MRI has transformed the field of pediatric and adolescent musculoskeletal imaging. When the more senior (and gray haired) of the two authors completed his pediatric radiology training, orthopedic radiology was a primarily plain film based discipline, occasionally supplemented by arthrography. Although much could be gleaned from the humble radiograph regarding the nature of orthopedic disorders, MRI has provided elegant depictions and insights of classic pediatric entities that would surely amaze the likes of John Caffey and Edward Neuhauser. With this technique, new challenges have arisen to comprehend the imaging findings in these classic disorders, and a wide array of newly appreciated entities has emerged with the wide utilization of MRI by pediatric, orthopedic and sports medicine specialists.

Despite these developments, a textbook devoted to MRI of pediatric and adolescent musculoskeletal diseases has been unavailable. Those with an interest in this area have had to rely upon published articles, as well as orthopedic, musculoskeletal and pediatric radiology texts. The goal of this work is to bring the literature of musculoskeletal MRI in children and adolescents together in an authoritative, but user friendly format. Cases are presented as “unknowns” in an effort to provide a dynamic learning process. The reader is given a brief history and initial images. A description of findings with appropriate annotated images and supplementary images follows. The diagnosis is then revealed and a discussion ensues. The discussion attempts to cover the salient features of the entity with related cases where appropriate. A differential diagnosis is given and, where appropriate, additional examples are illustrated. The result is a text that contains 315 pediatric and adolescent musculoskeletal MRI cases presented within the context of 102 unknowns.

To place this material more squarely in a clinical context, the authors invited two clinicians, Mininder Kocher, MD, MPH, a pediatric sports medicine orthopedic surgeon, and Mark Gebhardt, MD, a pediatric orthopedic oncologist, to join the effort. Sections entitled “Orthopedist’s Perspective” and “What the Clinician Needs to Know” are provided to inform the radiologist about the important clinical issues and what information is required to plan a management strategy. A modest bibliography for each case guides the reader to further discussions in original articles, reviews and other texts. The authors hope that this unique combination of both the radiologic and orthopedic points of view will enrich the readers’ learning experience and provide useful relevant information for the referring clinician.

Although the authors have sought to provide a solid and current presentation of both common and, where appropriate, unusual entities, space considerations have required exclusion of other entities. Like most first efforts, it is likely that this book will grow in scope and will undergo refinements in future editions, but for the present, we hope that this will be a useful instructional tool and reference source for radiologists and clinicians interested in pediatric and adolescent musculoskeletal disorders.

J. Herman Kan, MD
Paul K. Kleinman, MD
History

This is a 13-year-old girl with chronic right knee pain. She is otherwise well, without fever or systemic symptoms. CBC and ESR were normal.

Figure 2A. Coronal T1 of the right knee.

Figure 2B. Sagittal STIR.
Figures 2A, 2B, 2C. Focal ill-defined T1 hypointensity, STIR hyperintensity, and enhancement are present, centered at the physes of the distal femur and proximal tibia. There is minimal juxta-cortical edema in Hoffa’s fat pad. There is also mild periosteal enhancement along the distal femoral and proximal tibial metaphyses. No intraosseous fluid collections or soft tissue abscess are seen.

Figure 2D. Osteolysis with marginal sclerosis involves the anterior aspects of the physeal margins of the metaphyses of the distal femur and proximal tibia (arrows), corresponding to the signal abnormality on MRI.
Diagnosis

Chronic recurrent multifocal osteomyelitis (CRMO)

Questions

1. What MRI features are seen with pyogenic osteomyelitis and not CRMO?
2. What is the most common location for CRMO?

Discussion

Chronic recurrent multifocal osteomyelitis (CRMO) and pyogenic osteomyelitis share many features. Both may have osseous and adjacent soft tissue inflammation and they are typically located near the physis. Additional shared osseous findings include transphyseal spread, osteolysis or sclerosis, and varying degrees of periosteal reaction (1, 2). Pyogenic osteomyelitis is occasionally multifocal (Figures 2E, 2F), but unlike CRMO, there may be intraosseous and soft tissue abscesses, sequestra, and fistulous tracts (Answer to Question 1) (2). In the absence of these findings, CRMO and multifocal pyogenic osteomyelitis may be indistinguishable based on MRI features at individual sites.

CRMO is a diagnosis of exclusion after pyogenic osteomyelitis has been ruled out. By definition, an organism is not isolated by blood culture or biopsy. The term CRMO is a misnomer since it represents a non-pyogenic inflammatory disorder and is technically not considered osteomyelitis. CRMO is viewed as a seronegative arthropathy-like condition that occurs in children (3). Additional clinical features associated with CRMO include psoriasis, inflammatory bowel disease, recurrent arthritis, spondyloarthropathy, or sacroiliitis. CRMO is generally a self-limited disease and the majority of cases have no disability beyond childhood (4). SAPHO (synovitis, acne, pustulosis, hyperostosis, and osteitis) is considered the adult equivalent of CRMO.

CRMO has been observed most commonly in the tubular bones of the lower extremity (Answer to Question 2). The clavicles are next most common (see Case 11) (3). When the changes are restricted to the thorax and shoulder girdle, the term sternocostoclavicular hyperostosis is generally employed. Rarer locations include the spinal column and pelvic girdle (1, 5).

The principal differential diagnosis for CRMO is multifocal pyogenic osteomyelitis, and bone biopsy and culture are generally required for diagnosis. Less likely differential considerations include Langerhans cell histiocytosis, small round blue cell tumors, and trauma/stress reaction.

In this patient, the diagnosis of CRMO was invoked because of the multifocality and the absence of clinical or laboratory findings to suggest pyogenic osteomyelitis. A total body MRI showed no additional lesions. A biopsy showed changes of chronic osteomyelitis without bacterial organisms, and culture of the biopsy material showed no growth. Symptoms resolved with naproxen. She was not given antibiotics.

Orthopedic Perspective

Although patients with CRMO are usually not acutely ill, they may have erythema, low-grade fever, and abnormal laboratory values. The clinician relies on imaging to define the full extent of the process and identify a suitable site for open or percutaneous biopsy. Unlike pyogenic osteomyelitis, discrete fluid collections are not typical features of CRMO. Biopsy should target areas of granulation tissue and bone destruction, rather than bony sclerosis or nonspecific reactive edema to increase the diagnos-
tic yield. Patients are typically treated with anti-inflammatory medications and followed by a rheumatologist.

**What the Clinician Needs to Know**

1. Is the lesion pyogenic osteomyelitis, CRMO, or tumor?
2. Are there other lesions?
3. Which lesion is best suited for percutaneous biopsy?
4. Is the process subsiding on follow-up studies? Active lesions demonstrate juxta-cortical soft tissue edema, whereas the SI within inactive lesions is confined to bone (2).

**Answers**

1. Intraosseous or soft tissue abscesses, sequestra, and fistulous tracts.
2. Lower extremity tubular bones.
Findings

This is a 14-year-old boy with diffuse lower extremity pain and non-weight bearing. He had a severe upper respiratory tract infection 2 weeks prior to presentation. At the time of admission, he had a high fever and blood cultures were positive for *Staphylococcus aureus*.

Figures 2E, 2F. Two foci of abnormal enhancement are located in the right pubic ramus (arrow) and the left distal femoral metaphysis (*) and epiphysis (arrowhead). Without the clinical history or positive blood cultures, the imaging findings do not allow differentiation of pyogenic osteomyelitis from CRMO, Langerhans cell histiocytosis, metastases, or stress reaction.

Pitfalls and Pearls

1. CRMO is a misnomer because it is not a bacterial infection of bone. CRMO represents a non-pyogenic inflammatory disorder that primarily affects bone.
2. The imaging features of pyogenic osteomyelitis and CRMO are similar in the majority of cases. Therefore, the diagnosis of CRMO should be made only if pyogenic osteomyelitis has been completely excluded.
3. If CRMO is a consideration, a bone scan is indicated to assess for other lesions, and to identify the optimal biopsy site.

References