Pediatric Musculoskeletal protocols

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Introduction

There are qualitative and morphologic differences in the pediatric skeleton when compared to the adult. The growing pediatric frame includes structures not found in the adult including the physis and the epiphyseal cartilage. In addition, some components of the skeleton which are indeed present in the adult differ markedly in form and function in the child. Examples include the bone marrow and even the periosteum.

Imaging these structures require a different mix of fluid sensitive and nonsensitive sequences in order to arrive at a correct diagnosis. In some situations novel imaging sequences may be used but more commonly, the standard sequences may be applied in nonstandard packages.

Children are also much smaller than the adult. The total body mass available in any imaged part is on a par smaller than in an adult. The decreased fields of view, especially when considering the small hands and feet of a child restrict the available proton mass available to produce suitable images. Signal suffers at the benefit of noise.

The problem is exacerbated since speed is of the essence when imaging children. Shorter scan times benefit not only the child who is borderline for his or her ability to hold still but also shortens anesthesia times in those cases where anesthesia is necessary.

Pediatric cartilage imaging

While in an adult cartilage imaging invariably refers to the articular cartilage such is not the case in pediatrics. Both the physis and unossified epiphysis is made up of hyaline nonarticular cartilage. Both are a major site of pediatric musculoskeletal pathology requiring special imaging sequences. Sequences used for articular cartilage imaging may be deployed for physeal imaging with good success but substantial changes may be necessary.

The physis lies between the epiphysis and metaphysis and is the source of bone elongation in the child. It is made up of a columnar arrangement of chondrocytes embedded in a specialized collagenous matrix. Being made up of cartilage, the physis is well portrayed using standard methods of cartilage imaging such as intermediately weighted fat suppressed sequences and fast fat suppressed 3D gradient sequences. Of the two, the latter is usually of greater benefit since the ability to reconstruct 3D sequences into other planes especially when obtained isotropically is of great value.   Extensive use of these techniques is made when examining physeal bridges. A physeal bridge occurs when the vasculature of the physis especially those vessels feeding the resting zone of the physis is injured. The injury to the

resting or germinal zone robs the physis of a fresh stockpile of chondrocytes for physeal replenishment and growth ceases. A physeal bridge results as bone inevitably crosses the physis. Using 3D SPGR fat suppressed sequences a map of the physeal bridge may be obtained and the location and size of the bridge mapped. To accomplish this, a thick slab axial reconstruction of the physis is produced. Since the physis is bright and the adjacent bone is dark this axial reconstruction will show the area of the bridge as low signal against the normal background of the high signal physis.

T2 based imaging can also be of great use for physeal examination. The T2 of articular cartilge is 35-45 ms. The T2 if physeal cartilage is much longer so that long T2 sequences are of greater value for physeal imaging than when used to examine the cartilage investing the articular surfaces.

Intermediate weighted fat saturated sequences or fast fat suppressed gradient sequences are best at imaging epiphyseal cartilage. Edema within the epiphyseal cartilage may be difficult to appreciate against the background of the high signal epiphyseal cartilage. Fortunately there are few instances of isolated epiphyseal cartilage edema without adjacent osseous or articular abnormality.

More frequently it is the anatomic relationships between the epiphyseal cartilages at the articular level that is the goal of the exam. Since epiphyseal cartilage is not visualized radiographically, in cases of various dysplasias, MRI is called upon to portray the cartilaginous skeleton in infancy. Complex polydactylys and syndactyly can be well examined with a single isotropic fat suppressed SPGR sequence. Done correctly with enough signal to noise, multiplanar reconstructions can be produced from a single data set. These can be very helpful for surgical planning.

As in the adult articular cartilage imaging is also of considerable import in pediatrics albeit in a much more limited fashion. One instance where articular cartilage depiction is an important facet of the pediatric MRI examination is the study of osteochondritis dessicans (OCD). Both the criteria for instability of OCD fragments in children differs from that of adults and the treatment differs as well. In an adult OCD usually involves a traumatic injury to articular cartilage and articular sided drilling and microfracture is a preferred mode of treatment. In the adolescent age group the nascence of OCD is probably developmental with a varying and unknown traumatic contribution. If the articular cartilage is normal as it frequently is, drilling when performed is done through the bony epiphysis using a nonarticular sided technique. High resolution 3D cartilage imaging is therefore very helpful to guide therapy.

Marrow Imaging

Marrow goes through an orderly conversion during life from predominantly hematogenous and watery to fatty. In infants especially much of the marrow is bright on T2 weighted sequences being largely hematogenous. With IV contrast, hematogenous marrow enhances significantly. Given these characteristics, the diagnosis of marrow edema is difficult in infants. It is very difficult to see marrow edema confidently against the already bright

marrow. The challenge of MR marrow imaging in pediatrics is actually much more a challenge in interpretation rather than the actually MRI sequencing.

In some cases, dynamic imaging of marrow abnormality can be an effective tool. Legg Calves Perthes disease is most likely an ischemic necrosis of the femoral head. Although dynamic post contrast imaging is of questionable sensitivity and specificity for diagnosis in the acute phase it is highly useful for establishing the stage and progression of the disease in order to establish prognosis and guide surgical planning. Diffusion weighted imaging is also useful in this regard.

Need for speed

Speed is of the essence in pediatric MRI imaging. There are many instances where a child may not be able to endure 30-40 minutes in the magnet bore holding still but could tolerate a set of focused sequences taking a much shorter amount of time which even so answer the clinical question. In addition, in the many cases where anesthesia is necessary for the child to undergo a longer examination, time remains a consideration. A long anesthesia time includes a higher rate of complication and especially in infants with a tenuous hold on life exams need to be fast. "One size fits all" imaging in pediatrics is therefore much more limited.

In many cases a tailored exam is necessary in which the clinical question is answered by the most expedient means. While in an adult multiple imaging planes may be obtained, in pediatrics one plane may have to suffice. In addition to a certain extent the number of excitations may be limited as well as using other methods of limiting the time spent in the magnet.

In recent years, the medical community as well as the public have become more concerned with exposure to ionizing radiation predominantly through CT scanning. MRI is being used more frequently to answer clinical questions habitually reserved for CT scanning.

Magnets should be used as focused tools to answer a specific clinical question. When done correctly MRI can be a short and atraumatic experience.

Patients with pectus excavatum routinely undergo a limited CT scan of the chest as a method of assessing the need for surgical intervention. A Haller index is measured which is a ratio of the narrowest AP diameter of the chest to the width of the chest at that level. The same measurement can be produced using fast MRI scanning. FIESTA sequences are very short and can easily portray the acquired anatomy with scan times of about 20 seconds. A complete exam requires 5-10 minutes.

Patients with abnormal femoral anteversion also routinely are scanned by CT in order to estimate the degree of femoral anteversion and tibial torsion. Limited axial slice are obtained through the hips, knees and ankles and the appropriate angles calculated. Depending on the need for bony detail required this exam can also be easily performed by MRI in less than 5 minutes thereby obviating patient exposure to ionizing radiation. At our institution we use T2 FSE nonfat saturated sequences to produce images with the appropriate detail for our

orthopedic surgeons. The main magnet body coil is used for all images which further speeds the exam.

In summary, much of pediatric MR imaging relies on utilizing basic sequences but tailored to the pediatric age group. Cartilage imaging shifts from imaging of articular cartilage abnormality to include and emphasize portrayal of physeal and epiphyseal cartilage anatomy. Tradeoffs of time and signal become more important as there is a greater emphasis on speed during the examination. At the same time that MR exams become more focused MRI is used much more liberally to answer simple clinical questions which in the past was the province of CT scanning.