condylar fracture.

CLINICAL COURSE

The patient was treated conservatively and made an uneventful recovery.

DISCUSSION

Occult bony injuries may be defined as injuries that are suspected clinically but are radiographically occult. Before the advent of MR imaging, radionuclide techniques were the primary method used for further evaluation of occult bony injuries. MR imaging is currently the best technique for detection of musculoskeletal injury. It has comparative sensitivity to radionuclide techniques for detection of bone abnormalities. MR imaging offers the additional advantage of depicting soft tissue processes with superior resolution[1]. MR imaging also has the advantage of being noninvasive and does not expose the patient to ionising radiation.

MR imaging and scintigraphy have been shown to be sensitive in the early detection of both stress and occult fractures that are not visualised on radiographs[2]. The specificity and sensitivity of MR imaging in the detection of occult fracture is 100%, compared to a specificity of 98% and a sensitivity of 100% for bone scintigraphy. The occult fracture line is seen as a discrete band of low signal intensity on both the T1- and T2- weighted images. The fracture line is well seen on the T2-weighted images where surrounding high signal of haemorrhage and/or oedema provide contrast for the low signal intensity of the fracture line (Fig. 3). On T1-weighted images, oedema is seen as an adjacent area of diffuse low signal intensity.

Trabecular microfractures or bone bruises are typically located close to a joint surface, and are believed to result from compression or impaction forces. The MR imaging characteristics of these trabecular microfractures are remarkably constant and have been described most completely with regard to distal femoral and proximal tibial injuries. The findings are those of marrow fluid, appearing on T1-weighted images as a geographical and nonlinear area of signal loss involving the subcortical bone of the involved bone (Fig. 4). On T2-weighted and short tau inversion recovery (STIR) images, most or all of the lesions have increased signal intensity with involvement of the epiphysis and usually, a portion of the metaphysis. The presence of similar changes in the signal intensity of the

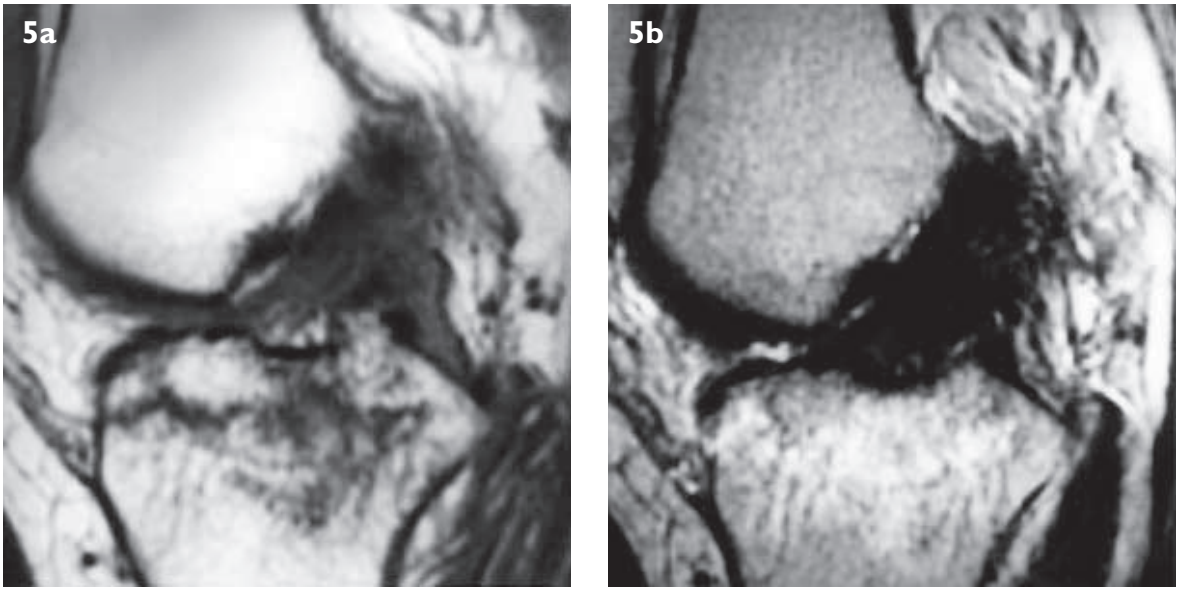

Fig. 5 71-year-old woman with upper tibial fracture associated with ACL partial tear. Sagittal (a) T1-weighted and (b) T2-weighted MR images show a tibial condylar subchondral fracture that extends to the articular surface. Extensive surrounding bone bruising is well depicted, particularly on T2-weighted images. The ACL is grossly swollen but intact, consistent with a partial ACL tear.

bone marrow on MR images in patients with osteochondral fractures supports the pathogenesis of bone bruises.

Knee

MR imaging can detect bone bruises that are not evident during arthroscopy and radiographs. In addition, resolution of MR abnormalities associated with bone bruises may coincide with the decrease or disappearance of patient's symptoms. Mink and Deutsch first described a band-like area of increased T2 signal intensity on the contralateral side of injury in five of eight patients with collateral ligament tears[3]. These were postulated to represent impaction fractures. Although collateral ligament injuries are associated with compressive forces on the contralateral side, the term impaction fracture suggests that bone and cartilage are affected. Bone bruises were thought to be the most appropriate term for describing these abnormalities. They were seen on the contralateral side of all five grade 2 or 3 collateral ligament injuries and in the lateral tibial plateau or lateral femoral condyle in 72% of the patients with complete anterior cruciate ligament (ACL) injuries[3]. Yao and Lee suggested that a history of acute trauma, a positive bone scan, and resolution on MR images support the concept that the lesion represents a bone injury[4].

Mink et al reported that MR imaging could depict stress fractures of the proximal tibia before radiographs could, reflecting the greater sensitivity of MR imaging to alterations in the composition of the bone marrow[5]. The lesion with which a bone bruise may be confused on MR imaging is a stress fracture of the amorphous type. The proximal tibia, especially its medial and posterior surfaces, is a common site of stress fracture. Patients with a tibial stress fracture may present with knee pain. The initial lesion may induce a regional hyperaemia that is not highly localised. MR imaging, with its multiplanar capability, facilitates a three-dimensional perception of the fracture and in addition, enables evaluation of the menisci, ACL, collateral ligament, and the congruity of the articular cartilage surfaces (Fig. 5).

Ankle

Fractures around the ankle often involve the growth plate in children, and carry a 30% risk of later growth disturbances[6]. An extensive injury may lead to total growth arrest and leg length discrepancy, while a partial injury to the growth plate may result in local tethering and angular deformity or progressive joint incongruity. Functional impairment and early osteoarthritis may follow growth plate injury. Physeal fractures have traditionally been evaluated radiographically. The disadvantage of radiographs is that the growth cartilage itself is not directly depicted, as it is on MR imaging, and injuries limited to the growth plate may be difficult to diagnose. The primary cause of false positive radiographical diagnosis is the Salter Harris type 1 fracture of the fibula in patients with only ligament injury depicted on MR imaging. In recent years, MR imaging has been recommended for complex or uncertain injuries (Fig. 6), suspected bone bridges and to clarify fractures before the ossification of the epiphyses. In addition

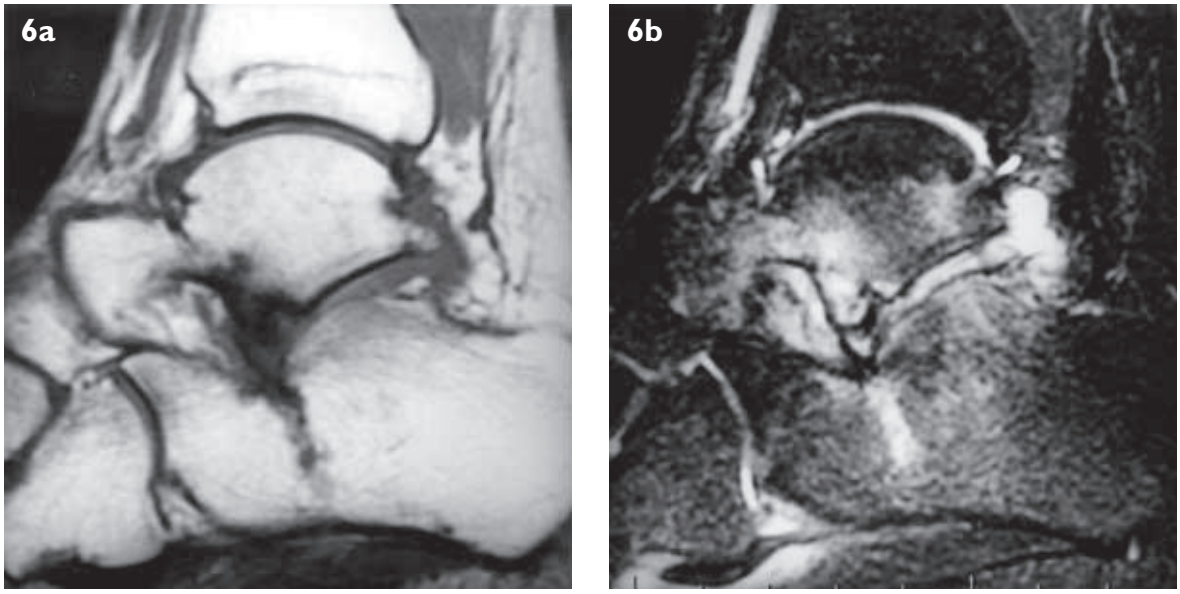

Fig. 6 35-year-old man with fractures of the talus and calcaneum. Sagittal (a) T1-weighted and (b) T2-weighted MR images show an oblique fracture in the talus and a vertical fracture in the mid-calcaneum. Both fractures involve the subtalar joint. There is patchy bone oedema in both bones, with ankle and subtalar joint effusions.

to fractures, post-traumatic bone bruises may also be detected on MR imaging.

Hip

Hip fractures are relatively common in the elderly and their treatment represents a significant portion of health care expenditure. Despite this, the diagnosis is not always clear-cut clinically and initial radiographs may be negative. MR imaging has been found to be required in 4% of patients who attended the accident and emergency department with post-traumatic hip pain, as initial radiographs did not clearly demonstrate a fracture[7]. MR imaging is now commonly used in the assessment of hip joint pathology. It has been shown to be sensitive to both stress and occult fractures. The main benefit of MR imaging is to direct early operative intervention in patients with undisplaced fractures. It has been demonstrated that early discharge provides more effective recovery in these patients and is cost effective[8].

MR imaging is more specific than bone scingraphy in detecting stress fractures of the hip. Early detection of these fractures is crucial, as continued stress may lead to a displaced fracture, with associated risk of avascular necrosis and irreversible damage to the joint[9]. Pandey et al found that MR imaging confirmed undisplaced fractures in 67% of patients with occult hip fractures that, if not treated appropriately, could have subsequently displaced[10]. The importance of restoring function for the elderly injured patient has been well recognised. The late detection of fractures increases morbidity, worsens prognosis and prolongs rehabilitation. The advantage of early detection of occult fracture of the proximal femur decreases the chance that a simple nondisplaced fracture would later displace and require more complex management[11].

Wrist

The scaphoid is the site of the most common undiagnosed fracture, with up to 25% of these fractures not being visible on the initial radiographs. MR imaging has a specificity and sensitivity of 100% in the diagnosis of occult scaphoid fractures, thus allowing immediate diagnosis, compared to at least 10 days to four weeks of repeated clinical and radiological examinations and cast immobilisation using the conventional diagnostic pathway. MR imaging appearances of wrist fractures consist of cortical fracture line, trabecular fracture line, bone marrow abnormality, or the combination of two or three of these anomalies[11-13].

Compared to radiography, MR imaging also enables better evaluation of osseous injury accompanying distal radial and other more usual carpal fractures, and can detect radiocarpal extension which requires surgical intervention. Scapholunate ligament disruption and injuries to the triangular fibrocartilage complex can also be diagnosed using MR imaging[11,12]. Early use of MR imaging also helps to prevent overtreatment, with several weeks of unnecessary immobilisation, in patients without a fracture. MR imaging has also been found to be valuable in diagnosis of complications of scaphoid fractures, such as delayed union, nonunion, or avascular necrosis[14].

Elbow

In children, elbow trauma may lead to bony, cartilaginous, or soft tissue injury. Radiographs do not show bone bruising, cartilaginous, or soft tissue injury and may underestimate physeal injury[15]. In their study of eight children with radiographically visible fractures around the elbow, Beltran et al reported that two of these children, both of whom had humeral condylar fractures, had unsuspected transphyseal fracture extension through unossified epiphyseal cartilage shown by MR imaging[16]. Carey et al found that in 14 suspected physeal injuries of the elbow, wrist, knee and ankle, MR imaging changed the radiographical diagnosis in 50% of the cases by showing either radiographically-occult fractures or unsuspected transphyseal extension[17]. In a study of selected children with moderately severe elbow trauma, MR imaging helped to clarify radiographically-equivocal fractures. Many childhood elbow fractures, both intra and extraarticular, are identifiable on MR imaging but not on radiography[15].

CONCLUSION

MR imaging has been shown to be useful in the detection of occult bone injuries with the added capability of revealing a broad spectrum of soft tissue injury[18]. MR imaging enables early detection and prevention of complications in patients with occult trauma, and should therefore be the next investigation performed if initial radiographs are nondiagnostic.

ABSTRACT

A 39-year-old man who presented with right knee pain following trauma was found to have a radiographically-occult fracture of the lateral tibial condyle on magnetic resonance (MR) imaging. The intra-articular fracture was seen as a curvilinear area of hypointensity on both T1- and T2- weighted MR images, with surrounding bone bruising. The MR appearances of occult fractures and bone bruising, and the role of MR imaging in the detection of these injuries in various other regions, such as the ankle, hip, elbow and wrist, are discussed.

Keywords: Bone bruises, fractures, magnetic resonance imaging, microfractures, occult fractures

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