MRI of Pediatric Foot and Ankle Conditions

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KEYWORDS

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KEY POINTS

- Skeletal maturation is a dynamic process, and although it is somewhat predictable, it also has several variable particularities that can be easily misinterpreted as diseases on imaging, especially on MRI fluid-sensitive sequences.
- On MRI, cartilage shows high signal intensity on fluid-sensitive sequences, so its bright appearance may draw the reader's attention erroneously to fractures, apophysitis and other mechanical overload situations, besides tumors, osteonecrosis, and inflammatory pathologic conditions, among other conditions.
- Normal primary ossification centers of the foot and ankle in children can have heterogeneous marrow signal intensity, with multiple foci of high signal intensity on fluid-sensitive sequences, known as a starry sky appearance, especially in tarsal bones. It was hypothesized that this might represent small islands of residual red marrow, areas of increased vascularity, or normal developmental stress caused by regular weight-bearing and weight gain. This pattern rarely persists in adults and usually disappears by the age of 15 years.
- The foot apophysis has single or multiple secondary ossification centers (SOCs) that may show multiple/fragmented aspects, high signal intensity on T2 fat-saturated weighted imaging/short tau inversion recovery, a sclerotic appearance (either on radiographs or other imaging examinations) and irregular margins that are consistent with normal development changes and should not be mistaken for disease. In the calcaneus and medial malleolus apophyses, these characteristics might be even more prominent. Extension of the edema outside of the SOCs to the bone marrow, and soft tissues of course, when associated with an appropriate clinical picture, favors the presence of pathologic conditions, such as mechanical overload, osteochondrosis, or fractures.

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INTRODUCTION

Increasing participation and intensity of training in organized sports among the pediatric population, associated with the higher availability, lower costs, and lack of ionizing radiation, has increased the demand for MRI in children and adolescents. On MRI, cartilage shows high signal intensity on fluid-sensitive sequences—T2 fat-saturated weighted imaging (T2FS) and short tau inversion recovery (STIR)—so its bright appearance may draw the reader's attention erroneously to fractures, apophysitis and other mechanical overload situations, besides tumors, osteonecrosis, and inflammatory pathologic conditions, among other conditions. The foot and ankle have several bones with abundant radiolucent and high signal intensity growth cartilages that gradually ossify and may create undulating or irregular margins, making the interpretation of the images even more problematic. Moreover, the immature skeleton has red marrow and hypervascularized areas in metaphyseal equivalents that also have a bright appearance on T2FS/STIR. The MR imaging appearance of the pediatric foot and ankle reflects the dynamic process of skeletal growth and maturation.[1–3]

In this article, the authors will review MRI aspects of medullar conversion, endochondral and intramembranous ossification, physis, apophysis and periosteum characteristics and anatomic variations, as well as traumatic and atraumatic disease presentations, highlighting how to differentiate them on imaging examinations, especially MRI.

BONE FORMATION

Bone formation occurs by intramembranous and endochondral ossification. Endochondral ossification is the dominant process in the skeleton and occurs in the extremities, as well as in several other parts of the body. It uses a preexisting cartilage model that is gradually replaced by bone.[4] Longitudinal (in long bones) and centrifugal (in tarsal bones) growth occurs by endochondral ossification, whereas an increase in diameter occurs by intramembranous deposition from the surrounding periosteum in long bones.[5]

The primary ossification center is located in the center of the bone and forms the future diaphysis and tarsal bones, whereas the secondary ossification centers (SOCs) are located at the ends of the bone and form the epiphysis and apophysis.[2]

Cartilaginous precursors develop in utero and form blueprints for both primary and SOCs about the ankle and foot.[1] Some ossification centers are partially ossified before birth, such as the primary ossification centers of the talus and calcaneus. However, other ossification centers are not ossified, and they are called nonossified precursors at this stage. Nonossified precursors are radiolucent on radiographs; however, they are well visualized on MRI, and how they are constituted by cartilage shows high signal intensity on T2/STIR images.[6]

Preossification centers develop within cartilaginous precursors and bring about SOCs. They represent local biochemical alterations in the hyaline cartilage matrix, which allow osteoblastic activity. They are visible on MRI, mostly in the medial malleolus, calcaneal apophysis, and navicular cartilaginous precursors. Later, they convert into ossification centers and disappear on MRI.[1] The age of the radiographic appearance and fusion of the primary and SOCs are shown in **Fig. 1**.

RED TO YELLOW MARROW CONVERSION

Early in development, the ossification centers are rich in red marrow, which has low T1 and intermediate/high signal intensity on T2/STIR, and enhancement after gadolinium
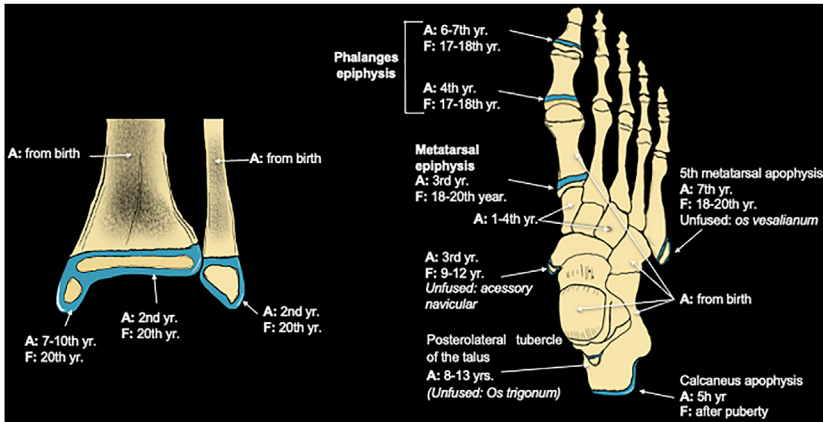
Fig. 1. The important primary and SOCs of the foot and ankle. Some unfused SOCs in the mature skeleton are accessory ossicles. A, age of radiographic appearance; F, age of radiographic fusion.

injection on MRI. Afterward, it will show fat marrow signal intensity, similar to adults, that is, high T1 and low T2/STIR signal intensity, without enhancement in postcontrast sequences. Bone marrow in newborns is composed mostly of hematopoietic marrow. Its conversion to fat marrow starts shortly after birth[7] or even before birth in the toes.[8] Conversion of the tarsal and metatarsal bones also initiates very early and is complete in 7-year-old children in the talus and calcaneus, for example.[9] However, even after this age, on MRI, normal primary ossification centers can have heterogeneous marrow signal intensity, with multiple foci of high signal intensity on fluid-sensitive sequences, known as a starry sky appearance (**Fig. 2**). It was hypothesized that this might represent small islands of residual red marrow, areas of increased vascularity, or normal
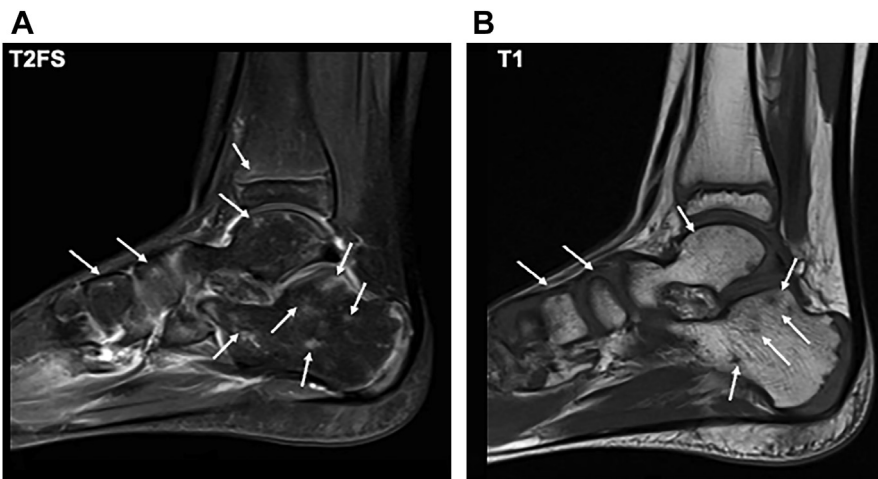

Fig. 2. Diffuse starry sky—normal bone marrow signal in a 7-year-old male ankle, characterized by focal areas of hypersignal intensity on T2FS (*A*) and low signal intensity on T1 (*B*) in the bone marrow of the talus, calcaneus, tibia, and tarsal bones (*arrows*).

developmental stress caused by regular weight-bearing and weight gain.[7] This pattern rarely persists in adults[1] and normally disappears by the age of 15 years.[7]

The most common locations for high signal intensity on T2/STIR of the bone marrow in healthy children are the talar dome, head and posterior tubercle, posterior calcaneus, and navicular bone.[7] These bones are developmentally similar to the pelvis, where similar islands of red marrow have been previously described.[10] Moreover, most of these foci of high signal are endosteal, which is similar to the residual red marrow seen in long bones, thus supporting that these findings can be consistent with the remaining red marrow.[7]

PHYSIS, ACROPHYSIS, AND APOPHYSIS

The tibial, fibula, metatarsal, and phalangeal primary physes are highly organized cartilaginous structures responsible for linear growth of the ankle and foot, whereas in the tarsal bones, peripheral secondary physis (acrophysis) is responsible for centrifugal growth. The physis is organized into 3 layers from the epiphysis to the metaphysis: the germinal, proliferative, and hypertrophic zones. The hypertrophic zone can be further subdivided into zones of maturation and degeneration and the zone of provisional calcification. In the adjacent metaphyseal side is the primary spongiosa, a highly vascularized structure in which osteoclasts and osteoblasts replace the calcified cartilage matrix to produce new bone. The cartilage layers of the physis, the zone of provisional calcification, and the primary spongiosa produce a characteristic trilaminar appearance on T2FS MRI.[1–3]

In toddlers, the physis has a regular, flat, and wide aspect. During weight-bearing and gait, it develops irregular, wavy, and thinner characteristics, with more conspicuous 3 layers on MRI; however, it always maintains a uniform physiologic thickness. Later, in adolescence, it will finally narrow and close. Usually, the physis fuses from the center to the periphery. However, the distal tibial physis has a more undulating pattern with a focal anteromedial upward deviation called Kump's bump or Poland's hump.[11] This represents the site of initial physiologic physeal closure, which is completed in girls from 12 to 15 years and boys from 15 to 18 years. A similar physeal undulation is commonly depicted at the anterolateral physis of the distal fibula.[1,3]

The apophysis develops from a single or multiple SOCs. Due to their high cartilage and red marrow content, they can show high signal intensity on MRI fluid-sensitive sequences. Similar to the epiphysis, the apophysis will also develop a physiologic wavy appearance.

PERIOSTEUM

The periosteum covers most bone structures, with the exception of their intra-articular surfaces and the carpal, tarsal, and sesamoid bones. In children, it is a loose structure with a well-defined outer fibrous layer and an inner cambial layer that is highly cellular and exhibits osteoblastic potential. Underneath its layers, there is the cortex, and together, they show a characteristic trilaminar aspect on MRI.

The inner layer is at its thickest in the fetus, and it becomes progressively thinner with age. In the adult, it becomes so thin that its inner and outer layers cannot be distinguished from themselves or from the cortex. The periosteum is a dynamic structure that plays a major role in bone modeling and remodeling under normal conditions (intramembranous ossification), and in different disorders, such as infections, tumors, hematomas, and systemic diseases, the osteogenic potential of the periosteum is stimulated, and new bone is produced.[5,12]

The perichondrium lies at the junction of the physis and the periosteum, surrounding the main physeal cartilage. The perichondrium is tightly fixed to the underlying physis, preventing its separation and acting as a barrier to the spread of subperiosteal hematomas, abscesses, and tumors to the epiphysis.[13]

ANATOMIC VARIANTS

There are several anatomic variations of the foot and ankle related to different bone morphologies, accessory ossification centers, nonfusion of ossification centers, sesamoid bones, and accessory muscles, among others, that go beyond the scope of this review. Thus, we will highlight just some examples that can cause some confusion during daily routine.

The foot apophysis has single or multiple SOCs that may show multiple/fragmented aspects, high signal intensity on T2FS/STIR, a sclerotic appearance (either on radiographs or other imaging examinations) and irregular margins that are consistent with normal development changes and should not be mistaken for disease. In the calcaneus and medial malleolus apophyses, these characteristics might be even more prominent (**Figs. 3** and **4**). Extension of the edema outside of the SOCs to the bone marrow (see **Fig. 3**), and soft tissues (see **Fig. 4**), of course, when associated with an appropriate clinical picture, favors the presence of pathologic conditions, such as mechanical overload, osteochondrosis or fractures.

Other SOCs may also suffer from mechanical overload or osteochondrosis, such as the navicular and fifth metatarsal tuberosities (see **Fig. 4**; **Fig. 5**) and the lateral tubercle of the posterior process of the talus (**Fig. 6**). The cleft epiphysis of the proximal phalanx of the hallux is an anatomic variant that might be misdiagnosed as a fracture.

Focal periphyseal edema (FOPE) zones are areas of periphyseal edema seen near the time of physeal closure that are thought to be a physiologic phenomenon related to changes in the distribution of forces around the physis as it closes, most often around the knee but they have also been described in other sites. They have also been reported to be a cause of nontraumatic pain; however, other conditions must first be excluded before attributing symptoms to FOPE.[14,15] It manifests with focal bone marrow edema centered at an open but narrow physis that extends into the metaphysis and sometimes involves the epiphysis. Periphyseal edema greater than 3 cm and/or a nonuniform physeal width should raise a suspicion about other pathologic processes.[1,2]
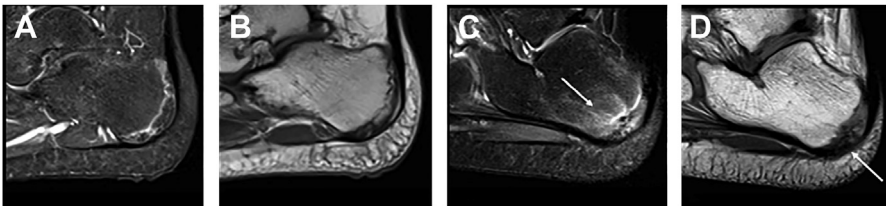

Fig. 3. Normal apophysis versus apophysitis (Sever)—normal calcaneous apophysis in a 13-year-old boy (*A*, *B*), with a fragmented aspect that is normal during developmental ossification identified on T2WFS (*A*) and T1 (*B*) MR images. Another apophysis in a 10-year-old boy with hindfoot pain (*C*, *D*), showing mild sclerosis accompanied by bone marrow edema (*arrows*) that extends to the adjacent calcaneus tuberosity, on T2WFS (*C*) and T1 (*D*) MR images signs that support the diagnosis of apophysitis in this clinical scenario.
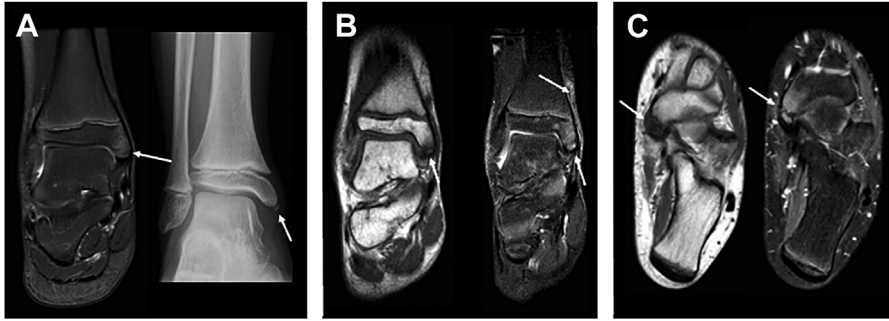
Fig. 4. SOCs: normal x overload. (*A*) Normal aspect of the secondary ossifying center of the medial malleolus in a coronal T2WFS MR image and frontal digital radiography of an 8-year-old boy (*arrows*). (*B*) A 7-year-old girl with medial ankle pain presenting with bone marrow (*lower arrows*) and overlying soft tissue edema that extends to the subcutaneous planes (*upper arrow*), suggestive of mechanical apophysitis. (*C*) MR images of a 9-year-old girl's foot depicting bone marrow edema at the SOC and at the navicular bone (*arrow*) (apophysitis).

PHYSEAL OR PERIPHYSEAL INJURIES
Traumatic or Microtraumatic

Growth plates are weaker than ankle ligaments and are vulnerable to shear and rotational forces. Therefore, injury mechanisms that may result in ankle sprains in adults can manifest as physeal or avulsion fractures in children, although ligament injuries in children are more common than previously thought.[16–18]

The incidence of ankle sprains has been estimated at 2.1 per 1000 person-years in the United States, and the peak incidence of ankle sprain occurs between 15 and 19 years of age. Half of all ankle sprains occur during sports activity, with lateral ankle sprain and syndesmotic sprain being the most common ankle and foot injuries in collegiate football players, occurring in 31% and 15% of players, respectively.[19] The

Fig. 5. Fifth metatarsal apophysis differential diagnoses. (*A*) MRI showing normal apophysis of the fifth metatarsal in a 12-year-old boy, lying laterally and longitudinally oriented (*arrows*). (*B*) MRI of the foot of a 13-year-old female gymnast with recurrent lateral pain, showing signs of apophysitis with bone marrow edema on the apophysis and adjacent proximal metaphysis of the fifth metatarsal (*arrows*). (*C*) MRI showing the transverse fracture line in a 6-year-old boy after a sports injury (*arrows*).
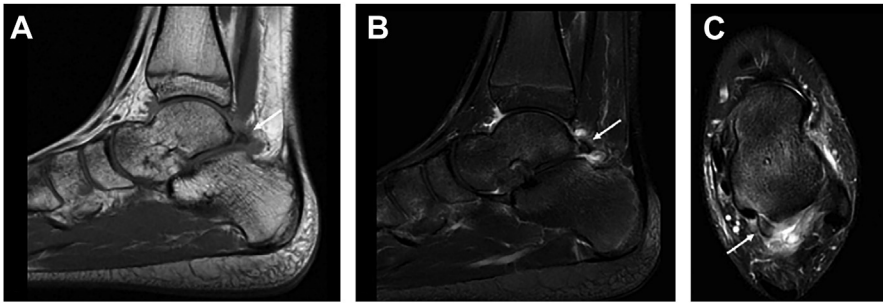
Fig. 6. Posterior impingement of the ankle. T1W (*A*) and T2W fat saturation (*B, C*) MR images of a 13-year-old boy depicting bone marrow edema on a nonfused SOC of the lateral tuberosity of the posterior process of the talus, with small articular effusion, reactional synovitis and Kager fat pad edema (*arrows*).

lateral ankle ligaments are most commonly injured, and they comprise the anterior talofibular ligament (ATFL), posterior talofibular ligament (PTFL), and calcaneofibular ligament (CFL).

Growth plate injury usually occurs near physeal maturity, that is, approximately between 12 and 15 year old. Of all physeal injuries, fractures of the distal tibial physis have among the highest rates of complications. Salter-Harris is the most common anatomic classification system for fractures involving unfused growth plates. It also has valuable prognostic significance. Complications are uncommon with types I and II. However, fractures that cross the physis into the epiphysis (Salter Harris III and IV types) may damage the germinative layer and thus are at a higher risk of causing physeal bars, growth arrest, angular deformities, articular incongruity, and precocious osteoarthritis.[16–18] On MRI, it is possible to visualize nondisplaced radiographically occult Salter-Harris I fractures, with physeal thickening, irregularities, and higher signal intensity on T2/STIR images. Comparison with other physis may be helpful in differentiating normal physis with high signal intensity from fracture. Of course, other types of Salter-Harris fractures that extend to the bone are also well defined on MRI. Other imaging findings might be associated with Salter-Harris acute fractures, such as osteochondral lesions (OCLs), periosteum displacement, subperiosteal hematoma, and periosteal entrapment, within the physis (**Fig. 7**). Avulsion of the superior extensor retinaculum of the ankle and subperiosteal hematoma of the distal fibula in children, although well described on ultrasound,[20] is not an uncommon finding on MRI after ankle sprain. A single traumatic event can cause one or multiple focal physeal widening, with a cartilaginous high signal extending from the physis into the adjacent metaphysis, showing a tongue-like morphology that is greater in its longitudinal dimension than in its width. These findings may be associated with growth disturbances and growth recovery lines.[21]

Chronic physeal stress injuries may affect the feet of young athletes, although more classically described in the wrist (gymnast wrist) and in the shoulder (little leaguer shoulder). It seems as a focal T2 hyperintense widening of the physis on MR, usually associated with bone marrow edema.[22]

Fatigue fractures or stress reactions are not uncommon in the pediatric athletic population and can be found in virtually any bone; however, the most common locations are the second and third metatarsals (**Fig. 8**), calcaneus (see **Fig. 8**) and distal tibia.[23,24] In stress reactions, there is a periosteal reaction and subcortical bone
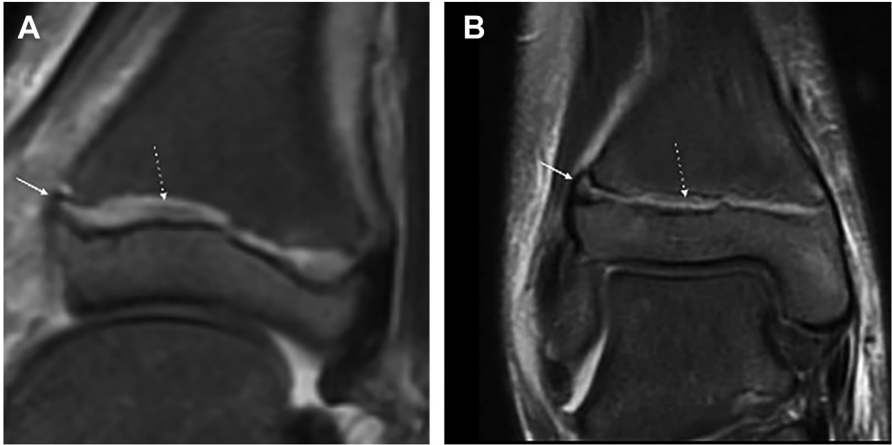
Fig. 7. Salter-Harris I fracture and periosteal entrapment. Sagittal (*A*) and coronal (*B*) T2FS MRI of the ankle of a 10-year-old boy after an ankle sprain. Note the enlargement and loss of the trilaminar pattern of the distal physis of the tibia, compatible with Salter-Harris type I fracture (*dotted arrow*). There is also periosteal interposition on the anterolateral epiphyseal plate (*arrow*).

marrow edema. In stress fractures, a fracture line is visible, usually incomplete and perpendicular to the bony trabeculae or sometimes longitudinal in the cortex of the long bones. Subchondral stress fractures are rare in children but are frequently observed in the elderly (insufficiency fractures).[23,24]

Inflammatory or Infectious

Foot and ankle pathologic conditions are common in juvenile idiopathic arthritis (JIA) and include joint disease, tenosynovitis, muscle atrophy, enthesitis, digital deformities, and biomechanical abnormalities. In a previous study surveying foot problems
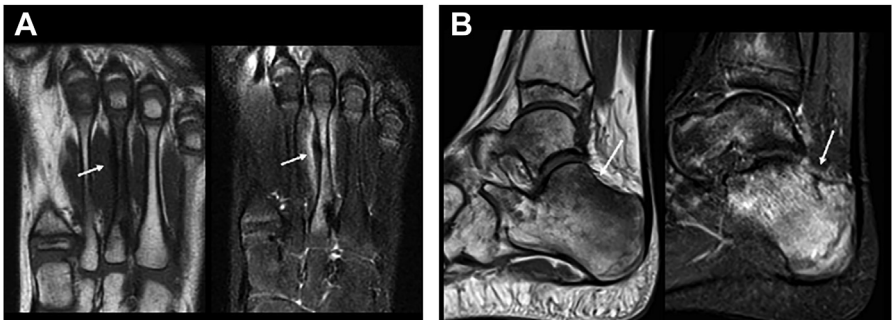

Fig. 8. Stress fractures. (*A*) MRI of the forefoot of a 6-year-old girl with intensive ballet practice and recurrent forefoot pain, without trauma history, showing bone marrow edema, periosteal reaction and a small transverse fracture line on the third metatarsal (*arrow*), compatible with a stress fracture. (*B*) MRI of the ankle of a 14-year-old boy with hindfoot pain related to soccer practice, showing a line of incomplete fracture involving cortical and medullary bone on the dorsal surface of the calcaneus, perpendicular to the trabecular bone, suggestive of a stress fracture.

in children with JIA, 63% reported some degree of foot-related impairment, and 60% reported foot-related participation restriction.[25]

Joint disease in JIA may include joint swelling, tenderness, pain, warmth, and stiffness. These symptoms typically occur because of synovitis (Fig. 9). Tenosynovitis (see Fig. 9) in JIA commonly affects the tibialis posterior and peroneal tendons, and muscle atrophy—plantar-flexor muscle atrophy may be observed in children with JIA.[26] Enthesitis is common at the Achilles tendon, and the medial tubercle of the calcaneus is typically seen in male patients with the enthesitis-related subtype of JIA.[27]

Chronic nonbacterial osteomyelitis (CNO), also known as chronic recurrent multifocal osteomyelitis (CRMO) (Fig. 10), is a noninfectious, autoinflammatory, and rare disorder that occurs primarily in children and adolescents (peak of incidence between 7 and 12 years) and is characterized by episodic skeletal pain with a protracted course.[28] Although consistent epidemiologic data are lacking, recent studies suggest that CNO is more common than previously thought[29] and may be one of the most prevalent autoinflammatory diseases.[30]

The most common sites of disease are the metaphyses or metaphyseal equivalents, especially in the lower extremities. The tibia has been reported as the most common bone involved. Typical lesions occur adjacent to the physis, are lytic and geographic on radiographs with bone marrow edema on MRI in the early stages and might be associated with periosteal reaction. They also may show a mirror-like appearance involving the epiphysis. Chronic lesions become sclerotic, with low signal intensity in all MRI sequences.[31]

Whole-body MRI (WBMRI) is a useful diagnostic approach. If the child has a good general condition, mild or absent fever, white blood cell count and inflammatory markers are normal or mildly changed, with most patients being healthy between recurrent episodes, and WBMRI shows multifocal typical lesions throughout the skeleton, both symptomatic and asymptomatic, a diagnosis of CRMO can be considered (see Fig. 10).[32] Abscess formation, fistulas, and/or sequestra must be excluded. However, traditionally, CNO is a diagnosis of exclusion, and biopsy can be required to exclude tumors or pyogenic osteomyelitis, showing sterile osteitis, especially in doubtful cases.[33]

However, in pyogenic osteomyelitis, symptoms are usually acute and more dramatic, and most of the cases are unifocal. MRI findings (Fig. 11) are present early in disease onset, unlike radiographs, in which at least 1 or 2 weeks are required to see bone destruction or periosteal reaction. MRI early findings are metaphyseal
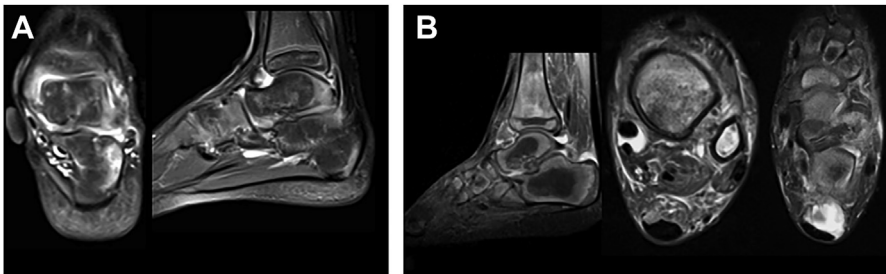

Fig. 9. Juvenile idiopathic arthritis. Ankle MR images of a 3-year-old girl (*A*) and an 8-year-old boy (*B*) with ankle pain, showing tibiotalar and subtalar joint effusion, marked tenosynovitis and retrocalcaneal bursitis (*arrows*). The findings and clinical correlation were compatible with oligoarticular juvenile idiopathic arthritis.
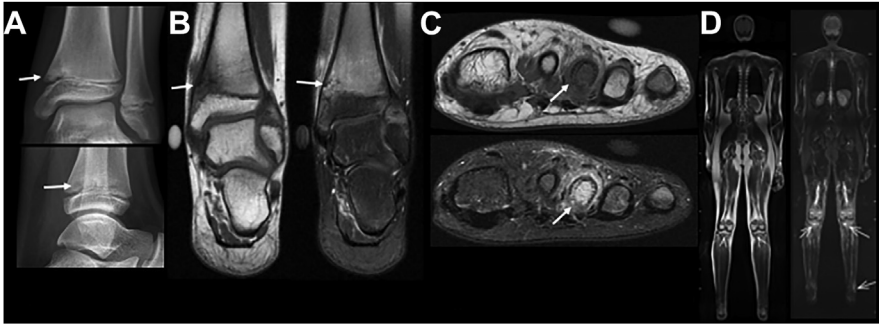
Fig. 10. Chronic nonbacterial osteomyelitis. A 13-year-old girl with fever, pain, and swelling of the left ankle for 10 days. Radiographs (*A*) showing discrete hypodense foci and bone irregularities on the medial side of the distal tibial metaphysis (*arrows*), with bone marrow edema on T1 and T2FS MRI images (*arrows*) (*B*). Biopsy and bacterial culture did not isolate any pathogens. After 1 year, bilateral midfoot pain presented with similar MRI findings on the metatarsals (*arrows*) (*C*). Due to the clinical hypothesis, the patient was submitted to WBMRI (*D*) that showed other bone alteration sites, some of them asymptomatic, which contributed to the diagnosis of chronic nonbacterial osteomyelitis.

heterogeneous bone marrow edema of ill-defined limits adjacent to the growth plates, with characteristic very low signal intensity on T1 (related to substitution of the bone marrow), associated with periosteal reaction and soft tissue edema. In the subacute phase, Brodie's intraosseous abscess with the penumbra sign is classically present (see **Fig. 11**), either associated or not associated with fistulae, soft tissue, or subperiosteal abscess. Sequestrum, involucrum, and cloaca are classic chronic osteomyelitis findings that can be assessed by radiographs, CT scans, or MRI.[34]

Fixed Flatfoot Deformity

There are a few causes of fixed flatfoot deformities in children, such as congenital vertical talus and the most common tarsal coalitions, especially calcaneonavicular and talocalcaneal, which are usually easily diagnosed on radiographs. However, in difficult
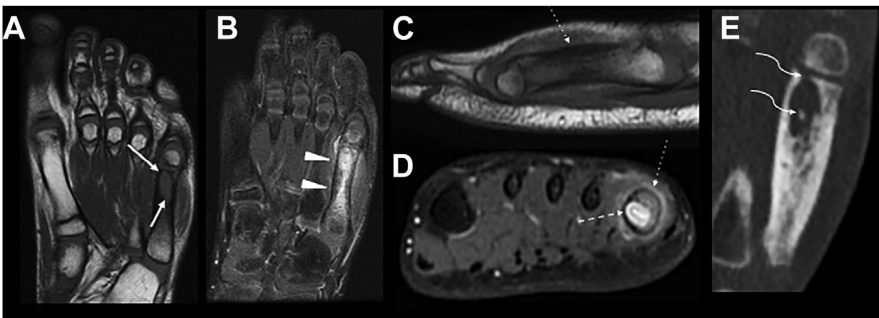

Fig. 11. Bacterial osteomyelitis. A 7-year-old girl presenting with pain and swelling of the forefoot. MR images (axial T1 (*A*), axial T2FS (*B*), sagittal T1 (*C*), and coronal T1FS after gadolinium injection (*D*)) showing bone marrow edema (*arrowheads*) and intraosseous abscess with the penumbra sign (*arrows*) on the distal metaphysis of the fifth metatarsal, with a solid corticoperiosteal reaction (*dotted arrows*) and enhancement (*dashed arrows*). CT scan (*E*) showing a bony sequestrum and extension to the distal physis (*curved arrows*).

or atypical cases, cross-sectional studies can be helpful[35] such as in extra-articular posteromedial talocalcaneal coalition[36] (**Fig. 12**) or the accessory anterolateral talar facet.[37]

Moreover, there are also other types of tarsal coalitions, such as widespread coalition, and between the third metatarsal and the lateral cuneiform joint (see **Fig. 12**).[38]

Osteochondritis Dissecans of the Talar Dome

OCL is an umbrella term for focal injury of the articular cartilage and underlying bone, and it does not imply cause or age of injury (either acute or chronic).[39] However, OCL in clinical practice is used as a synonym for traumatic osteochondral fracture. However, osteochondritis dissecans (OCD) is a chronic and idiopathic type of OCL with a risk for instability and disruption of adjacent articular cartilage that may result in premature osteoarthritis.[40] The cause is unclear; there are probably multiple contributing factors, such as genetic, vascular, or (micro)traumatic, leading to deficiency in subchondral bone formation and subsequent chondral lesions, which may result in an unstable subchondral fragment. OCD is frequently related to repetitive athletic stress (**Fig. 13**); therefore, microtraumatic stress is the favored cause. OCD can be further subdivided into juvenile (children and young adolescents who have open growth plates) or adult (older adolescents and young adults after the growth plates have closed) forms. The adult form of OCD is an incompletely healed juvenile OCD.[39]

Bone Tumors of the Foot

A comprehensive review of bone tumors is not the aim of this review; however, a few bone tumors might be confused with stress reaction/fracture, inflammatory or infectious diseases, such as osteoid osteoma (OO), chondroblastoma, and Ewing sarcoma (ES), although uncommon in the foot and ankle.

Osteoid Osteoma

Some OO cases, when in atypical locations, such as the foot, may present unusual clinical and imaging findings that can lead to misdiagnosis. Medullary OO is the most common type that occurs in tarsal bones and is usually accompanied by less
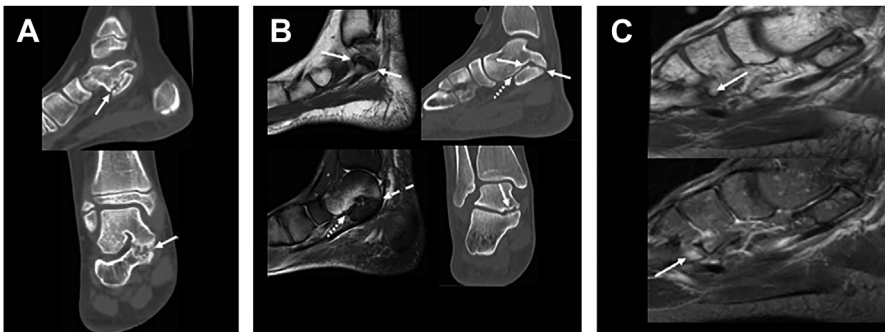

Fig. 12. Tarsal coalition. (*A*) Ankle CT of a 9-year-old girl showing fibrocartilaginous talocalcaneal coalition at the middle subtalar joint, with irregularity of the apposed bone surfaces and subcortical cysts. (*B*) Ankle MRI and CT of an 18-year-old boy after an ankle sprain showing fibrocartilaginous extra-articular posteromedial coalition (*arrow*). Note the middle (*dotted arrow*) and posterior (*dashed arrows*) subtalar joints with the usual bone and chondral morphology. The areas of marrow edema have a contusional etiology. (*C*) Foot MRI of a 12-year-old boy showing partial plantar fibrocartilaginous coalition between the lateral cuneiform and the base of the third metatarsal, also with mechanical overload edema.
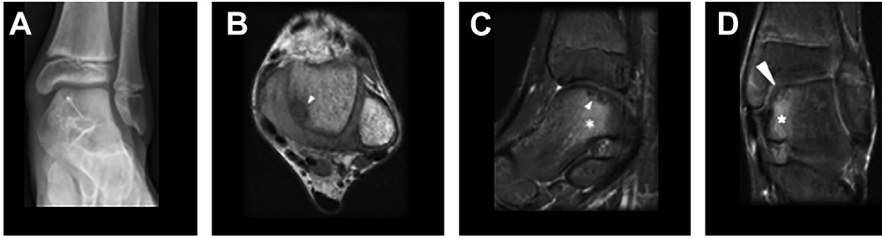
Fig. 13. Osteochondritis dissecans. An 8-year-old boy with deep ankle pain for 2 years, which worsened after physical activities. (*A*) CR mortise shows mild irregularity of the bone plate at the medial segment of the talar dome (*arrow* in A). (*B–D*): MRI showing osteochondritis dissecans at the posterior medial shoulder of the talus, with mild impaction of the subchondral bone plate (*arrowheads*), and adjacent bone marrow edema (*asterisk*).

cortical thickening than typical OO and it may induce bone expansion. Because the bones of the hands and feet are small and close to each other, it may be difficult to locate the cause of inflammation, which may spread to adjacent bones, joints, and soft tissues. Additionally, there may be prominent soft tissue swelling, resembling infection, or inflammatory arthritis. When OO is located in the distal phalanx, it may also cause nail deformities, which are also confounding factors. In addition, the clinical presentation may be unusual, with atypical pain or even the absence of pain.[41,42]

CHONDROBLASTOMA

Chondroblastoma is a benign cartilage tumor developing in the epiphysis or apophysis of skeletally immature individuals that, in the majority of cases, presents with a periosteal reaction and edema/inflammation in the adjacent cortex, marrow, and soft tissue that can lead to misdiagnosis of stress reaction/fracture, osteomyelitis, or arthritis. On imaging, it is usually a geographic lytic lesion with sclerotic margins, heterogeneous high signal intensity on T2FS/STIR and intermediate signal intensity on T1WI. Only one-third to a half of the cases present the characteristic chondroid matrix on MRI (at least in some part of the lesion), that is, lobulated contours with markedly high signal intensity on fluid-sensitive sequences, associated with low signal intensity foci, related to chondroid calcifications.[43,44]

Ewing Sarcoma

ES is a highly aggressive bone and soft-tissue tumor that usually affects children and young adults. ES in bone may mimic osteomyelitis clinically and radiologically. On imaging examinations, both ES and osteomyelitis may present as aggressive permeative lesions, periosteal reactions, and soft tissue masses. ES, however, usually does not destroy the cortex, and the periosteal reaction might be more aggressive (spiculated) and shows avidly solid enhancement after gadolinium injection, whereas in osteomyelitis, the periosteal reaction tends to be linear and thicker, soft tissue masses are related to cortex breakthrough and abscess formation, and intraosseous Brodie abscess may be present in the subacute phase. In addition, signs of chronic osteomyelitis, such as sequestrum, involucrum, and cloaca, typically do not cause diagnostic doubts.[45,46]

Dysplasia Epiphysealis Hemimelica

Dysplasia epiphysealis hemimelica (DEH) is a rare disease that usually affects boys (3 M:1F) aged younger than 8 years and is also known as Trevor Fairbank disease

or *tarsomègalie.* It is characterized by epiphyseal overgrowth and osteocartilaginous epiphyseal lesions caused by idiopathic benign cell proliferation. DEH may manifest as a painless deformity, limited range of motion, impingement, mechanical pain, and/or localized growth disturbances. It tends to affect the epiphyses or apophysis of the same side of one lower extremity. On imaging, there is abnormal hypertrophy of the epiphyseal cartilage and subsequent excessive ossification, which results in lobulated ossified masses, asymmetric epiphyseal enlargement, irregular ossification centers within one side (ie, medial vs lateral) of an affected epiphysis, or any combination of these features. MRI provides a better understanding of epiphyseal cartilage overgrowth that is not yet ossified on radiographs, presenting high signal intensity on fluid-sensitive sequences.[47]

SUMMARY

Skeletal maturation is a dynamic process, and although it is somewhat predictable, it also has several variable particularities that can be easily misinterpreted as diseases on imaging, especially on MRI fluid-sensitive sequences. Therefore, knowledge of the physiologic patterns of development in children and adolescents and disease presentations are crucial for making the correct diagnoses and providing proper treatment to the pediatric population.

CLINICS CARE POINTS

- Increasing participation and intensity of training in organized sports among the pediatric population has increased the demand for MRI in children and adolescents. Therefore, MRI aspects of physeal fractures or overload, apophysitis, stress reactions and fractures, periosteal avulsions, subperiosteal hematomas and ligament injury, among other mechanical and traumatic pathologic conditions must be well known by orthopedists and radiologists.
- Knowledge of the physiologic patterns of development in children and adolescents and disease presentations are crucial for making the correct diagnoses and providing proper treatment to the pediatric population.
- Autoinflammatory disorders, infectious diseases, and bone tumors that show bone marrow and soft tissue edema on MRI, although not frequent in the foot and ankle, might be confused with stress reaction/fracture. Imaging associated with clinical history play a pivot role differentiating then.

DISCLOSURE

The authors have nothing to disclose.

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