Osteoid osteoma is characterized by an intracortical nidus with a variable amount of calcification, as well as cortical thickening, sclerosis, and bone marrow edema. When these findings are present, a diagnosis of osteoid osteoma is easily made. However, osteoid osteoma may display imaging findings that can be misleading, and it can be difficult to differentiate osteoid osteoma from other conditions such as infection, inflammatory and noninflammatory arthritis, and other tumors. In addition, stress fracture, intracortical abscess, intracortical hemangioma, chondroblastoma, osteoblastoma, and compensatory hypertrophy of the pedicle may mimic osteoid osteoma. To make the correct diagnosis, it is necessary to identify the nidus, and it is important to be familiar with the radiologic findings of osteoid osteoma and its mimics.
Introduction

Osteoid osteoma is a benign bone tumor that occurs most frequently in men and boys between 7 and 25 years old (1). Most patients experience pain that worsens at night and is promptly relieved by the administration of salicylates (2). The term *nidus*, which was described as the “core” or “niduslike focus” by Jaffe in 1953 (3), refers to the tumor itself and is composed of bone at various stages of maturity within a highly vascular connective tissue stroma (4). The center of the nidus usually is the most highly mineralized part, and it may display various amounts of mineralization (Fig 1) (5).

There are two classification schemes for osteoid osteoma, both of which describe the location of the tumor in bone. With the first scheme, tumors are classified as cortical, medullary (cancellous), or subperiosteal on the basis of radiographic findings. This method is more traditional and more frequently used than the other classification scheme (6). With this scheme, cortical osteoid osteomas are the most common. They usually occur in the shaft of the long bones, especially the femur and tibia. Subperiosteal osteoid osteomas are the least common. With the other, recently suggested classification scheme, tumors are categorized as subperiosteal, intracortical, endosteal, or intramedullary on the basis of computed tomographic (CT) and magnetic resonance (MR) imaging findings (7). With the use of cross-sectional imaging, it has been suggested that subperiosteal osteoid osteomas are more common than was initially believed. It also has been postulated that intracortical and medullary lesions migrated from subperiosteal origins as a result of bone remodeling, with subperiosteal deposition and endosteal erosion.

In this article, we discuss the typical imaging findings of intracortical osteoid osteoma, including lesions that occur in uncommon locations; intraarticular osteoid osteoma, a separate clinical entity; associated severe inflammatory changes that can confound a diagnosis; and conditions that mimic osteoid osteoma, including stress fracture, intracortical abscess, and other tumors and pseudotumors.

Typical Imaging Findings

Typical radiographic findings of osteoid osteoma include an intracortical nidus, which may display a variable amount of mineralization, accompanied by cortical thickening and reactive sclerosis in a long bone shaft. The radiolucent focus often is referred to as the nidus because the focus usually is located in the center of an area of reactive sclerosis. The nidus is round or oval and usually smaller than 2 cm (8). Bone density may be decreased because of disuse due to pain (9).

At CT, the nidus is well defined and round or oval with low attenuation (Fig 2). An area of high attenuation may be seen centrally, a finding that represents mineralized osteoid (10) (Fig 3). Reactive sclerosis is apparent and ranges from mild cancellous sclerosis to extensive periosteal reaction and new bone formation, which may obscure the nidus. Enhancement of a hypervascular nidus may be seen at dynamic CT (11).

MR imaging depicts not only the nidus and accompanying sclerosis but also adjacent bone marrow and articular abnormalities (12). The nidus has low to intermediate signal intensity on T1-weighted images and variable signal intensity on T2-weighted images, depending on the amount of mineralization present in the center of the nidus. Edema in adjacent bone marrow and soft tissue and joint effusion also may be seen (Fig 3) (13,14). Because of the recent increases in spatial resolution, a partially mineralized nidus generally has a targetlike appearance, with a high-signal-intensity periphery (the unmineralized portion) and...
Figure 2. Subperiosteal osteoid osteoma of the tibial diaphysis in an 18-year-old man. (a) Oblique radiograph shows a radiolucent nidus (arrow) amid an area of fusiform cortical thickening. (b) Axial unenhanced CT image shows a low-attenuation nidus (arrow), without mineralization, surrounded by reactive bone formation (white arrowheads). The attenuation of the reactive bone is slightly lower than that of the native cortex (black arrowheads). The nidus is classified as subperiosteal because it is adjacent to the outer margin of the native cortex.

Figure 3. Intracortical osteoid osteoma of the proximal tibial metaphysis in a 14-year-old girl. (a) Axial unenhanced CT image shows periosteal reaction, thickening of the anteromedial cortex, and a low-attenuation nidus (arrow) with central mineralization. Reactive sclerosis of the bone marrow (*) is seen adjacent to the nidus. (b) Axial T2-weighted MR image shows the nidus, with high signal intensity peripherally and heterogeneous signal intensity centrally. Periosteal elevation (arrowheads) also is seen. (c, d) Axial unenhanced (c) and gadolinium-enhanced fat-suppressed (d) T1-weighted MR images show the low-signal-intensity nidus (arrow in c), which has strong enhancement, and edema in the surrounding bone marrow (*) and soft tissue (arrowheads in d). The periphery of the nidus, which is composed of unmineralized stroma, enhances more intensely than the central portion does.
marrow and soft-tissue edema, joint effusion, and synovitis are better appreciated at MR imaging than at CT (14).

Intraarticular Osteoid Osteoma

Intraarticular osteoid osteoma, which occurs within or near a joint, is considered a separate clinical entity (19). The most commonly involved joint is the hip. The ankle, elbow, wrist, and knee are less commonly affected (20). Intraarticular osteoid osteoma is rare, and its clinical manifestations may be puzzling. Pain is not necessarily worse at night in patients with intraarticular osteoid osteoma, and joint pain that is relieved by salicylates may have other causes. Joint tenderness and joint effusion may be prominent, and these symptoms may contribute to the diagnostic confusion (19,20).

Imaging findings of intraarticular osteoid osteoma differ from those of intracortical osteoid osteoma. With intraarticular osteoid osteoma, reactive cortical thickening is minimal or absent, a finding believed to be due to a lack of cambium, the inner layer of the peristeum.
An unusual location may complicate the diagnostic process. The most common location of spinal osteoid osteoma is the lumbar segment (Fig 8), followed by the cervical segment and the thoracic segment. The sacrum is the least commonly affected spinal segment (Fig 9) (25). In most cases, the nidus is located in the neural arch (26). Patients with spinal osteoid osteoma present with radicular pain, gait disturbance, limb atrophy, and painful scoliosis (10). Scoliosis is thought to result from asymmetric muscle spasms; when scoliosis is present, the nidus typically is on the concave side of the lumbar curvature (Fig 8) (27). It is difficult

Cambium, which is responsible for bone formation, may be absent from the joint capsule of the hip (19–22). However, recent studies have shown that the periosteum of the femoral neck has osteogenic potential (23,24). A high level of suspicion is required if the nidus is small and minimal reactive bone formation is present (Figs 5, 6).

**Uncommon Locations of Osteoid Osteoma**

Osteoid osteoma is most common in the femur and tibia; more than 50% of cases occur in these locations. Approximately 30% of osteoid osteomas occur in the spine, hands, or feet (4,5). The least common locations are the skull, scapula, ribs, pelvis, mandible, and patella (Fig 7) (4,5).

**Figure 6.** Intraarticular osteoid osteoma of the femoral condyle in a 29-year-old man. (a) Lateral radiograph of the knee shows a densely mineralized nidus (arrow) at the lateral femoral condyle. (b) Axial T2-weighted MR image shows the low-signal-intensity nidus with central calcification (arrow) and a high-signal-intensity, unmineralized periphery (arrowheads).

**Figure 7.** Osteoid osteoma of the posterior arc of the rib in a 25-year-old man. (a) Anteroposterior radiograph shows a teardrop-shaped nidus (arrow) with central mineralization. Mild reactive sclerosis and cortical expansion of the host bone also are seen in the surrounding bone. (b) Axial unenhanced CT image shows the calcified nidus (arrow) in the anterior cortex of the rib, with mild reactive sclerosis (arrowheads) surrounding the nidus.
are a nidus in the neural arch and bone marrow edema in the involved pedicle and lamina that extends to the posterolateral vertebral body (29). In the hands and feet, cancellous osteoid osteoma occurs in the carpal and tarsal bones, and all types of osteoid osteoma may occur in the metacarpal, metatarsal, and phalangeal bones (Fig 10). Carpal and tarsal osteoid osteoma to diagnose spinal osteoid osteoma on the basis of radiographic findings because of the complexity of spinal anatomy and overlapping areas of soft tissue. CT is best for localization of the nidus before treatment is begun (10,28). Characteristic MR imaging features of spinal osteoid osteoma

**Figures 8, 9.** (8) Osteoid osteoma of the lumbar spine in a 22-year-old man. (a) Anteroposterior radiograph shows mild scoliosis and an enlarged left L3 pedicle with sclerotic change (arrow). The curvature of the scoliosis is leftward, with the lesion located within the concavity. (b) Axial unenhanced CT image shows the nidus (white arrow) within the hypertrophied superior articular process. The pedicle also is hypertrophied (black arrow), and reactive sclerosis is seen in the marrow of the left pedicle and the superior articular process. (9) Osteoid osteoma of the sacrum in a 16-year-old boy. Sagittal reformatted CT image shows a calcified nidus (arrow) protruding into the central canal, with reactive sclerosis (*) around the nidus.

**Figure 10.** Osteoid osteoma of the metacarpal bone in a 23-year-old man. (a) Axial T2-weighted MR image shows an intramedullary nidus (arrow) with peripheral sclerosing bone and no mineralization. (b) Coronal gadolinium-enhanced T1-weighted fat-suppressed MR image shows strong enhancement of the nidus and adjacent bone marrow edema (*). Bone marrow edema also is seen at the proximal phalangeal base (arrowheads). Hypertrophied synovial enhancement is suggestive of synovitis in the metacarpophalangeal joint.
may display less reactive sclerosis, a finding that can be misleading. Because of the proximity of the bones in the hands and feet, an inflammatory reaction that originates from one carpal or tarsal lesion often spreads to adjacent bones and joints. Moreover, soft-tissue swelling may be prominent in osteoid osteomas of the hands and feet, a finding that may resemble infection or inflammatory arthritis (4).

**Confusing Imaging Findings**

When osteoid osteoma is accompanied by severe inflammatory changes such as a prominent periosteal reaction, exaggerated synovial hypertrophy and joint effusion, and extensive bone marrow and soft-tissue edema, it may be difficult to reach a diagnosis (Figs 11, 12). Findings such as these may
cause radiologists to suspect an entity other than osteoid osteoma. Although clinical symptoms may not be helpful in forming a diagnosis, the presence of an infectious disease may be determined on the basis of laboratory test results. Prominent periosteal reaction and a young age increase the possibility of osteomyelitis or a malignant bone tumor, such as Ewing sarcoma. The presence of severe synovial hypertrophy and a large joint effusion may cause an osteoid osteoma to resemble septic arthritis or chronic inflammatory arthritis. When a small nidus is masked by extensive bone marrow and soft-tissue edema, traumatic injury or infection may be suspected. To make a correct diagnosis, it is essential to identify the nidus and be open to the possibility of an osteoid osteoma.

**Conditions That Mimic Osteoid Osteoma**
Several conditions have imaging findings that may mimic osteoid osteoma, such as localized cortical thickening, reactive sclerosis surrounding an osteolytic lesion, and bone marrow edema. These conditions include stress fracture, intracortical abscess, intracortical hemangioma, chondroblastoma, osteoblastoma, and compensatory hypertrophy of the pedicle. To distinguish these entities from osteoid osteoma, it is helpful to be familiar with the imaging findings specific to the mimics and recognize the lack of a typical nidus.

**Stress Fracture**
A stress fracture occurs when the stress on a bone exceeds the capability of the bone to repair itself. At radiography, localized thickening of the cortex may be seen in late stages, a finding similar to that of osteoid osteoma. Stress fracture is common in the diaphysis of lower-extremity bones and the femoral neck and is usually caused by weight-bearing activity. A stress fracture appears as an infraction in the center of an area of cortical thickening, whereas osteoid osteoma appears as a round nidus (Fig 13) (30). Cross-sectional imaging, especially in the coronal and sagittal planes, is useful for differentiating between the two conditions (31). In a stress fracture, the extent of cortical thickening varies from a focal cortical ridge to extensive thickening that is bidirectional to the periosteal and endosteal aspects. In osteoid osteoma, the extent of cortical thickening depends on the transverse and longitudinal location of the tumor in bone, but no prominent cortical ridges are present. A stress fracture is more likely than osteoid osteoma if the size of the cortical lesion decreases during a short follow-up period, although there are a few reports of spontaneous regression of an osteoid osteoma. Bone scintigraphy may help differentiate a stress fracture from osteoid osteoma. On scintigraphic images, a stress fracture demonstrates linear, intense uptake of the tracer, whereas osteoid osteoma displays the “double-density” sign, in which intense central uptake is seen at the site of the nidus and moderate uptake is seen in the surrounding area (32).

**Intracortical Abscess**
In 1940, Jaffe and Lichtenstein (33) described an osteoid osteoma as “osteomyelitis or abscess of the bone.” Before this description, osteoid osteomas were classified as intracortical bone abscesses or sclerosing nonsuppurative osteomyelitis. At radiography, an intracortical abscess and an osteoid osteoma often are indistinguishable. When a sequestrum is present, the appearance of an intracortical abscess is very similar to that of an osteoid osteoma with a calcified nidus. However, it is easier to differentiate between the two conditions at CT. In osteoid osteoma, the inner side of the nidus is smooth, and a round calcification is seen in the center of the nidus. In an intracortical abscess, the inner margin is irregular, and an irregularly shaped sequestrum is seen eccentrically (Fig 14) (34). Intracortical abscesses display low signal intensity on T1-weighted MR images, high signal intensity on T2-weighted MR images, and peripheral rim enhancement on gadolinium-based contrast material–enhanced images (35). The center of an intracortical abscess does not enhance, whereas in osteoid osteoma, an unmineralized nidus composed of highly vascular stroma enhances strongly.

**Other Tumors and Tumorlike Lesions**

**Intracortical Hemangioma.**—Intracortical hemangioma is a rare tumor that most often occurs in the tibia (36). According to the literature, only 12 cases have been described, nine of which were in the tibia. The other three cases involved the femur, ulna, and mandible (37,38). Histologic analysis of intracortical hemangiomas
Figure 13. Tibial stress fracture in a 10-year-old girl. (a) Lateral radiograph of the left lower leg shows mild bowing of the tibia, fusiform cortical thickening in the anterior cortex, and a radiolucent teardrop-shaped lesion (arrow) with a small radiopaque focus in the center of the thickened cortex. (b) Sagittal T1-weighted MR image shows the low-signal-intensity lesion (arrow) within the thickened cortex. (c) Axial T2-weighted MR image shows the irregular shape of the lesion.

Figure 14. Intracortical abscess of the femoral diaphysis in a 15-year-old girl. (a) Axial unenhanced CT image shows an intracortical osteolytic mass with an irregular margin and a central linear hypoattenuating lesion (arrow), a finding indicative of a sequestrum. (b) Axial T2-weighted MR image shows the high-signal-intensity intracortical lesion surrounded by prominent periosteal reaction (arrowheads).
shows expanded haversian canals that contain a proliferation of dilated cavernous vessels filled with bloody material (38). A typical radiographic finding of intracortical hemangioma is an intracortical osteolytic lesion with cortical thickening or periostitis (Fig 15). It is difficult to differentiate an intracortical hemangioma from an osteoid osteoma on the basis of radiographic features alone. According to a study of imaging findings of intracortical hemangioma, radiography depicts an intracortical osteolytic lesion with vertically aligned intralosional calcifications of the trabeculae (37). At CT, a hypoattenuating intracortical lesion with spotty internal calcification, or a so-called wire-netting appearance, is seen. MR imaging shows a hyperintense lesion with hypointense septa, features that correlate with those seen at CT.

**Chondroblastoma.**—A chondroblastoma is an uncommon benign chondroid tumor that is usually less than 4 cm long. Similar to osteoid osteoma, it frequently occurs in the young and is aggressive, with periosteal reaction and extensive bone marrow edema seen at imaging (39). A small chondroblastoma may be indistinguishable from an osteoid osteoma. The most common sites of chondroblastoma are the epiphyses of the femur, humerus, and tibia (5). An epiphyseal and intramedullary location may help differentiate a chondroblastoma from an osteoid osteoma, which is commonly diaphyseal and intracortical (Fig 16). When mineralized, chondroblastoma demonstrates punctate calcification, whereas osteoid osteoma displays a concentric pattern of mineralization (39–41).

**Osteoblastoma.**—Because they are clinically and histologically similar, some authors consider osteoblastoma and osteoid osteoma to belong to the same family of benign osteoblastic bone tumors (42). However, in most of the literature they are described as distinct clinical entities. Osteoblastoma is less painful than osteoid osteoma and
does not respond to salicylates (43). Moreover, unlike osteoid osteoma, osteoblastoma displays progressive growth and has malignant potential (44). At imaging, osteoblastoma usually appears more expansile, is larger than 2 cm, and has less reactive sclerosis surrounding the mass than osteoid osteoma does (Fig 17) (45).

**Compensatory Hypertrophy of the Pedicle**

When unilateral spondylolysis is present, the contralateral pedicle thickens and demonstrates sclerotic change. Compensatory hypertrophy of the pedicle may be mistaken for osteoid osteoma because spinal osteoid osteoma frequently occurs in the posterior neural arch and induces thickening and sclerosis of the pedicle. Contralateral spondylolysis and lack of a typical nidus are indicative of compensatory hypertrophy of the pedicle (Fig 18) (46).

**Summary**

Typical findings of osteoid osteoma are an intracortical nidus with fusiform cortical thickening, reactive sclerosis, and bone marrow edema. Osteoid osteoma may have an imaging appearance
similar to those of other conditions, which can lead to confusion. It is helpful to be aware of these conditions and their distinguishing imaging features. A meticulous search for the nidus should be emphasized in a radiologic diagnosis of osteoid osteoma.

References
Radiologic Diagnosis of Osteoid Osteoma: From Simple to Challenging Findings

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