Magnetic Resonance Imaging Following Suspicion for Fetal Brain Anomalies

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KEYWORDS

- Fetal MR imaging • CNS anomalies
- Fetal brain • Sulcation • Ventriculomegaly
- Cortical malformation

Fetal ultrasound is considered the standard of care in the evaluation of fetal anomalies; however, limitations exist, including decreased visibility of fetal structures because of maternal body habitus, position of the fetal head, ossification of the fetal skull, and, in some cases, oligohydramnios. On the identification of a fetal brain anomaly by ultrasound, further evaluation is necessary to better define the anomaly and to rule out other associated anomalies. In the developing fetus, many brain structures are forming at around the same time; thus, the detection of one anomaly necessitates the evaluation for others. Fetal MR imaging is a complement to ultrasound and has several advantages, including visualization of the entire brain (as opposed to ultrasound where the upside cerebral hemisphere is often shadowed because of reverberations from overlying structures). MR imaging is also capable of assessing the sulcation pattern and developing cortex, which is difficult to visualize on ultrasound.[1–6] In addition, when an anomaly is detected, fetal MR imaging may provide better definition of the lesion because of improved contrast resolution and identify other lesions not visible on ultrasound.

Fetal MR imaging has been demonstrated to accurately detect anomalies within the second and third trimesters, providing additional information for prenatal counseling and delivery planning. In a study by Levine and colleagues of the central nervous system (CNS) of 145 fetuses, additional findings were found on MR imaging in 32%. Another study by Simon and colleagues[7] of 73 fetuses found that in 46% of cases the finding on fetal MR imaging changed patient management from what it would have been based on the ultrasound findings alone. When CNS anomalies are identified by ultrasound, MR imaging may demonstrate additional findings that may alter patient management.[6,8,9] Several studies have identified anomalies by MR imaging that were not visualized on ultrasound, including anomalies of sulcation, periventricular nodular heterotopia, callosal agenesis, periventricular white matter injury, cerebellar dysplasia, germinal matrix, and intraventricular hemorrhage.[7,10–14]

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FETAL MR IMAGING TECHNIQUE AND LIMITATIONS

The use of fetal MR imaging began in the early 1980s in Europe, at which time fetal sedation was used. Since that time, improvements in technique have resulted in our ability to image the fetal brain without maternal or fetal sedation and thus in its increasing clinical use in the United States. Currently, most fetal MR imaging is performed using ultrafast T2-weighted MR imaging techniques known as single-shot fast spin echo (SSFSE) or half-Fourier acquired single-shot turbo spin echo (HASTE). These rapid pulse sequences allow acquisition of a single image in less than 1 second, reducing the artifact from fetal motion. In addition, T1-weighted images are used to visualize fat and hemorrhage, and gradient echo T2 images are used to visualize hemorrhage. Diffusion-weighted MR imaging can also now be performed in fetal MR imaging and is helpful in cases of suspected parenchymal injury, such as stroke or periventricular white matter injury. Diffusion-weighted MR imaging is also sensitive to maturational changes in the microstructure of fetal brain tissue, a process that normally occurs with increasing gestational age.[15,16] Diffusion tensor MR imaging provides even more information concerning tissue microstructure and maturational processes, although further technical advances are required before it can be successfully applied to fetuses.[17–19] MR spectroscopy is being investigated for the assessment of brain maturation and alterations in brain metabolism,[20–22] although it is limited by long acquisition time (4.5 minutes) and currently is only performed in the third trimester when the head is larger and engaged in the maternal pelvis.[23] Functional MR imaging is also being used in research protocols, but is not used in routine practice.[24–26] Fetal MR imaging is usually performed around 22 weeks' gestation, to decrease the effect of fetal motion that occurs with younger fetuses and the brain is larger, and, therefore, more easily assessed than at a younger gestational age.

A study by Blaicher and colleagues[27] found that the diagnostic accuracy increases with gestational age, and concluded that fetal MR imaging should be performed from 20 weeks onward, although we have found 22 weeks to be the optimal age for performing fetal MR imaging.

Patients are imaged on a 1.5 Tesla scanner using an eight-channel torso phased array coil, which is placed over the mother's abdomen. Preferably, the patient is imaged in the supine position, allowing for optimal coil geometry. Ultrafast SSFSE images (TR 4000, TE 90, FOV 24 cm, matrix 192 × 160) are obtained in coronal, axial, and sagittal planes, and 3-mm slice thickness is used for the brain (2 mm for the spine). No sedation is given to the mother, but she is instructed not to eat for 4 hours before the examination, because this tends to decrease the frequency of fetal movement. In addition, the patient is screened for any contraindications to MR imaging before the examination.

In addition to fetal motion, limitations of fetal MR imaging include the small size of the structure being evaluated combined with increased distance of the structure from the receiver coil, which limits the resolution. Improvements in coil technology, such as parallel imaging with increased number of channels, are resulting in the reduction in these limitations. Maternal claustrophobia and discomfort from lying still for the study period are also problems, because the MR imaging examination typically lasts at least 45 minutes. If the mother cannot lie on her back, she can be imaged in the left lateral decubitus position, which may ease discomfort, although this does result in decreased image quality.

MR IMAGING SAFETY

MR imaging of the fetus is considered to be safe; however, studies on the safety of MR imaging in pregnant women are limited. Follow-up studies of children who underwent fetal MR imaging have thus far demonstrated no long-term adverse effects; however, these studies have been limited by small sample size.[28–30] Because the effect of MR imaging on the developing fetus has not been determined, it is not recommended in the first trimester to avoid the potential risk for the magnetic fields interfering with organogenesis. Biologic effects, miscarriage, acoustic noise exposure, and heating effects are the potential risks from exposure to the magnetic field. Studies using pregnant animals and animal fetuses have not provided a consensus as to risk, and whether or not the information can be applied to humans is uncertain because the equipment and scanner parameters were variable in these studies.[31–35] To provide guidance for imaging, a 2002 American College of Radiology white paper states, "Pregnant patients can be accepted to undergo MR images at any stage of pregnancy if, in the determination of a Level Two MR Personnel –designated attending radiologist, the risk-benefit ratio to the patient warrants that the study be performed."[36] All pregnant women should undergo counseling and sign a consent form before MR imaging.

In addition, the use of gadolinium for fetal MR imaging has been avoided. Gadolinium is a "rare earth" element, which is toxic when it is in an