MR Imaging of Bone Marrow Edema Pattern: Transient Osteoporosis, Transient Bone Marrow Edema Syndrome, or Osteonecrosis

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The bone marrow edema (BME) pattern of signal intensity changes on magnetic resonance (MR) images (decreased on T1-weighted and increased on T2-weighted) is a nonspecific finding encountered with several entities, including transient osteoporosis of the hip, transient BME syndrome, osteonecrosis, trauma, infection, and infiltrative neoplasm. Transient osteoporosis, an unusual but distinct syndrome characterized by self-limited pain and radiographically evident osteopenia, can be distinguished from other causes of the BME pattern, particularly osteonecrosis, on the basis of clinical findings and the development of radiographically evident focal osteopenia within 8 weeks after the onset of pain. This is an important distinction, since all patients with transient osteoporosis recover completely, without intervention. The term transient BME syndrome can be used to describe any patient in whom a reversible BME pattern is seen on MR images. Although the transient BME syndrome is also self-limited and quite likely related to transient osteoporosis, the authors believe that to avoid confusion, this nonspecific term should be reserved only for patients who do not develop radiographically evident osteopenia.

Abbreviation: BME = bone marrow edema

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See the commentary by Kransdorf following this article.
INTRODUCTION
In magnetic resonance (MR) imaging of the hip, a diffuse pattern of abnormal marrow signal intensity is occasionally seen. This diffuse pattern involves most of the femoral head and usually extends into the femoral neck and intertrochanteric region. The abnormality is characterized by decreased signal intensity on T1-weighted and increased signal intensity on T2-weighted images, without evidence of the focal lesions that are considered specific for osteonecrosis. This MR imaging pattern has become popularly known as the "bone marrow edema" (BME) pattern (1), since the signal intensity characteristics are consistent with increased free water or edema within the normal fatty marrow of the proximal femur. The BME pattern seen with MR imaging is a nonspecific finding that has been described in association with a number of conditions including (a) transient osteoporosis of the hip, a self-limited painful condition of unknown cause, characterized by focal radiographic osteopenia of the femoral head that resolves with time (2-9); (b) "transient bone marrow edema syndrome" (1,10); and (c) osteonecrosis of bone (11-14). Other conditions, such as osteomyelitis (15), trauma (16), or infiltrative neoplasms (17) have been reported to produce an MR appearance similar to the BME pattern, but these can usually be distinguished on the basis of their clinical differences. The distinction between transient osteoporosis, transient BME syndrome, and osteonecrosis, however, is less clear, but still crucial, since the prognosis and treatment of osteonecrosis differ considerably from those of the other two self-limited conditions.

This article is a review of these three entities that may produce the BME pattern on MR images. The condition of transient osteoporosis is reviewed, including various theories regarding its cause. The current status of the transient BME syndrome and its relation to transient osteoporosis are also reviewed. Finally, the association between conventional osteonecrosis of bone, the BME pattern, and the entities described above are discussed.

TRANSIENT OSTEOPOROSIS
Transient osteoporosis is one of several related conditions that have in common the development of self-limited pain and radiographic osteopenia affecting one or several joints, most commonly the hip. Transient osteoporosis of the hip was first described in the American literature in 1959 by Curtiss and Kincaid (18), who reported the condition in two women, both of whom were in the third trimester of pregnancy. Numerous case reports and series have followed (19-26). Although the cause of transient osteoporosis is controversial, typical clinical radiologic and pathologic features have been described that support the concept of transient osteoporosis as a distinct entity.

Transient osteoporosis typically occurs in middle-aged men or in women in the third trimester of pregnancy. There is spontaneous onset of pain, usually progressive over several weeks. Patients generally do not have risk factors for osteonecrosis, although there is sometimes a history of minor trauma. Laboratory values are normal or nonspecific.

Imaging findings in a typical case of transient osteoporosis of the hip are presented in Figure 1. Plain radiographs in cases of transient osteoporosis may show normal findings early, but within several weeks (usually 4-8), patients develop variable, often profound osteopenia of the femoral head and neck region, sometimes mildly involving the acetabulum. The joint space is always preserved. There is a striking loss of the subchondral cortex of the femoral head, which is virtually pathognomonic for transient osteoporosis (3,9,26).

Skeletal scintigraphy shows markedly increased homogeneous uptake in the femoral head. Scintigraphic findings are positive before osteopenia is seen on radiographs (24). The epicenter of the scintigraphic abnormality is usually at the center of the femoral head (24).

MR imaging in cases of transient osteoporosis shows a diffuse BME pattern involving the femoral head, neck, and sometimes intertrochanteric region. There is inconsistent mild involvement of the acetabulum. A small joint effusion is invariably present. No focal changes typical of osteonecrosis are found. The MR imaging signal intensity changes may be diffuse or may spare a segment of the femoral head (7). The signal intensity changes are frequently heterogeneous, particularly on T2-weighted images. Like skeletal scintigraphy, MR imaging may demonstrate findings positive for transient osteoporosis before the development of radiographic changes.
Figure 1. Transient osteoporosis of a left hip. (a) Pelvic radiograph obtained 8 weeks after onset of pain in a 28-year-old woman without significant medical history shows marked osteopenia of the proximal femur. The subchondral cortex is strikingly indistinct (arrow). (b) Bone scan obtained at the same time shows marked, homogeneous uptake centered in the femoral head. (c, d) Initial MR images of the hips (repetition time, 700 msec; echo time, 20 msec [700/20] [c] and 2,500/90 [d]) show a BME pattern in the left hip and a joint effusion (arrow in d). With conservative treatment, the symptoms and radiographic findings returned to normal within several months. (e–g) Follow-up radiograph (e) and MR images (700/20 [f] and 2,500/90 [g]) obtained 3½ years later show normal findings.
Figure 2. Migratory regional osteoporosis. (a) Initial radiograph of the pelvis in a 32-year-old man who had spontaneous onset of pain shows mild osteopenia of the right hip. (b) MR image (550/30) shows a BME pattern that spares the medial aspect of the femoral head (arrow). With conservative treatment, his symptoms improved. (c) Repeat MR image (760/15) at 6 months, obtained 2 days after the onset of pain in the left hip, shows a new BME pattern in that hip. The BME pattern in the right femoral head has resolved. (d) Radiograph obtained 6 weeks later shows osteopenia and an indistinct subchondral cortex (arrow) in the left hip. (e, f) Follow-up MR images (366/20 [e] and 2,000/80 [f]) obtained 4 months later demonstrate a return to normal. (Fig 2c and 2d reprinted with permission from reference 9.)
Clinical improvement occurs over several weeks to months without specific treatment. The plain radiographic appearance gradually returns to normal, usually lagging behind clinical improvement by 4–8 weeks (26). MR imaging and skeletal scintigraphy both show complete resolution in several weeks. There have been no reports of progression to typical radiographic or clinical osteonecrosis in cases of radiographically verified transient osteoporosis.

Some patients later develop similar changes in the opposite hip or in other joints, in which case the term regional migratory osteoporosis may be used (27–30). A typical example of regional migratory osteoporosis is shown in Figure 2.

Possible causes of transient osteoporosis include trauma, synovitis, neurovascular dysfunction, and transient ischemia.

The BME pattern is similar to the typical MR imaging pattern observed in “bone bruises” (16) and in some radiographically occult fractures of the femoral head in elderly women that have recently been reported (31). However, no consistent history of trauma is elicited from patients with transient osteoporosis, making trauma an unlikely cause in most cases.

The presence of a joint effusion in all cases of transient osteoporosis suggests a possible synovial origin. However, synovial fluid examination and synovial biopsies are usually nonspecific, occasionally showing slight inflammatory reaction. No organisms have been isolated, and no links between transient osteoporosis and any specific arthritis have been found.

Several authors regard transient osteoporosis as a mild variant of reflex sympathetic dystrophy (28,32,33). Indeed, the clinical, radiographic, and scintigraphic characteristics of these conditions have similarities. One case report has documented electromyelographic changes compatible with denervation (similar to reflex sympathetic dystrophy) in a patient with regional migratory osteoporosis (28).

There are also some histologic similarities between reflex sympathetic dystrophy and transient osteoporosis (34). However, several clinical differences have been pointed out by Lakhanpal et al (29). Reflex sympathetic dystrophy is usually associated with trauma, more often involves the upper extremities, shows evidence of vasomotor dysfunction, and tends to be more debilitating than transient osteoporosis (29). Koch et al (35) reported that, unlike transient osteoporosis, reflex sympathetic dystrophy typically does not show a BME pattern on MR images. Despite these differences, it is possible that transient osteoporosis and reflex sympathetic dystrophy may have common causes.

Some authors have suggested that transient osteoporosis occurs as a result of a transient ischemic insult to the bone (6,14,19,30). Such an ischemic insult is postulated to cause limited cell death, possibly involving only the hematopoietic and fatty elements. In contrast, osteonecrosis is conventionally considered to include osteocyte death along with other bony elements. Thus, there may be a spectrum of ischemia from mild or limited events such as transient osteoporosis to extensive bone death progressing to mechanical failure typical of osteonecrosis (14).

Histologic findings in cases of transient osteoporosis are often nonspecific, but some evidence of limited cell death is often reported, particularly involving marrow and hematopoietic cells (8,36). However, neither histologic nor radiographic evidence of advanced osteonecrosis has been described with transient osteoporosis. Transient osteoporosis and osteonecrosis also occur in distinctly different patient populations. This lack of overlap does not support the ischemic origin of transient osteoporosis, unless one assumes that transient osteoporosis and osteonecrosis represent different end points of a similar insult in different patient populations. Thus, the cause of transient osteoporosis remains obscure.

TRANSGIENT BME SYNDROME

Transient BME syndrome is a generic term used by some authors to describe the appearance of a diffuse BME pattern on MR images, which eventually resolves (1,10). In this sense, the term is used to describe an MR imaging finding and does not define a single entity or clinical syndrome. Some authors include patients with clear-cut transient osteoporosis in this group, but we would
Figure 3. Transient BME syndrome. (a) Radiograph of the pelvis in a 61-year-old woman obtained 4½ weeks after the onset of pain in the left hip while getting out of bed shows normal findings. (b, c) MR images (600/25 [b] and 2,000/120 [c]) obtained 1 week later show a BME pattern (arrow). (d–f) Repeat MR images (533/20 [d] and 2,500/80 [e]) obtained at 4 months and a radiograph (f) show normal findings. (Courtesy of Thomas L. Pope, Jr, MD, Department of Radiology, Bowman Gray School of Medicine, Winston-Salem, NC.)

prefer that the term transient BME syndrome be reserved only for patients in whom osteopenia is never demonstrated radiographically. This may include patients who underwent radiography, but the timing of which prevented osteopenia from being demonstrated; those in whom the osteopenia was not well demonstrated radiographically; and some patients in whom truly no osteopenia occurs. An example of the transient BME syndrome is presented in Figure 3.
As with transient osteoporosis, the symptoms and MR imaging findings of transient BME syndrome are self-limited, making a distinction between these two conditions on the basis of radiographic findings of osteopenia somewhat arbitrary. Some authors maintain that core decompression of the femoral head results in rapid relief of symptoms in patients showing BME MR imaging patterns and is therefore warranted symptomatic therapy (37). The patient in Figure 4 underwent core decompression, after which symptoms and abnormalities seen on MR images regressed. Regardless of whether core decompression may relieve symptoms more rapidly, it is important to remember that both transient osteoporosis and transient BME syndrome are self-limited and that more aggressive procedures, such as total joint replacement, must certainly be avoided.

**OSTEONECROSIS MANIFESTING THE BME PATTERN**

In MR imaging of the femoral head, osteonecrosis is most commonly recognized as focal subchondral signal intensity changes. Lesions that are circumscribed by a rim of low signal intensity on T1-weighted images or a “double line” consisting of concentric low- and high-signal-intensity bands on T2-weighted images are virtually pathognomonic of osteonecrosis. There are scattered reports in the literature of osteonecrosis manifesting a BME pattern on MR images (11–14). Although confirmation and follow-up for many of these cases are limited, we believe that osteonecrosis can occasionally manifest a BME pattern on MR im-

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**Figure 4.** Transient BME syndrome treated with core decompression. A radiograph obtained 6 weeks after the onset of symptoms in a 35-year-old man with a history of seizure disorder and cerebrovascular accidents showed normal findings. (a, b) Coronal T1-weighted (a) and axial T2-weighted (b) MR images (parameters unspecified) show a BME pattern in the right femoral head. A repeat radiograph obtained 4 weeks later showed no change. A core decompression was performed, after which the symptoms rapidly resolved. (c, d) Follow-up T1-weighted (c) and fat-suppression (d) images (parameters unspecified) obtained 3 months later show the core tract (arrow) but otherwise normal appearance of the femoral heads. (Courtesy of James B. Vogler III, MD, North Florida Radiology, Gainesville.)

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Figure 6. Osteonecrosis with progressive collapse manifesting a BME pattern. (a) Initial radiograph obtained for right thigh pain in an 82-year-old man with a medical history remarkable for treatment with corticosteroids shows normal findings. (b, c) Coronal (600/20 [b]) and axial (2,000/100 [c]) MR images obtained 4 weeks later show a BME pattern in the right femoral head, neck, and intertrochanteric regions. Conservative treatment was elected. (d) Radiograph obtained 7 months later shows progressive subchondral collapse and clear evidence of osteonecrosis. (Courtesy of Mark W. Ragozzino, MD, Department of Radiology, New Hanover Memorial Hospital, Wilmington, NC.)

Figure 5 is an example of bilateral BME changes that evolved into focal subchondral changes in the femoral heads, typical of osteonecrosis. In some cases, the diffuse changes in signal intensity of BME may partly obscure a subchondral focal lesion. Vande Berg et al (10) called this appearance the “pseudo-homogeneous edema pattern” of osteonecrosis. This pattern usually occurs with advanced osteonecrosis. Plain radiographs in such cases usually show evidence of collapse of the subchondral bone; the findings can readily be distinguished from those of transient osteoporosis or transient BME syndrome (10). Radiographic evidence of advanced osteonecrosis cannot always be demonstrated at presentation, however, as shown in Figure 6.

Figure 5. Bilateral BME patterns progressing to radiographically occult osteonecrosis. (a, b) MR images (800/20 [a] and 2,000/80 [b]) obtained 4 weeks after the onset of left hip pain in a 71-year-old man show a BME pattern. (c, d) MR images (500/21 [c] and 2,120/120 [d]) obtained 4 months later demonstrate disappearance of the BME pattern, replaced by a smaller focal subchondral signal intensity abnormality (arrow). (e, f) MR images (500/23 [e] and 2,120/120 [f]) obtained 5 months later demonstrate a new BME pattern on the right side. (g, h) Final MR images (500/23 [g] and 2,120/120 [h]) obtained 2 months later demonstrate bilateral small subchondral lesions considered typical for osteonecrosis (arrows). Plain radiographs have remained negative for evidence of osteonecrosis. (Courtesy of David A. Turner, MD, Department of Radiology, Rush-Presbyterian-St Luke’s Medical Center, Chicago, Ill. Reprinted, with permission, from reference 13.)
The distinction between transient osteoporosis or transient BME syndrome and osteonecrosis is crucial to avoid unnecessary therapy. Vande Berg et al (10) believe that high-resolution T2-weighted MR images are useful in distinguishing osteonecrosis from transient BME syndrome and transient osteoporosis because these images usually show an underlying focal subchondral defect with osteonecrosis. Although the diffuse changes in signal intensity in both transient osteoporosis and transient BME syndrome may be more apparent in the subchondral location, focal or circumscribed lesions are absent. However, the value of high-resolution T2-weighted images in distinguishing between osteonecrosis and transient osteoporosis and BME syndrome needs to be confirmed.

The distinction between osteonecrosis and the self-limited conditions of transient osteoporosis and transient BME syndrome may be aided with clinical information. In particular, the presence or absence of risk factors associated with osteonecrosis is important. On the basis of a review of the literature, patients with transient osteoporosis or transient BME syndrome generally do not have risk factors for osteonecrosis.

**SUMMARY**

The BME pattern seen on MR images is not specific for any single entity but encompasses the following differential diagnoses: (a) transient osteoporosis or migratory osteoporosis, (b) transient BME syndrome, (c) osteonecrosis, (d) occult trauma or bone bruise, (e) infection, and (f) infiltrative neoplasm.

Transient osteoporosis is a specific entity that can usually be differentiated from other disorders, including irreversible osteonecrosis, on the basis of radiologic and clinical findings. Plain radiographic evidence of focal osteopenia is the single most important finding and may only become evident 6–8 weeks after the onset of symptoms. A sufficient period of radiographic follow-up is therefore essential to ensure that the diagnosis is not missed. Once identified, transient osteoporosis requires no specific therapy, since all patients recover.

The term transient BME syndrome is used by some authors to include all patients demonstrating a reversible, diffuse BME pattern on MR images. We believe this term should be reserved for those patients in whom the BME pattern is not accompanied by radiographic evidence of osteopenia and for whom no other clinical diagnosis is apparent.

Osteonecrosis may occasionally manifest a BME pattern on MR images. Radiographs in many of these cases show obvious evidence of osteonecrosis. In equivocal cases, close evaluation of the MR imaging patterns for focal subchondral lesions may possibly aid in distinguishing this pattern of osteonecrosis from transient osteoporosis or transient BME syndrome. For this reason, high-resolution T2-weighted images have recently been recommended by some authors.

**REFERENCES**


