MR Imaging of the Neonatal Musculoskeletal System

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KEYWORDS

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Evaluation of the neonatal musculoskeletal system with magnetic resonance (MR) imaging is not commonly needed. Radiography and ultrasound remain the initial imaging modalities for most common and uncommon musculoskeletal conditions encountered in this age group. However, because of the exquisite tissue contrast provided by MR imaging, its use is expanding, especially for evaluation of complex malformations, infections, and tumors of the neonatal musculoskeletal system. The ability of MR to image the abundant cartilage present within the neonate makes MR imaging invaluable in the assessment of the neonatal musculoskeletal system.

MR imaging of the neonate poses several unique challenges that may arise either before or during scanning. Considerations include patient transport, the need for sedation and monitoring, as well as safe patient positioning. When imaging, careful consideration of coil selection, scan parameters, and sequences is vital. The interpretation of images may also be challenging because the appearance of the neonatal musculoskeletal system and type of underlying disorder often differ from those encountered in older children.

This article discusses some practical aspects of MR imaging of the neonatal musculoskeletal system. It reviews the normal neonatal appearance of the musculoskeletal system and focuses on some common and uncommon musculoskeletal disorders for which MR imaging has been shown to be of benefit in the neonate.

EXAMINATION TECHNIQUE

Patient Preparation

Close cooperation between the neonatal service and the radiology department is required for successful acquisition of a diagnostic neonatal MR study. We carry out MR examinations in the neonate as far as possible without the use of anesthesia, instead using a feed-wrap-and-snooze technique. This technique is described in a step-by-step approach by Mathur and colleagues.[1]

There are several principles to optimize success in pediatric musculoskeletal imaging.[2] When sedation or general anesthesia are needed, the MR compatibility of any necessary ventilatory or monitoring equipment must be considered. The number of intravenous solutions should be minimized as much as possible. The neonate is wrapped snugly and placed in a regular transfer incubator or, if available, a specialized neonatal MR-compatible incubator. The advantage of an MR-compatible incubator is that fewer patient transfers are required, which reduces the

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likelihood of disturbing the neonate or dislodging monitoring leads and intravenous lines. The use of a dedicated nurse, familiar with neonatal procedures and associated specialized equipment, helps to smoothly transfer from nursery to MR scanner and back again. Clear and up-to-date communication with the ward about the anticipated study start is important to enable suitable scheduling of feeds, generally 30 to 40 minutes before scan initiation.

Field of View and Coil Selection

It is important to find an appropriate balance between the desired anatomic coverage, required spatial and matrix resolution, and signal/noise ratio. These factors, along with coil sensitivity and magnetic field strength, help determine the field of view (FOV) and slice thickness to be used. The use of small FOVs with similar matrix sizes to those used in adult studies decreases the signal/noise ratio greatly and may create excessive noise and uninterpretable images. However, if the FOV is too large for a given matrix size, then the spatial resolution may not be adequate for evaluation of neonatal anatomy. Generally, selection of a pixel size of just less than 1 mm by 1 mm with slice thicknesses of 3 to 5 mm is adequate.

The volumes to be imaged in the neonate for detailed evaluation may be small, requiring dedicated imaging coils able to acquire the required small FOVs in adequate detail. At present, in our institution, we primarily use either the head coil, and place the entire baby within the coil for larger anatomic coverage or, for smaller regions, use surface coils.

Choice of Scan Sequences and Parameters

As for all pediatric MR imaging, the order of sequence selection is important. The sequences with the highest anticipated yield should be performed first, so that, if the neonate rouses, enough of the study will hopefully have been completed to give diagnostic information. In general, MR imaging studies of the neonatal musculoskeletal system include a variety of standard fast spin-echo and gradient sequences with or without fat suppression, such as T1-weighted (T1-W), T2-weighted (T2-W), spoiled gradient echo or fast low angle shot, and short tau inversion recovery (STIR). Both two-dimensional and three-dimensional sequences are being used.

T1-W images

T1-W images are helpful in the interpretation of bone marrow involvement in patients with yellow marrow, with abnormalities typically appearing as low signal on T1-W images. However, in the neonate, hematopoietic marrow predominates, which also appears low signal on T1-W images, obscuring recognition of focal or more diffuse marrow lesions. Use of in-phase and out-of-phase sequences may help.[3]

Water-sensitive images

STIR and fat-suppressed TSE T2-W imaging are the most commonly used water-sensitive images. Fat-suppressed T2-W imaging is the preferred method when magnetic field inhomogeneity is not a concern because it is more efficient than STIR imaging. Fat-suppressed T2-W imaging is also the method used when contrast enhancement is present because STIR suppresses any signal that has a short T1, including gadolinium.

Proton density

Proton density imaging has a high signal/noise ratio that can provide excellent spatial resolution for evaluation of musculoskeletal structures. It is one of the most commonly used sequences in musculoskeletal imaging in older children and adults and also works well in neonates, particularly with fat suppression.

Gradient echo sequences

Gradient echo (GRE) images are particularly useful for imaging cartilage and for looking for magnetic susceptibility artifacts, as seen in hemorrhage. Hyaline epiphyseal and physeal cartilage is of high or intermediate signal, whereas hemorrhage shows as blooming. This sequence is particularly useful in distinguishing between cartilage and adjacent joint fluid. With increasing T2 weighting, signal contrast is increased between cartilage (lower signal) and fluid (higher signal). Three-dimensional gradient sequences are often used for dedicated joint imaging and multiplanar reconstruction.

Use of 3 Tesla MR imaging

The experience with 3 Tesla (3T) MR imaging of the neonate is still in its infancy. With 3T, there is increased signal available, which is used to decrease overall examination time and/or increase image resolution. In practice, for neonatal imaging, a combination of these benefits is usually used to both reduce overall scan time and improve spatial resolution. Early experience with pediatric 3T MR imaging has shown that it can provide good image quality even at small FOVs, showing cartilage, ligaments, and nerves in good detail. In addition, the ability to decrease examination time helps to decrease motion artifact and the need for sedation, which can reduce potential patient