Magnetic Resonance Imaging of the Pediatric Knee

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KEYWORDS

• Knee • Pediatric • Normal • Trauma • Developmental • Arthritis • Neoplasm

KEY POINTS

- Marrow conversion begins in the epiphyses 6 months after the radiographic appearance of the secondary ossification center. Transition to fatty marrow then continues from the mid-diaphysis toward the metaphyses.
- Irregular ossification involving the posterior femoral condyle epiphysis should be considered normal variation rather than an osteochondral lesion (OCD) in the absence of overlying cartilage abnormality and underlying bone marrow edema.
- Unlike adults who are more likely to suffer from ligamentous and meniscal injuries, trauma in pediatric patients characteristically involves the physis and adjacent bones.
- In contrast to adult OCDs, the hyperintense signal between the osteochondral fragment and native bone must mirror joint fluid to suggest instability in children.
- Synovial sarcoma is the most underrecognized malignant tumor that commonly occurs about the knee; lack of recognition is due to its seemingly benign magnetic resonance imaging characteristics.

INTRODUCTION

In pediatric patients, the knee is the most common joint to be assessed with magnetic resonance (MR) imaging. MR imaging of the knee is performed in children and adolescents to evaluate various traumatic, inflammatory, developmental, and neoplastic conditions. Its high resolution and excellent soft-tissue contrast allow for complete evaluation of both osseous and soft-tissue structures around the knee joint, and its lack of ionizing radiation makes it a preferred modality for advanced imaging in children. At younger ages, sedation is often necessary to obtain diagnostic images, presenting risks that must be taken into account when deciding on the necessity of the study. Furthermore, one must have a solid understanding of the normal skeletal development and variations in development of the distal femur, proximal tibia, and proximal fibula to avoid misdiagnoses.

Older children and adolescents are most commonly imaged to evaluate athletic and traumatic injuries. From infancy through school age,

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however, MR imaging is more often performed to evaluate developmental conditions such as Blount disease or to assess for causes of atraumatic pain such as infection or inflammatory arthritis. Neoplasms, both benign and malignant, commonly occur about the knee throughout childhood. Only the most common benign tumors and the most underdiagnosed malignancy are discussed in this article.

NORMAL SKELETAL MATURATION

To appropriately interpret pediatric musculoskeletal images, one must be aware of normal changes that occur with skeletal maturation. The epiphyses at both ends of tubular bones are positioned between the primary physis (growth plate) and the joint. Initially, the epiphysis is entirely cartilaginous. The secondary ossification center forms through endochondral ossification, beginning at the center of the epiphysis. Whereas the primary physis is responsible for longitudinal growth of the bone at each metaphysis, the secondary physis surrounding the secondary ossification center is responsible for spherical growth.[1]

The normal sequence of marrow conversion in pediatric patients must be understood, so as not to delay the diagnosis of infiltrative malignancy, such as leukemia, when imaging children who present with vague joint pain, swelling, or even pathologic fracture. At birth the marrow is entirely hematopoietic, resulting in relatively low signal intensity that is similar to or slightly higher than that of skeletal muscle on T1-weighted images. Normal marrow is usually higher in signal intensity than marrow infiltrated by disease. On T2-weighted images, hematopoietic marrow shows high signal intensity which is less than that of simple fluid and similar to that of muscle. Therefore, very low signal intensity marrow on T1-weighted images and increased signal intensity on water-sensitive sequences is concerning for malignancy.

During the first year of life, conversion from hematopoietic to fatty marrow begins. This marrow conversion progresses from the periphery to the center of each bone in the appendicular skeleton. Epiphyseal conversion occurs first, within 6 months of the radiologic appearance of the secondary ossification center. Transition to fatty marrow then continues, beginning at the middiaphysis and progressing toward the metaphyses. Hematopoietic marrow can be seen into early adulthood within the proximal metaphyses of the femora and humeri, as these are the last sites to convert. The transition back to red marrow in patients with anemia or who are receiving growth factors occurs in the reverse order, extending from the metaphyses centrally to the diaphysis before conversion in the epiphyses occurs. Residual hematopoietic marrow about the knee will appear flame-shaped, with a base adjacent to the physis.[1]

The periosteum is a thin, linear, hypointense structure paralleling the bone. It is tightly bound at the level of the physis but loosely attached along the shaft of the bone. Blood, pus, or tumor easily elevates the periosteum. In children, a layer of fibrovascular tissue separates the periosteum, resolving after physeal closure. This feature is most evident in long bones at the level of the metaphysis, and is best seen along the posterior distal femoral metaphysis as high signal intensity on water-sensitive sequences with intense contrast enhancement (**Fig. 1**). This "metaphyseal stripe" should not be mistaken for a subperiosteal fluid collection.[1]

Normal signal characteristics of the physeal structures on T2-weighted images vary. From distal to proximal, the cartilage of the primary physis (growth plate) is hyperintense, with the adjacent zone of provisional calcification appearing as a thin hypointense line. Immediately proximal resides the primary spongiosa of the metaphysis, which is hyperintense because of its vascularity.[1] The hyaline cartilage of the unossified epiphysis appears hypointense compared with the overlying articular cartilage.[1,2] During early

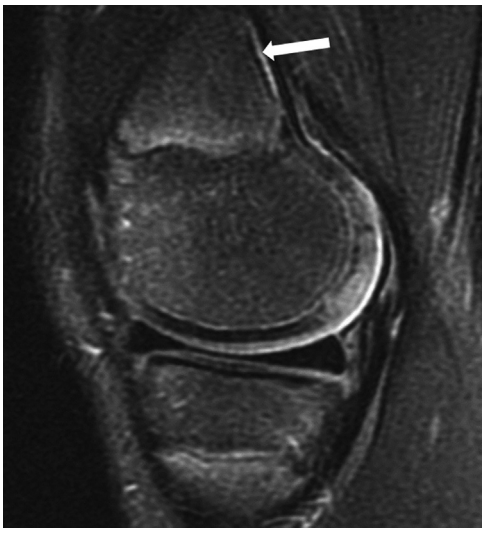

Fig. 1. Parasagittal T2-weighted, fat-suppressed image of the knee in a 10-year-old boy shows decreased signal intensity of the epiphyseal cartilage along the weight-bearing surface of the medial femoral condyle with the T2 hyperintense overlying articular cartilage. Along the posterior femoral condyle the epiphyseal cartilage is more heterogeneous, with the more focal hyperintense region likely related to early ossification. Note the normal posterior metaphyseal stripe (*arrow*).