INTRODUCTION

The radiological diagnosis of bone tumors, often identified as incidental findings in asymptomatic patients, requires caution and evaluation by a specialist. For knee pain, conventional radiography is a complementary method of diagnosis that is essential to the investigation.

The fundamental elements for the differential diagnosis and evaluation of bone tumors using conventional radiography are patient history and age, together with the clinical presentation, anatomical location of the lesion, definition of the zone of transition between the lesion and host bone, and the radiographic characteristics of the lesion\(^{1,2}\).

From these data, it is possible to establish differential diagnoses that are more precise, which can guide physicians in pursuing the investigation, carrying out staging and biopsy as necessary.

This study describes the main radiography findings of the most common bone tumors around the knee. All imaging diagnoses in this paper were confirmed by histopathological analysis.

PSEUDOTUMORS

Pseudotumors are not categorized as true neoplasms, because they lack the specific pathological characteristics and contain no neoplastic cells. Pseudotumors frequently are the result of metabolic stimulation or hyperactivity of normal cells, such as osteoclasts.

Simple bone cyst and aneurysmal bone cyst

A simple bone cyst of unknown cause is characterized by a well-defined, unicameral, radiolucent lesion, not breaking through the adjacent cortical bone, with a sclerotic rim\(^{1,2}\), as shown in Figures 1A and 1B.

Typically, simple bone cysts are metaphyseal lesions and appear during childhood or adolescence. Fracture occurs as the first clinical manifestation in up to 70% of cases\(^{1}\). The clinical diagnosis can be presumed with conventional radiography, but computed tomography (CT) and magnetic resonance imaging (MRI) allow for better lesion staging\(^{1,2}\).
With more striking radiographic features, aneurysmal bone cysts are painful metaphyseal lytic lesions which expand the adjacent cortex. They are fast growing and therefore have only a thin sclerotic rim or none at all. It is an expansile lesion with cavities containing hematomatous material from the trabecular bone, resulting in discrete intralesional streaks of fibrotic bone, which can be observed on conventional radiography (Figure 1C).

Fibrous dysplasia

Fibrous dysplasia is a benign fibro-osseous pseudotumor in which normal bone is replaced with fibrous tissue permeated with immature heterogeneous trabecular bone. It can be monostotic or polyostotic and affects the immature skeleton1,2.

Bone infarction

Bone infarction has many causes, such as alcoholism, collagen diseases, glucocorticoid use, and blood diseases, and can affect all age groups1–3. The lesions are characterized by medullary bone necrosis and loss of normal bone trabeculae, leading to localized sclerosis.

Asymptomatic until it affects the joints, bone infarction is found upon investigation for adjacent articulation pain3. On conventional radiography, it can be difficult to differentiate bone infarction from enchondroma and chondrosarcoma. Bone scintigraphy is useful for determining whether the lesion metabolically active or not2,3. MRI is helpful in evaluating the extent of the lesion, as well as in conducting a detailed study of the adjacent articulation, and can reveal findings typical of osteonecrosis. Biopsies are reserved for cases in which the diagnosis is unclear or there is a need to exclude the possibility of a true neoplasm3.

Conventional radiography shows focal or diffuse medullary osteosclerosis in one or more bones. Periarticular metaphyseal involvement is common. The lesions are mixed, with lytic areas permeated by areas of sclerosis, restricted to the bone marrow, and do not affect the cortex or induce periosteal reaction (Figure 3).
BONE-FORMING TUMORS

Osteosarcoma

Osteosarcoma is a malignant bone-forming tumor in which the mesenchymal neoplasm cells are capable of forming osteoid tissue or immature bone. The age distribution is bimodal, with the first peak of incidence in the second decade of life and the second after 50 years of age. Swelling and pain are the main complaints, which in general are followed by signs of inflammation and functional loss.

The radiologic manifestations of osteosarcoma can vary, depending on the histological subtype. The tumors can be purely lytic, such as the telangiectatic subtype, or totally sclerotic, such as the osteoblastic subtype. It is typically a metaphyseal lesion in an immature skeleton, with possible invasion of the growth plate. In rare cases, there can be noncontiguous intramedullary lesions in the same bone, characteristic of skip metastasis, which denotes a worse prognosis.

In the more advanced stages, the tumor breaks through the cortical bone and invades adjacent tissues. At that stage, it induces a complex “sunburst” periosteal reaction showing up on conventional radiography as Codman’s triangle and ossification in the soft tissues, giving the “bone outside the bone” appearance. Local and distant staging, followed by needle biopsy, are mandatory.

CARTILAGE-FORMING TUMORS

Osteochondroma

Frequently described as the most common benign tumor of the skeleton, osteochondroma can present as single or multiple lesions that are sessile or pedunculated, characteristic of hereditary multiple osteochondromatosis.

Patients normally do not feel pain but complain of a bony mass near a joint, most often the knee. In the specific case of the knee, osteochondroma can limit the range of movement and compress the peripheral nerves.

An osteochondroma is composed of normal bone and is covered by cartilage, typically metaphyseal (composed of cortical and medullary material) and centrifugal to the joint, without radiological signs of aggressiveness. An important radiological feature is the continuity between the cortex of the lesion and that of the host bone. Osteochondromas grow from their cartilage cap, which is similar to a growth plate, and stop growing after skeletal maturation. If there is a volume increase after skeletal maturity, further diagnostic investigation should be conducted to exclude the possibility of sarcomatous transformation. Transformation to chondrosarcoma is rare, occurring in ≤ 5% of all cases of multiple osteochondromatosis.

Enchondroma

An enchondroma is a benign tumor characterized by the formation of mature hyaline cartilage tissue. It can present as single or multiple lesions. It is often asymptomatic and typically affects the bones of the hand, the bones of the foot,
or the proximal femur. In the knee, enchondroma can be an incidental finding of an ancillary examination performed because of other complaints from the patient or when associated with complications such as pathological fracture\(^1,2\), as depicted in Figure 6.

An enchondroma is lytic and ovoid, with foci of intralesional calcification and no adjacent sclerotic rim. In the bones of the hand, it can be expansile, although it always remains within the borders of the cortical bone. Diagnostic workup with MRI and CT is useful in cases of diagnostic uncertainty and to confirm intralesional calcification\(^8\).

Chondroblastoma

Also known as Codman’s tumor, chondroblastoma is a benign yet aggressive cartilage-forming bone tumor that affects the epiphysis in immature skeletons. The clinical presentation includes joint pain and localized swelling in young patients with an open growth plate. The distal tibia, proximal femur, and proximal humerus are the most common locations\(^1,3\).

Radiography of a chondroblastoma (Figure 7) shows well-defined osteolytic epiphyseal lesions, with a narrow zone of transition, a reactive sclerotic rim which generally does not break through the cortex, and foci of calcification within the lesion, characteristic of the cartilaginous origin of this benign tumor.

Chondromyxoid fibroma

Chondromyxoid fibroma is an aggressive benign cartilaginous bone tumor, with proliferation of myxoid and fibrous tissues. It accounts for 0.5% of all primary bone tumors and can affect all age groups, although it is most common among adolescents and young adults\(^1\).

The clinical presentation of chondromyxoid fibroma consists of progressive pain in the affected segment, local swelling, and (in some cases) other signs of inflammation. Although the radiographic features of chondromyxoid fibroma can vary, it often presents as a metaphyseal, lytic, eccentric, expansile lesion, with a narrow zone of transition and a reactive sclerotic rim. Foci of intralesional calcification are uncommon (Figure 8). The differential diagnosis mainly includes simple aneurysmal bone cyst and, in some cases, giant cell tumor. In case of uncertainty regarding the possibility of a more aggressive lesion, staging and biopsy constitute the safest course of action\(^1,3\).

Chondrosarcoma

Chondrosarcoma is a malignant cartilaginous tumor, described as one of the most common primary malignant bone tumors, second only to multiple myeloma. It comprises a heterogeneous group of lesions with morphological factors and biological behavior that range from non-metastatic, slow-growing lesions to highly aggressive lesions with early metastatic dissemination\(^1,3,4\).
Chondrosarcoma predominantly affects males, often after the fifth decade of life, and is rare among young individuals. The most common site is the hip, followed by the femur, including the area around the knee, and the humerus\(^{1,3,4}\).

The radiographic features of chondrosarcoma include osteolytic lesions with signs of local aggressiveness and soft tissue masses with calcification (Figure 9). The treatment is basically surgical, given that the majority of these tumors do not respond to chemotherapy or radiotherapy\(^{1-4}\).

**MEDULLARY TUMORS**

**Ewing’s sarcoma**

Ewing’s sarcoma is a small round-cell tumor, arising in the bone marrow, that occurs predominantly in the long bones of patients with an immature skeleton. It accounts for approximately 12% of all malignant tumors, most frequently affecting patients ≤ 15 years of age, without a predilection for males or females\(^1\). The area around the knee is affected in up to 10% of cases\(^{1,3}\). It is the third most frequent among bone sarcomas, after osteosarcoma and chondrosarcoma\(^{1-3}\).

Ewing’s sarcoma is a very aggressive lesion, the main complaints being intense pain and swelling of the affected segment, localized signs of inflammation, and systemic symptoms such as weight loss, adynamia, and fever\(^2\).

On radiographs, Ewing’s sarcoma typically presents as a radiolucent, ill-defined infiltrative lesion located on the diaphysis of long bones, inducing a typical “onion-skin” periosteal reaction, and frequently produces large soft tissue masses without foci of calcification\(^{1-3,9,10}\), as shown in Figure 10.

The differential diagnosis of Ewing’s sarcoma includes osteomyelitis, eosinophilic granuloma, lymphoma, neuro-
blastoma metastasis, leukemia, and, in some cases, telangiectatic osteosarcoma, which appears as an essentially lytic lesion on conventional radiography.

In patients with radiologically aggressive Ewing’s sarcoma, staging (local and systemic) is mandatory and should precede biopsy. An MRI scan is quite helpful in local staging and in evaluating the involvement of the soft tissues\(^9\). As for osteosarcomas, the treatment protocol consists of neoadjuvant chemotherapy, followed by surgery and adjuvant chemotherapy\(^{1-3}\).

Multiple myeloma

Multiple myeloma is the most common primary bone neoplasm. Most cases occur in patients in the fifth or sixth decade of life. Clinically, the initial complaint is bone pain, often generalized, together with pallor and alterations in kidney function in the more advanced stages. From a biochemical point of view, severe anemia can be seen, as can an increase in erythrocyte sedimentation rate, serum protein electrophoresis showing a monoclonal spike in the gammaglobulin fraction. Plasmacytic hyperplasia on myelography confirms the diagnosis\(^1-4\).

As exemplified in Figure 11, the radiologic findings in multiple myeloma include diffuse osteopenia accompanied by osteolytic lesions with the typical punched-out aspect, an endosteal lesion, a broad zone of transition (sometimes ill-defined, with imprecise borders), and no periosteal reaction; the condition can evolve to pathological fracture, with accentuation of localized acute pain\(^1,2\).

Plasmacytoma is a tumor that is histologically identical to multiple myeloma, although it is localized, without systemic repercussions or alterations on protein electrophoresis. It can be diagnosed only through biopsy\(^1-3\).

OTHER CONNECTIVE TISSUE TUMORS

Non-ossifying fibroma

Non-ossifying fibroma affects children and teenagers and is characterized by juxta cortical radiolucent lesions, well-circumscribed by a sclerotic rim, without breaking through the cortical bone, without a periosteal reaction, and extending to the bone marrow. Although the fibrous cortical defect is histologically identical to that of ossifying fibroma, the radiological features vary, because the lesion does not reach the bone marrow, being restricted to the cortex, near the growth plate (Figure 12). Non-ossifying fibroma occurs in ≤ 30% of the population. Some authors use the term fibroxanthoma for both\(^1,6\). The lesions are asymptomatic and tend to calcify with age. They can be multiple or isolated, as well as monostotic or polyostotic\(^1-3\). The differential diagnosis includes fibrous dysplasia, simple bone cyst,
and even chondromyxoid fibroma. In some cases, non-ossifying fibroma is discovered as an incidental finding, often on MRI scans obtained for the investigation of meniscal or ligament tears.

The radiological findings of non-ossifying fibromas are quite characteristic, and bone biopsy for diagnostic confirmation is rarely necessary\(^1\)-\(^3\).

**METASTASES**

Frequently, bone tissue is the site of a metastatic lesion, which, in addition to indicating a worse prognosis, can evolve to pathological fracture and can worsen the quality of life and treatment of the patient\(^1\)-\(^4\). Bone metastases can present with osteolytic, osteoblastic, or mixed patterns\(^2\)-\(^4\). The presentation varies and frequently surprises radiologists and surgeons (Figure 13).

When a metastasis is aggressive, it is essential that careful local and systemic staging be carried out, including ancillary tests such as CT, MRI, and scintigraphy\(^1\)-\(^3\),\(^9\). If the primary site is not identified during staging, a lesion biopsy is fundamental for the histopathological and immunohistochemical evaluations\(^6\).

**GIANT CELL TUMOR OF BONE**

Giant cell tumors of bone comprise a special group of bone tumors, which do not form bone or cartilage but simply promote osteoclast-mediated bone resorption, and can also be referred to as osteoclastomas. A giant cell tumor of bone is considered an aggressive benign tumor that rarely metastasizes. It usually affects patients in the third or fourth decades of life, and the most common sites are the distal femur, proximal tibia, and proximal humerus\(^1\),\(^2\),\(^6\),\(^11\).

Clinically, the complaints of patients with giant cell tumor of bone include pain, localized swelling, and functional impairment. The radiological aspect is fairly characteristic, including an eccentric epiphyseal lytic lesion with metaphyseal extension, in skeletally mature patients, without a sclerotic rim, frequently with cortex rupture and invasion of the articular or soft parts\(^1\),\(^2\),\(^11\), as depicted in Figure 14.
CONCLUSION

The study of bone tumors is a challenge. The attending physician and radiologist should both be aware of the clinical characteristics of the patients being investigated and the radiographic features of the lesions. The characteristics of the lesions seen on conventional radiography can define the differential diagnosis, resulting in an appropriate clinical assessment.

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