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Acute nontraumatic adult knee pain: the role of MR imaging

Dolore acuto non traumatico del ginocchio nell'adulto: ruolo della risonanza magnetica

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Abstract
Acute nontraumatic pain in the adult knee can be seen in many settings, such as transient bone marrow oedema syndrome (TBMOS), regional migratory osteoporosis (RMO), spontaneous osteonecrosis (SONK) and insufficiency fractures. Early differentiation among them is crucial to avoid unnecessary treatment. TBMOS and RMO are considered to be self-limiting conditions without long-term sequelae. On the other hand, the clinical course of SONK is thought to be dependent on the size of osteonecrosis. Recent data suggest the term SONK is misleading one and should be replaced. Insufficiency fractures may demonstrate a similar clinical syndrome without a history of a single traumatic injury. The imaging pathway for knee pain has evolved considerably with the advent of magnetic resonance (MR) imaging, which is very sensitive in the early depiction of bone marrow oedema. Therefore, in patients with acute nontraumatic knee pain whose radiographs are negative or inconclusive, MR imaging is the method of choice for further evaluation. This article discusses the potential aetiologies and reviews MR imaging findings of the most common disorders afflicting the subchondral knee-joint area.

Keywords Knee joint/adults · Bone marrow oedema · MR imaging/diagnosis · Insufficiency fracture · Spontaneous osteonecrosis · Transient osteoporosis

Abstract
Il dolore acuto non traumatico del ginocchio nell'adulto può essere presente in molte situazioni, come la sindrome dell'edema transitorio del midollo osseo (TBMOS), l'osteoporosi migrante regionale (RMO), l'osteonecrosi spontanea (SONK) e le fratture da stress. La diagnosi differenziale precoce è importante per evitare un trattamento inutile. La TBMOS e l'osteoporosi migrante regionale sono considerate condizioni autolimitantesi prive di sequele a lungo termine. D'altra parte, si ritiene che il decorso clinico dell'osteonecrosi spontanea dipenda dall'entità dell'osteonecrosi. Dati recenti suggeriscono che il termine osteonecrosi spontanea potrebbe indurre ad errore, per cui andrebbe modificato. Le fratture da stress possono presentarsi con un'analoga sindrome clinica senza una storia di lesione traumatica. La diagnostica per immagini nel dolore del ginocchio si è notevolmente evoluta con l'avvento della risonanza magnetica (RM), che ha un'elevata sensibilità nella identificazione precoce dell'edema midollare. Quindi, in pazienti con dolore acuto non traumatico del ginocchio i cui radiogrammi sono negativi o dubbi, l'RM è il metodo di scelta per ulteriori indagini. Questo articolo discute la potenziale eziologia e riesamina i reperti RM delle patologie più comuni dell'area sub-condrale dell'articolazione del ginocchio.

Parole chiave *Articolazione del ginocchio/adulti · Edema del midollo osseo · RM/diagnosi · Fratture da stress · Osteonecrosi spontanea · Osteoporosi transitoria*

Introduction

Acute pain in the adult knee without any history of trauma is usually associated with the development of bone marrow oedema (BMO) and/or joint effusion. BMO in the uninjured adult knee can be due to a variety of causes ranging from osteomyelitis, inflammatory and degenerative arthritis to transient osteoporosis, spontaneous osteonecrosis and insufficiency fracture. Osteomyelitis can be distinguished from the other causes by the presence of signs of infection. Differentiation of the remaining conditions can be troubling to both the radiologists and the treating clinician due to overlapping imaging findings and similar clinical presentations. Furthermore, limited data exist on the prevalence of most of these entities [1–3].

Magnetic resonance (MR) imaging is the modality of choice for early detection of subchondral BMO. BMO pattern, demonstrated as an ill-defined area of low signal intensity on T1-weighted and high signal intensity on short tau inversion recovery (STIR) and fat-suppressed proton-density (PD)/T2-weighted images, is a nonspecific imaging finding and does not allow a conclusive diagnosis. In this article, we review the MR imaging findings of acute, nontraumatic BMO pattern in the knee excluding inflammatory and infectious disorders.

Differential diagnosis

Transient bone marrow oedema syndrome

Transient BMO is a generic term that describes diffuse BMO on MR images and that resolves on follow-up examinations. The term bone marrow oedema was introduced in 1988 by Wilson et al., who noticed that patients with hip pain and BMO on MR images showed no evidence of osteopenia on plain radiographs [4]. The latter was suggested by the authors to distinguish transient bone marrow oedema syndrome (TBMOS) from transient osteoporosis of the hip, which is the most common cause of BMO, with well-established imaging and clinical criteria [5]. Others believe that the terms transient osteoporosis and TBMOS correspond to the same clinical entity, as osteopenia is associated with the time the radiographs were taken from symptom onset [6]. Osteopenia, whenever it appears, is depicted on radiographs 4–6 weeks from symptom onset [7, 8].

The key feature that separates TBMOS from other conditions presenting with the BMO pattern is its self-limited nature. Although many studies have been published on transient osteoporosis of the hip, only a few reports exist on this disorder in the knee region. A series on 24 lesions in 18 patients with histological confirmation showed that transient osteoporosis of the knee is a distinct clinical entity [9]. A recent study on 98 patients presenting with acute BMO in the knee showed that extension of BMO to a non-weight-bearing surface, presence of subchondral sparing, short duration of symptoms before MR imaging and middle age at presentation are mostly associated with the transient pattern of this disorder [10].

There is considerable confusion in the literature regarding the pathophysiology of TBMOS. A neurogenic compression theory was first addressed by Curtiss and Kincaid in 1959 [11]. Schweitzer and White demonstrated a BMO pattern in volunteers with altered weightbearing that was similar to the oedema pattern seen with a stress fracture [12]. It was thought that this pattern, not resulting though in florid BMO, may represent a subclinical stress fracture. Some authors believe that TBMOS represents idiopathic transient ischaemia, which resolves without leaving a demarcated zone of necrosis. Therefore, BMOS of the hip was thought to correspond to an early reversible stage of nontraumatic avascular osteonecrosis, with a diffuse pattern. The relationship of TBMOS to avascular necrosis (AVN) remains under debate. The first study proposing that TBMOS may simulate early, reversible, AVN was by Parker et al. [13]. It has been hypothesised that the magnitude of the ischaemic stimulus is the main determinant of the potential for spontaneous repair. According to these authors, there is an ischemic threshold that determines whether the lesion will progress from reversible BMO to irreversible AVN. Moreover, the role of the regional accelerated phenomenon activation has been stressed [14]. This theory was based on the frequent coexistence of systemic osteoporosis with TBMOS. Almost all of the above theories have focused on the hip involved with transient BMO. Limited data exist in the literature on the knee involved with transient BMO and its association with AVN.

TBMOS usually affects middle-aged men and, less frequently, women. Within the knee joint, any bone can be affected, but the femoral condyles are the most common site. The medial femoral condyle is more frequently involved. Occasionally, the tibia and patella are affected [9, 10]. Patients present with self-limiting acute knee pain of acute or subacute onset, which may mimic meniscal injury. The pain usually resolves within 1 year paralleling the resolution of the imaging findings. Laboratory tests are usually unhelpful, and histological examination is unnecessary [9, 10].

On plain radiographs, osteopenia is rarely (<20%) depicted at presentation, the joint space is not affected and no subchondral lesions are noticed [10]. The radiographic findings may persist weeks after symptom resolution, and evidence of complete remineralisation may be delayed for up to 2 years [14–16]. Bone scan is considered very sensitive but not specific for detecting TBMOS. Increased uptake in the affected knee can be seen within a few days after

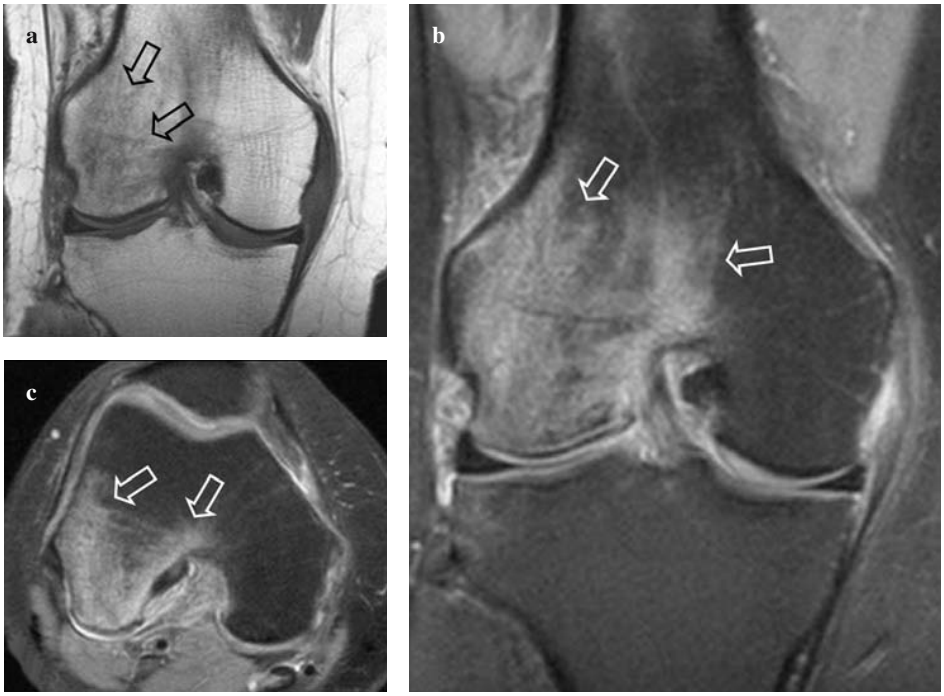

Fig. 1a-c Transient bone marrow edema syndrome in a 44-year-old female patient with sudden onset of pain 7 weeks before imaging. Coronal T1-weighted turbo spin echo (TSE) magnetic resonance (MR) image (**a**) shows the bone marrow oedema as a low signal intensity, indistinct area in the lateral femoral condyle (*arrows*). Fat-suppressed transverse (**b**) and coronal (**c**) proton-density (PD) TSE MR images show more clearly bone marrow oedema as high signal intensity lesions (*arrows*). There was complete resolution of clinical and imaging findings 5 months later, the treatment being only weight-bearing protection and occasional analgesics.

Fig. 1a-c *Sindrome dell'edema transitorio del midollo osseo in una donna di 44 anni con improvvisa insorgenza di dolore 7 settimane prima dell'esecuzione di quest'esame. L'immagine RM Turbo Spin-Echo (TSE) T1-dipendente coronale* ***(a)*** *mostra l'edema del midollo osseo come un segnale a bassa intensità, area non ben distinguibile nel condilo femorale laterale (frecce). Le immagini RM PD-TSE con soppressione del grasso assiale* ***(b)*** *e coronale* ***(c)*** *mostrano più chiaramente l'edema del midollo osseo come alterazioni ad elevata intensità di segnale (frecce). Dopo 5 mesi si è avuta una completa risoluzione del quadro clinico e radiografico mediante scarico dell'articolazione e terapia analgesica.*

symptom onset. This increased uptake is detected in all three phases, reflecting hyperemia, increased capillary permeability and increased osteoblastic activity. Symptom resolution is followed by reduced uptake in the perfusion and blood-pool phases [16]. On MR imaging, the affected bone generates signal hyperintensity to normal bone marrow on fat-suppressed sequences and hypointensity to bone marrow on T1-weighted sequences (Fig. 1). The described MR imaging findings usually appear in less than 48 h after symptom onset and resolve in a period ranging from 4 to 12 months, depending upon the individual patient and treatment. Following intravenous contrast agent administration, there is marked enhancement of the affected bone in the BMO area, indicating high vascularity. In addition, joint effusion and soft-tissue oedema adjacent to the BMO are common findings. MR imaging may also reveal subchondral areas or lines, which have been shown to correlate with the final outcome when present on the initial imaging (Fig. 2) [17]. Other studies showed that no correlation exists between the presence of subchondral lines and progression to articular collapse [10]. Newer techniques, such as diffusion-weighted imaging, seem to offer no additional information, as in all cases of TBMOS, there is no restricted diffusion in the affected bone (Fig. 3).

TBMOS treatment includes the use of mild analgesics and nonsteroidal anti-inflammatory drugs (NSAIDs) in conjunction with partial weightbearing. Calcitonin, which is aimed at minimising bone loss during the acute phases of the disease, and prostacyclin analogues have also been used [18].

A number of patients with TBMOS will present with a migrating pattern of clinical and imaging findings. The knee joint can be involved as one of the affected joints in regional migratory osteoporosis (RMO). RMO was first described by Duncan et al. as a disorder manifested by arthralgia migrating to other joints or within the same joint. It affects the weightbearing joints and is associated with severe focal osteoporosis [19]. Similar to TBMOS, RMO affects middle-aged men who have no history of injury or a predisposing factor for osteonecrosis and who present with arthralgia. Clinical examination reveals tenderness, joint effusion and swelling, whereas the range of motion is not significantly

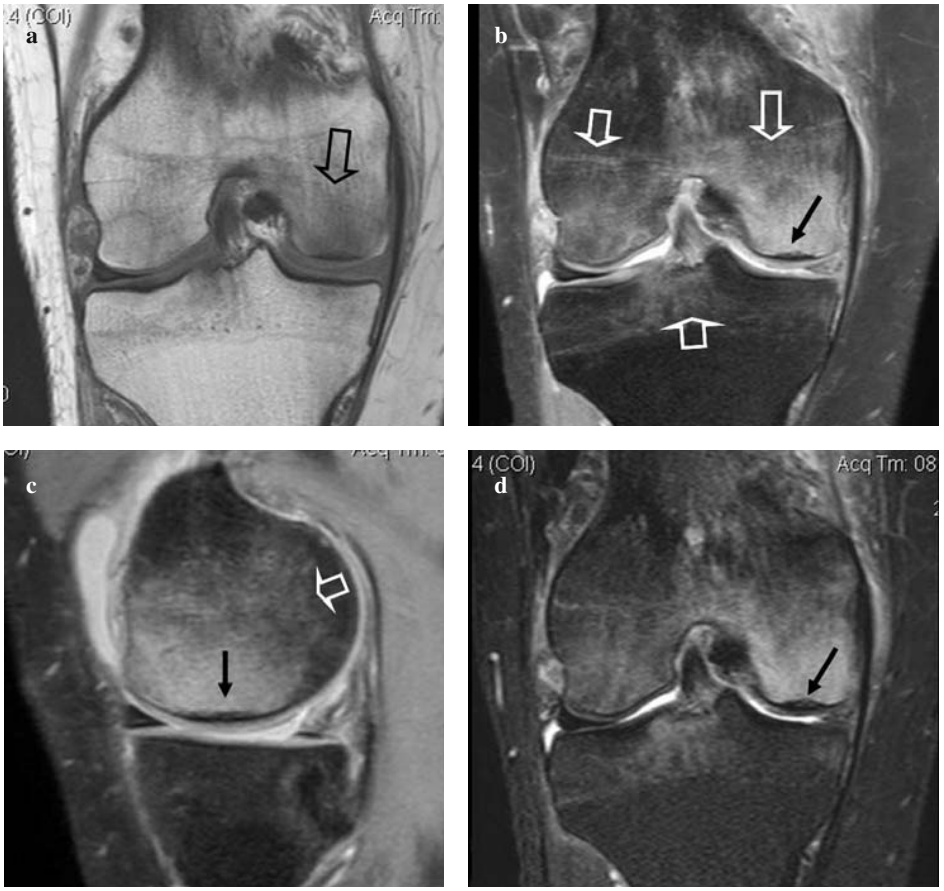

Fig. 2a-d Transient bone marrow oedema syndrome in a 52-year-old female patient with sudden onset of pain 4 weeks before imaging. Coronal T1-weighted turbo spin echo (TSE) magnetic resonance (MR) images (**a**) show low signal intensity bone marrow oedema in the medial femoral condyle (*arrow*). Fat-suppressed coronal (**b**) and sagittal (**c**) proton-density (PD) TSE magnetic MR images show high signal intensity bone marrow oedema in both the medial and lateral femoral condyles as well as the central tibial epiphysis (*open arrows*). Subcortical sclerosis is also seen (*thin black arrow*). Coronal short tau inversion recovery (STIR) MR image (**d**) confirms the presence of bone marrow oedema and subcortical sclerosis (*thin black arrow*). Joint effusion is also seen.

Fig. 2a-d *Sindrome dell'edema transitorio del midollo osseo in una donna di 52 anni con improvvisa insorgenza di dolore 4 settimane prima dell'esecuzione di quest'esame. L'immagine RM TSE T1-dipendente coronale* ***(a)*** *mostra l'edema del midollo osseo come un segnale a bassa intensità nel condilo femorale mediale (freccia). Le immagini RM PD-TSE con soppressione del grasso coronale* ***(b)*** *e sagittale* ***(c)*** *mostrano l'edema del midollo osseo come un segnale ad elevata intensità in entrambi i condili femorali così come nell'area centrale dell'epifisi tibiale (frecce vuote). Si visualizza anche la sclerosi subcorticale (freccia nera sottile). L'immagine RM STIR coronale* ***(d)*** *conferma la presenza di edema midollare e di sclerosi sub-corticale (freccia nera sottile). Si evidenzia anche il versamento articolare.*

affected. BMO migration occurs in 5%–41% of patients with transient osteoporosis of the hip [5, 9]. BMO migration and arthralgia may be observed in the same or a different joint in an unpredictable time interval, although it has been reported to usually occur within 2–12 months after the original location [19–21]. The commonest pattern of spread is proximal to distal in the lower limb, with the joint nearest the diseased one being the next to be involved. RMO in the knee joint typically affects the femoral condyles [22, 23]. BMO migration can be observed within the same or the contralateral knee joint, but the prevalence is not known [13, 24, 25]. A possible explanation for BMO migration within the same knee joint or to the contralateral limb is based on altered biomechanics due to an antalgically increased loading on the nonaffected condyle in patients initially developing BMO in one of them [12]. This might lead to microfracturing of the trabeculae with accompanying oedema. An association with systemic osteoporosis can also be hypothesised, as the presence of demineralisation may facilitate the development of microfractures [23, 24, 26].

Although radiographs in RMO are usually normal initially, severe osteopenia is detected within a few weeks. Bone scan is not specific, demonstrating increased uptake in all three phases. On MR imaging, the affected region is of high signal intensity on T2-weighted images and low signal intensity on T1-weighted images (Fig. 4). A joint effusion

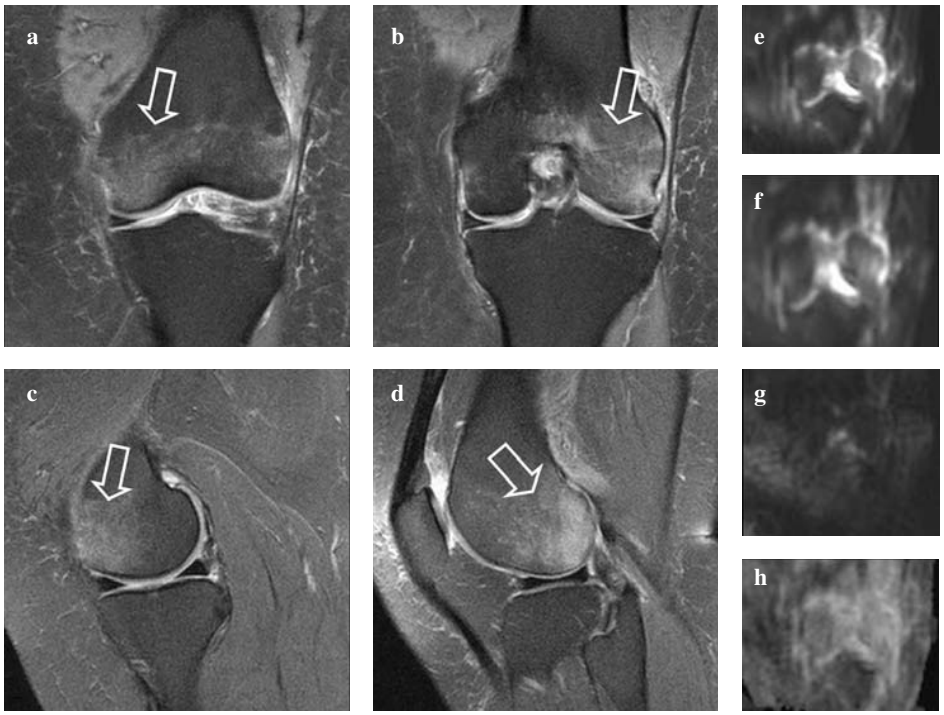

Fig. 3a-h Transient bone marrow oedema syndrome in a 53-year-old female patient with sudden onset of pain 6 weeks before imaging. Coronal (**a,b**) and sagittal (**c,d**) fat-suppressed proton-density (PD) turbo spin echo (TSE) magnetic resonance (MR) images show high signal intensity bone marrow oedema in both the medial and lateral femoral condyles (*arrows*). Diffusion weighted images show gradual suppression of the bone marrow oedema signal (b value 0 in **e**, 50 in **f** and 400 in **g**). The apparent diffusion coefficient (ADC) map (**h**) shows no restricted diffusion in the bone marrow lesion.

Fig. 3a-h *Sindrome dell'edema transitorio del midollo osseo in una donna di 53 anni con improvvisa insorgenza di dolore 6 settimane prima dell'esecuzione di quest'esame. Le immagini RM PD-TSE con soppressione del grasso coronali **(a,b)** e sagittali **(c,d)** mostrano l'elevata intensità di segnale dell'edema del midollo osseo in entrambi i condili femorali, mediale e laterale (frecce). Le immagini pesate in diffusione mostrano una graduale soppressione del segnale nell'edema (valore b 0 in **e**, 50 in **f**, 400 in **g**). La mappa ADC **(h)** mostra che non vi è riduzione di diffusione nella lesione del midollo osseo.*

may also be present. RMO is a self-limiting condition without long-term sequelae. Core decompression has been shown to be effective in pain relief. Nevertheless, there is considerable concern about further weakening an already osteopenic bone, which might be fractured [17, 23, 24]. It has been proposed to use the term transient regional osteoporosis in order to describe both the transient localised and the transient migratory BMO [27].

Spontaneous osteonecrosis of the knee

Spontaneous osteonecrosis of the knee (SONK) is another cause of acute knee pain. It was initially described by Ahlback et al. in 1968 [28]. It is a disease afflicting elderly patients, after the sixth decade of life, and is three times more common in women. There is an overall prevalence of SONK of 3.4 % in patients over the age of 50 years, increased up to 10% after the age of 65 [29, 30]. Pain is typically characterised by sudden onset and is well localised. The pain may also be present at rest and frequently causes significant functional impairment. There is no history of an acute injury. SONK is usually unilateral, with the medial femoral condyle involved most often [31]. The precise aetiology and pathophysiology of this condition remain unclear. Traumatic as well as vascular theories have been proposed. The causative factor was initially thought to be vascular insufficiency, with venous occlusion leading to venous hypertension and hypoxia. Bone microcirculation is confined within a nonexpandable compartment. Thus, any increase in bone marrow pressure on the arterial site or the venous site can cause bone ischaemia. Nonetheless, increased intraosseous pressure has also been observed in patients with osteoarthritis of the knee where secondary osteonecrosis has been observed histologically [32]. However, primary osteoarthritis of the knee usually presents with a gradual symptom onset and in most cases progresses slowly over a period of time. Furthermore, the pathognomonic serpentine-like pattern of osteonecrosis observed in the subchondral marrow on MR images is never found in SONK [31, 33–35].

Trauma has also been postulated as a causative factor of SONK. The most commonly accepted theory is that the

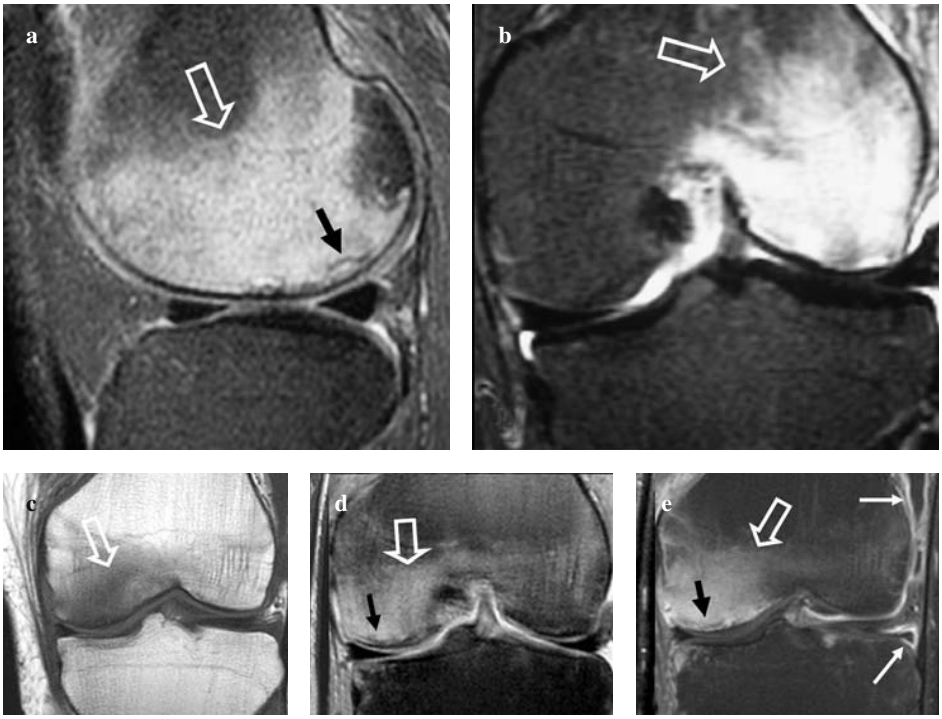

Fig. 4a-e Transient bone marrow oedema with migratory pattern in a 51-year-old male patient. Sagittal (**a**) and coronal (**b**) fat-suppressed proton density (PD) turbo spin echo (TSE) magnetic resonance (MR) images show extensive bone marrow oedema in the lateral femoral condyle 3 weeks after symptom onset. There is also a small subcortical insufficiency fracture (*black arrow* in a). Three months later, after significant resolution of clinical symptoms, new pain appeared at the medial compartment. The coronal T1-weighted (**c**), fat-suppressed PD-TSE (**d**) and fat-suppressed contrast-enhanced T1-weighted spin echo (SE) MR images show migration of marrow oedema from the lateral to the medial femoral condyle (*arrows*). There is almost complete resolution of the oedema in the previous location. A small subcortical insufficiency fracture is seen (*black arrows*), together with a moderate reactive synovitis (*long white arrows*).

Fig. 4a-e *Edema transitorio del midollo osseo con pattern migrante in un uomo di 50 anni. Le immagini RM PD-TSE con soppressione del grasso in sagittale* ***(a)*** *e coronale* ***(b)*** *mostrano l'ampio edema midollare a livello del condilo laterale del femore 3 settimane dopo l'insorgenza dei sintomi. C'è anche una piccola frattura sub-corticale da insufficienza (freccia nera in* ***a****). Tre mesi più tardi, dopo significativa riduzione dei sintomi, è apparso un nuovo dolore nel compartimento mediale. Le immagini coronali T1-dipendente* ***(c)****, PD-TSE con soppressione del grasso* ***(d)*** *e SE T1-dipendente con soppressione del grasso ed infusione di mezzo di contrasto* ***(e)*** *mostrano la migrazione dell'edema midollare dal condilo laterale a quello mediale del femore (frecce). Nella precedente localizzazione c'è una quasi completa risoluzione dell'edema. Piccola frattura sub-corticale da insufficienza (frecce nere), insieme ad una moderata sinovite reattiva (frecce bianche lunghe).*

weightbearing articular surface of the knee is subjected to altered stresses and is predisposed to developing a subchondral insufficiency fracture. This alteration in biomechanics can be related to an unstable meniscal tear or prior meniscal resection [34]. In addition, a high predilection for SONK in patients with large radial meniscal tears and meniscal root tears has already been reported [35]. Yamamoto et al. reported that lesions diagnosed as SONK were subchondral insufficiency fractures secondary to osteoporosis and that the osteonecrotic area was considered the result of the fracture [36]. In the setting of cartilage loss due to underlying osteoarthritis or weakened bone due to osteopenia, the repetitive impact and stress on the subchondral bone may induce microfractures, thus leading to intraosseous oedema. This cycle continues, with increased marrow pressure finally resulting in necrosis. Therefore, the term SONK is misleading, as osteonecrosis does not seem to be the causative event.

The reported clinical course of SONK varies from resolution to progression of symptoms [10]. The course depends mainly on a lesion's radiographic size and stage, as well as on the ratio of lesion size to condyle size. If the lesion involves a region of subchondral bone >2.3 cm^2, there is a higher incidence of developing secondary osteoarthritis. It has been reported that knees with lesions >5 cm^2 tend to have a poor prognosis, whereas lesions <5 cm^2 usually have a better outcome, being self-limiting. Moreover, if the aforementioned lesion-to-condyle ratio is >40%, the outcome is poor in most cases. If patients are seen late, the already developed degenerative changes might mask the underlying initiating cause of osteonecrosis [31, 34].

During the early course of the disease, plain radiographs are usually normal. Sometimes they may remain normal throughout the entire course. Later, a radiolucent area

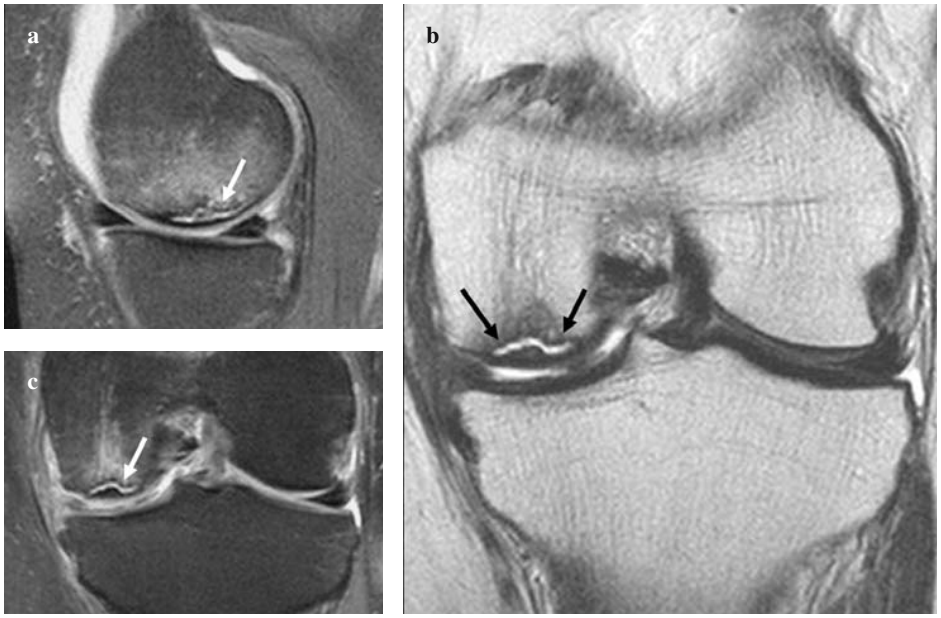

Fig. 5a-c Subchondral fracture of the medial femoral condyle (also known as spontaneous osteonecrosis) in a 70-year-old osteoporotic female patient with sudden onset of pain in the medial compartment of the knee. Turbo spin echo (TSE) magnetic resonance (MR) images, fat-suppressed proton-density (PD) sagittal (**a**), fat-suppressed PD coronal (**b**) and T2-weighted coronal (**c**) images show the subarticular high signal intensity fracture line (*arrows*) with associated bone marrow oedema. There is no articular collapse. Medial meniscal degeneration is also seen.

Fig. 5a-c *Frattura sub-condrale del condilo mediale del femore (nota anche come osteonecrosi spontanea) in una donna di 70 anni affetta da osteoporosi con insorgenza improvvisa di dolore nel compartimento mediale del ginocchio. Le immagini RM PD-TSE con soppressione del grasso in sagittale **(a)** e coronale **(b)** e T2-dipendente coronale mostrano l'elevata intensità del segnale della linea di frattura subcorticale (frecce) con edema midollare associato. Non c'è crollo articolare. Si vede anche la degenerazione del menisco mediale.*

subchondrally located may be seen. In the late stage of SONK, plain films show articular collapse, which may progress to secondary osteoarthritis. If the tibia is affected, extensive collapse of the plateau can be seen, with subsequent rapid progression to osteoarthritis within a 1-year period. Bone scan is more sensitive than radiography in the acute phase of SONK. Initially, scintigraphy may demonstrate a "cold-in-hot" image, reflecting a crescent-shaped area of increased uptake circumscribed by a cold zone of decreased uptake. In the advanced stages of the disease, a nonspecific increased uptake is usually demonstrated [33].

MR imaging is more sensitive than bone scan and radiographs. The MR imaging findings of SONK include subchondral BMO located most often at the medial femoral condyle and indistinguishable from that seen in TBMOS. In the acute phase of the disease, a subchondral fracture line may be obscured by the extensive BMO. Later in the course of SONK, a subchondral crescent or linear focus of low signal intensity on T1-weighted and high on T2-weighted MR images may be seen (Fig. 5). Subsequently, subchondral bone collapse may lead to secondary degenerative changes (Fig. 6). Diffusion-weighted imaging offers no additional information, as there is no restriction of diffusion, similar to TBMOS (Fig. 6). Although it has been reported that MR imaging may fail to diagnose the early stage of the disease [37], with the advent of fat suppressed techniques it is expected that BMO should be depicted in less than 48 h after symptom onset.

In the early stage of the disease, the course is usually benign. If flattening of the affected condyle is observed on plain radiographs, progression of the condition cannot be ruled out. The spectrum of treatment includes a conservative strategy and surgery. Surgery may be performed with arthroscopy alone, arthroscopy and drilling, valgus tibial osteotomy or total knee arthroplasty. The nonoperative scheme consists of physical exercises and NSAIDs. Core decompression by extra-articular drilling into the femoral condyle has also been recommended as an effective treatment in the initial stages [34–36].

It is now most often suggested that SONK is a misleading term. The substantial evidence that the underlying condition could be osteoporosis or osteoarthritis has led various authors to suggest alternative and more representative terms, such as subchondral insufficiency fracture of the knee or focal subchondral osteonecrosis [38]. A recent study in patients with acute nontraumatic BMO of the knee showed that generalised osteopenia or osteoporosis is associated with a greater risk of articular collapse, concluding that bone mineral densitometry might be used as an outcome predictor [10]. In the same study, it was

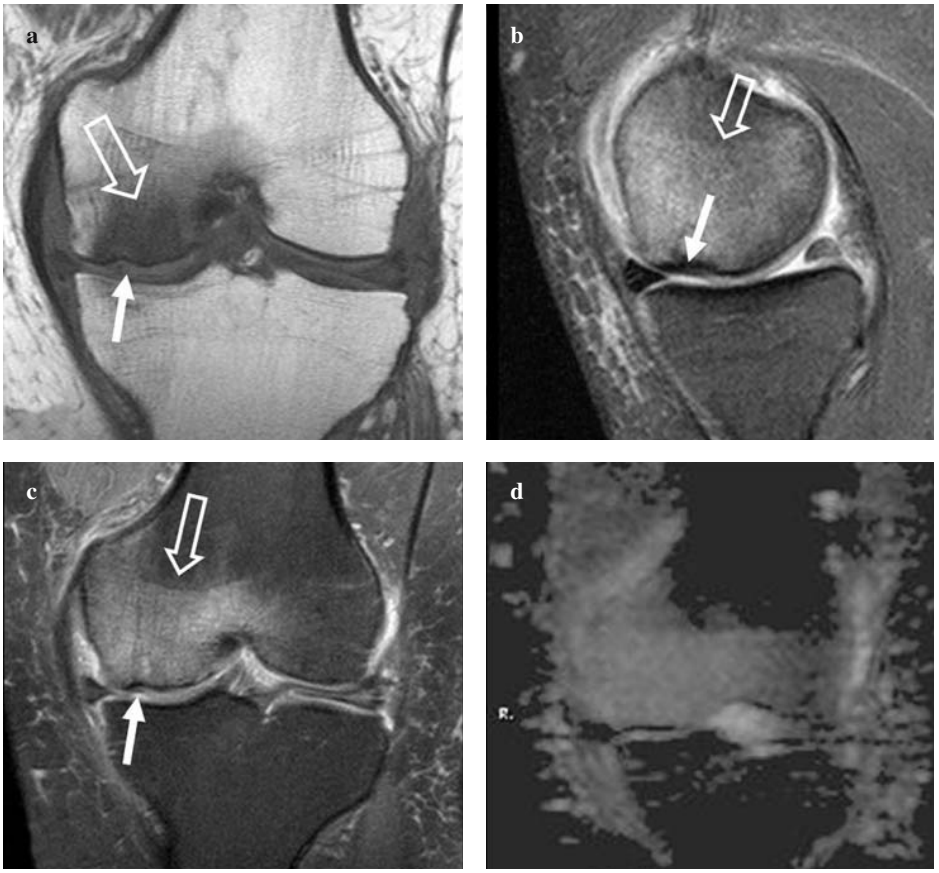

Fig. 6a-d Nontraumatic articular collapse (also known as spontaneous osteonecrosis) in a 77-year-old osteoporotic male patient with sudden onset of pain 4 weeks before imaging. Coronal T1-weighted (**a**), fat-suppressed sagittal proton-density (PD) (**b**) and fat-suppressed coronal PD (**c**) turbo spin echo (TSE) magnetic resonance (MR) images show bone marrow oedema in the medial femoral condyle (*open arrows*) and articular collapse (*thin arrows*). **d** The apparent diffusion coefficient (ADC) map shows no restricted diffusion in the abnormal area. Meniscal degeneration is seen in both compartments, with dislocation in the medial side.

Fig. 6a-d *Crollo articolare non traumatico (noto anche come osteonecrosi spontanea) in un uomo di 77 anni affetto da osteoporosi con insorgenza improvvisa di dolore 4 settimane prima dell'esecuzione di quest'esame. Le immagini RM TSE T1-dipendenti coronale* ***(a)****, PD-TSE con soppressione del grasso in sagittale* ***(b)*** *e coronale* ***(c)*** *mostrano l'edema del midollo osseo nel condilo mediale del femore (frecce vuote) ed il crollo articolare (frecce sottili).* ***(d)*** *la mappa ADC evidenzia che la diffusione nell'area patologica non è ridotta. Si vede degenerazione meniscale in entrambi i compartimenti, con dislocazione dal lato mediale.*

suggested that the term insufficiency bone-related arthropathy of the knee (IBrAK) might be more appropriate to describe the SONK disorder [10]. In general, poor clinical outcome defined as articular collapse either at presentation or during the course of the disease correlates with delay in diagnosis, older age at presentation with a female preponderance, weightbearing location of BMO on MR imaging, presence of acute subchondral fractures and impaired bone mineral density status [10].

Insufficiency fractures

Insufficiency fractures (IF) occur when normal muscular activity creates forces applied to a bone that is deficient in mineral and/or elastic resistance. IF may be seen in healthy women with recent gestation and prolonged lactation as well as in the elderly, postmenopausal women and patients with osteopenia due to steroid administration, metabolic or endocrine disorders. By definition, IF occur either spontaneously or after minimal repetitive stress or trauma. In the knee area, IF typically involve the medial proximal tibial condyle.

At onset, IF are manifested by spontaneous onset of severe and localised pain in the tibia rather than the knee joint. The pain may deteriorate with movement or weightbearing and will usually subside with rest. Early plain radiographs may be normal. MR imaging will disclose extensive BMO demonstrated as high signal intensity, poorly defined area on STIR or fat-suppressed T2-weighted MR images with a low signal intensity fracture line within it (Figs. 7, 8). Plain radiographs obtained at 3–4 weeks after symptom onset may reveal a sclerotic line that corresponds

Fig. 7a-c A 75-year-old female patient with known osteoporosis and medial compartment knee-joint osteoarthritis presenting with a sudden onset of pain 2 weeks before imaging. Sagittal proton-density (PD) (**a**), coronal T1-weighted (**b**) and coronal fat-suppressed PD (**c**) turbo spin echo (TSE) magnetic resonance (MR) images show a low signal intensity line (*thin arrows*), which represents an insufficiency fatigue fracture in the medial tibial condyle. There is also associated bone marrow oedema, joint effusion, medial meniscal degeneration and bone marrow oedema in the medial femoral condyle (*open arrow in* c), presumably representing stress reaction before development of an insufficiency fracture.

Fig. 7a-c *Donna di 75 anni con osteoporosi nota e con osteoartrite del compartimento mediale del ginocchio presentatasi con dolore improvviso 2 settimane prima dell'esecuzione di queste immagini. Le immagini RM PD-TSE sagittale* ***(a)****, T1-dipendente coronale* ***(b)*** *e PD-TSE con soppressione del grasso in coronale* ***(c)*** *mostrano una linea con bassa intensità di segnale (frecce sottili), che rappresenta una frattura da stress nel condilo tibiale mediale. Sono presenti anche edema del midollo osseo, versamento articolare, degenerazione del menisco mediale ed edema midollare nel condilo mediale del femore (freccia vuota in* ***c****), che probabilmente rappresentano una reazione da stress prima dello sviluppo di una frattura da insufficienza.*

to the trabecular fracture, without any cortical discontinuity. Occasionally, apart from the fracture itself and the associated marrow oedema ipsilaterally, marrow oedema (Fig. 7) or linear structures (Fig. 8) may be seen in other sites of the same joint, which could represent stress reaction either to biomechanical stress or to a new prefracture state.

Treatment for IF includes immobilisation of the affected extremity with a cast and analgaesics. Disease course and outcome are favourable, with complete recovery in almost all patients and a favourable long-term prognosis [39, 40]. A high index of suspicion of this type of fracture may help avoid unnecessary diagnostic tests and guide appropriate treatment.

Conclusion

Acute BMO pattern of the knee is often seen on MR images in adults with acute joint pain. Among the most frequent nontraumatic disorders, TBMOS, SONK and IF should be included in the main differential diagnosis. As a rule, MR imaging findings of BMO are not pathognomonic, and the radiologist's role is important in differentiating the above conditions. Patient's age and gender, history, bone mineral status, time of imaging from symptom onset, BMO pattern and associated subchondral lesion analysis will show the most probable diagnosis, guide the appropriate treatment and assess the clinical outcome.

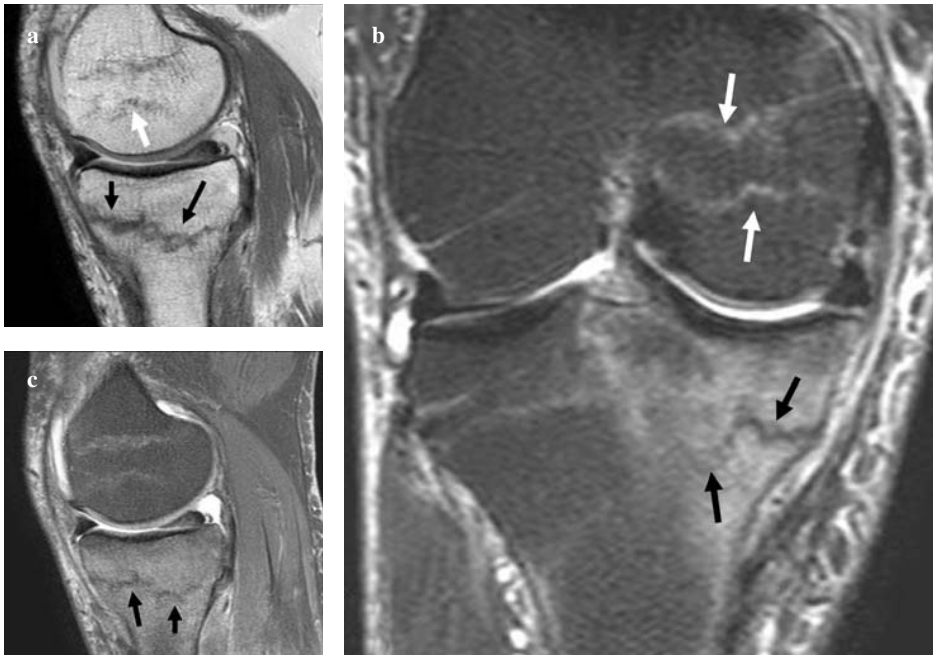

Fig. 8a-c A 72-year-old female patient with known osteoporosis presenting with sudden onset of medial compartment pain 1 week before imaging. Plain radiographs were normal, and the clinical diagnosis was spontaneous osteonecrosis. Sagittal proton-density (PD) (**a**) fat-suppressed PD sagittal (**b**) and coronal (**c**) turbo spin echo (TSE) magnetic resonance (MR) images show a low signal intensity line (*black arrows*), which represents an insufficiency fatigue fracture in the medial tibial condyle. There is also associated bone marrow oedema, joint effusion and soft tissue oedema. The linear structures in the medial femoral condyle marrow (*white arrows*) presumably represent stress reaction before development of an insufficiency fracture.

Fig. 8a-c *Donna di 72 anni con osteoporosi nota, presentatasi con dolore improvviso al compartimento mediale 1 settimana prima dell'esecuzione di queste immagini. La radiografia dell'articolazione era normale ed è stata posta diagnosi clinica di osteonecrosi spontanea. Le immagini RM PD-TSE sagittale* ***(a)*** *e con soppressione del grasso sagittale* ***(b)*** *e coronale* ***(c)*** *mostrano una linea a bassa intensità di segnale (frecce nere), che rappresenta una frattura da stress nel condilo tibiale mediale. Sono presenti anche edema del midollo osseo, versamento articolare ed edema del tessuto molle. Le strutture nel midollo del condilo femorale mediale (frecce bianche) rappresentano probabilmente una reazione da stress prima dello sviluppo di una frattura da insufficienza.*

Conflict of interest statement The authors declare that they have no conflict of interest to the publication of this article.

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