Exostosis of the bone is a common finding in children presenting with a mass in the extremity. The appearance of a solitary exostosis of the bone can be characteristic and the diagnosis of an osteochondroma is often made without further imaging. Multiple osteochondromas are seen in multiple hereditary exostoses. Osteochondromas can be in specific locations such as the epiphysis in Trevor’s disease. There are also several “osteochondroma-like” lesions that can occur as normal variants or as the result of trauma, congenital anomalies, systemic disorders, or various causes of periosteal reaction. In this article, we will review the imaging of the common osteochondroma and its associated diseases and then focus on a variety of causes of bony exostosis that can have a similar appearance.

Osteochondromas

Solitary osteochondromas are common lesions and may account for up to half of benign bone tumors. An osteochondroma is an outgrowth of benign cartilage from the growth plate that undergoes endochondral bone formation. The etiology of osteochondroma is not clear. Many believe an osteochondroma to be a true bone neoplasm. This may be supported by the increased incidence of osteochondromas in patients who have undergone radiation. Others have suggested that the outgrowth is a result of injury to the peripheral growth plate as suggested in animal models where the growth plate has been traumatized and a typical solitary osteochondroma is produced.

Whatever the etiology (neoplastic or traumatic), patients with solitary osteochondromas typically present with a non-tender slow-growing mass. Occasionally, fractures of the pedunculated osteochondroma can occur. Mass effect on adjacent structures such as bone (especially when they occur in the forearm and leg), nerves, vessels, muscles, or even the spinal cord can also be symptomatic (Fig. 1).

Osteochondromas occur in any long bones that undergo endochondral bone formation. The lesions usually begin growing at the growth plate and are most frequently found in the metaphysis or metadiaphysis and tend to grow away from the physis. The most common location for these lesions is in the lower extremity. The femur is the most common location followed by the tibia and then humerus (Figs. 2 and 3).

Radiographically these lesions appear either pedunculated with a stalk or sessile with broad cortical attachment. There is characteristic medullary and cortical continuity seen in both types of lesions. The appearance of the cartilaginous cap is variable but can have rings of calcifications seen with other chondroid lesions. Radiographically, mineralization or ossification of the cap can be seen with skeletal maturation (Fig. 4). The thickness of the cap is typically measured by MRI and can vary widely in thickness based on skeletal maturation.

Excision of the osteochondroma is typically definitive, although recurrence has been reported in 2% of excised lesions.

Hereditary Multiple Exostoses (HME)

HME is one of the most common skeletal dysplasias in children and, as the name implies, is an inherited disorder transmitted as an autosomal dominant trait. Males are affected more frequently than females due to incomplete penetrance in females. The overall incidence is approximately nine per million.

Patients with HME are typically identified during the first decade of life. Patients most commonly present with a palpable mass or deformity from angulation of an extremity. Short stature is seen in 40% of patients, although most patients still fall within two standard deviations of the mean. The short stature is thought to result from bowing and angulation deformity as well as the development of exostoses during peak growth periods of childhood and puberty.

The osteochondromas of HME differ from the patients with solitary osteochondromas in that 90% of the lesions are of the sessile type (Fig. 5). Lesions in patients with HME have been described in almost every bone in the body excluding the calvarium. The most common location is about the knee (distal femur and proximal tibia). In fact, it is so com-
Figure 1  Osteochondroma of proximal tibia with mass affect on the fibula.

Figure 2  Sessile osteochondroma of the distal femur.

Figure 3  MR imaging of osteochondroma of the distal femur with mass affect on muscle.

Figure 4  Ossification of cartilaginous cap of a pedunculated osteochondroma of the proximal tibia.
mon around the knee that another diagnosis should be considered if the bones about the knee are completely normal. Other common locations include humerus, elbow, wrist, hip, ankle, ribs, hands, feet, and scapula. Vertebral involvement is rare but can occur and has been described arising from the posterior elements and from the vertebral body itself. The distribution of lesions can be bilateral and almost perfectly symmetric or unilateral and very asymmetric (Fig. 6). The difference in distribution patterns may be attributed to different genetic types of HME.

Radiographically the evaluation of the patient with HME centers on deformity and possible complications. Deformation is most commonly manifested as bowing of the bones. Coxa valga is seen in the proximal femurs, which can lead to uncovering of the femoral heads. The forearm is frequently bowed with ulnar deviation and shortening of the ulna (Fig. 7). Growth disturbance of the distal radius and ulna can also result in a Madelung deformity of the wrist (Fig. 8). In addition to bowing of the leg, synostosis of the bones may occur when large osteochondromas grow together. This is typically seen in the distal tibia and fibula but can occur in other parts of the body (Fig. 9). Progressive erosion of an adjacent bone can be seen especially in the forearm and leg where long bones are juxtaposed (Fig. 10).
Complications seen with both solitary osteochondromas and HME include fracture, vascular injury, bursa formation, neurologic compromise, and malignant transformation. The most worrisome of these complications is malignant transformation. For solitary osteochondromas, malignant transformation occurs in less than 1% of cases. In HME, the frequency is higher. Studies have shown a prevalence of malignancy ranging from 2 to 25%. The most recent studies seem to favor a prevalence of around 3 to 5%.

Radiographic manifestations include increasing size of an exostosis after puberty, lucencies or indistinctness developing within the exostosis, destruction of cortical bone, and soft-tissue mass. Cross-sectional imaging is useful in the evaluation of the cartilaginous cap. Generally, a cartilaginous cap thicker than 1.5 to 2 cm in a skeletally mature patient should be considered worrisome for possible malignant degeneration. In children, the cartilaginous cap can be thicker, sometimes normally reaching a thickness of up to 3 to 5 cm.

Trevor’s Disease

Trevor’s disease or dysplasia epiphysealis hemimelica is another process where exostosis of the bone is seen in children. No inheritance pattern has been established. In Trevor’s disease, there is cartilaginous outgrowth typically involving tarsal bones or epiphyses of long bones. Histologically, the exostoses are identical to osteochondromas with a cap of hyaline cartilage and endochondral ossification. The distal femur, distal tibia, and talus are most frequently involved. The process is typically unilateral; however, there are several case reports of bilateral disease. Multiple bones of the same extremity are commonly involved and the lesions occur along the medial epiphysis more often than the lateral.

Radiographically, small ossifications are seen along the medial or lateral aspect of a developing epiphysis or tarsal bone. The small ossifications eventually become confluent with the epiphysis, forming an asymmetric mass. Deformation and angulation do not commonly occur; however, when present, they can be severe and debilitating. Because the lesions occur in the epiphysis, arthrography can be used to define the extent of the lesion. Arthrography is also useful to distinguish exostosis from loose bodies seen in synovial osteochondromatosis.

Posttraumatic Exostosis

In children and adolescents partial or complete avulsion fractures commonly occur due to the inherent weakness of the apophyses compared with the tendons. Avulsion injuries at the musculotendinous junction continue to occur until patients reach their mid-twenties. The healing process of such injuries may leave a prominent exostosis of the bone, which should not be mistaken for an osteochondroma or any other neoplastic or infectious process. Entities such as Osgood–Schlatter and Sinding-Larsen-Johansson, which have been mistakenly attributed to posttraumatic conditions, are not true exostoses.

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to osteonecrosis, now are considered to be part of this spectrum of partial avulsive injury to the apophysis. The resulting exostosis from a patient with chronic Osgood–Schlatter disease can be dramatic (Fig. 15).

Myositis ossificans from trauma is a well-established cause of soft-tissue calcifications. When the injury is deep, the periosteum of the bone can be involved and ossification can attach to the bone. The result of this process can be mistaken for an osteochondroma (Fig. 16). Synostosis can even be seen when myositis ossificans occurs between bones that are closely apposed. This can look similar to

Figure 9 Synostosis of exostoses of the distal fibula and tibia.

Figure 10 A large osteochondroma of the proximal fibula causing erosion of the lateral tibial metaphysis.

Figure 11 MR imaging of a thick cartilaginous cap in an adolescent.
patients with HME where two large osteochondromas fuse together. Subungual exostosis is an uncommon lesion that can appear very similar to an osteochondroma. The exostosis occurs at a nail bed of a digit of the hand or foot. The great toe is most commonly affected. The lesion is thought to be due to trauma with a reaction similar to myositis ossificans. Histologically they consist of trabecular bone with a cap of fibrocartilage. Radiographically they appear as a lobulated bony protuberance emanating from the nail bed.

Turret exostosis is another type of posttraumatic exostosis specific to the proximal or middle phalanx of the hand. Radiographically the lesion appears to develop from disruption of the periosteum with formation of a subperiosteal hematoma. Radiographs demonstrate a broad-based bony exostosis, which may often be separated from the rest of the phalanx by a lucent line (Fig. 17).

Bizarre parosteal osteochondromatous proliferation (BPOP) is a rare, benign lesion that was first described by Nora and coworkers in 1983 in the hands and feet of young patients with HME where two large osteochondromas fuse together.

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adults. The lesion is characterized by heterotopic bone rising from otherwise normal cortex, typically without evidence of periosteal change or medullary contiguity (Fig. 18). BPOP is believed to be the result of minor blunt trauma to the affected area.34

Normal Variants and Congenital Anomalies Mistaken for Osteochondromas

The supracondylar process of the humerus may be easily mistaken for an osteochondroma. It is simply an outgrowth of bone that occurs along the anteromedial surface of the distal humerus and is typically oriented toward the joint, whereas pedunculated osteochondromas are oriented away from the joint (Fig. 19). A persistent portion of the coraco-brachialis muscle may insert on the process. It can also serve as an anomalous origin of the pronator teres muscle. Patients with this anomaly may develop symptoms from compression of the median nerve by the ligament of Struthers, which originates from the supracondylar process and inserts to the medial epicondyle.35 Other similar bony processes occur throughout the body such as the os intermetatarsale, which occurs between the first and second metatarsals, and the trochlear process of the calcaneus, which can be very prominent.

Congenital anomalies can produce osteochondroma-like lesions. In patients with diastematomyelia a bone spur can form within the central canal (Figs. 20 to 22). This can be differentiated from an osteochondroma by the presence of a tethered cord with the cord split into two halves at the level of the bony spur. This is best depicted on MR imaging.

Innumerable normal variations and normal appearances of bone exist in children that can have an appearance similar to osteochondromas. The oblique view of the first metatarsal in young children has a prominent exostosis-like process distally, which is normal (Fig. 23). Another common finding in children is spurring around the growth plate that occurs with partial or incomplete closure along
the periphery of the physis. These epiphyseal and metaphyseal spurs should not be mistaken for exostosis of the bone or fractures (Fig. 24). Anomalies of the digits have a wide variety of appearances with duplications, supernumerary, and bifid digits as well as other various types of polydactyly (Fig. 25).

Systemic Disorders

Systemic disorders such as pseudohypoparathyroidism, pseudopseudohypoparathyroidism, tumoral calcinosis, and myositis ossificans progressiva can have osteochondroma-like lesions and can be difficult to differentiate from hereditary multiple exostoses. In particular, myositis ossificans progressiva, a rare progressive familial disease, can have an appearance strikingly similar to HME because of the diffuse ossification of ligamentous insertions resulting in metaphyseal exostoses. Fortunately, these systemic disorders with soft-tissue ossification and osteochondroma-like lesions often have characteristic findings of the hands and other laboratory data to differentiate them from HME.

Periosteal Reaction

There are many causes of periosteal reaction that can cause bone formation and exostosis that can appear similar to osteochondromas. Potential etiologies include a parosteal osteosarcoma, osteoid osteoma, and osteomyelitis. Parosteal osteosarcoma with its typical sessile attachment to the external cortex can radiographically mimic an osteochondroma. Patients with a parosteal osteosarcoma (Fig. 26) are usually...
older and present with a painful mass. Also, in contrast to osteochondromas, parosteal osteosarcomas arise from the cortex of the bone and do not commonly involve the medullary cavity.\textsuperscript{38} Even so, definitive differentiation is usually a combination of imaging and clinical and histological evaluation.\textsuperscript{39}

In summary, exostosis of the bone is a common finding in children. Despite the many normal variants, posttraumatic lesions, systemic disorders, and various causes of periosteal reaction that can mimic osteochondromas, the diagnosis of a solitary osteochondroma and HME is often established without advanced imaging because of their characteristic conventional radiographic appearance.
Figure 23  Oblique view of the foot shows a prominent exostosis-like process distally in the first metatarsal.

Figure 24  Normal variant epiphyseal spurs of the distal radius in an adolescent.

Figure 25  Bifid distal phalanx.

Figure 26  Parosteal osteosarcoma of the distal femur.
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