The Role of Magnetic Resonance Imaging in Diagnosing Fetal Brain Pathologies

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Magnetic resonance (MR) imaging has become a vital clinical diagnostic tool in assessing and diagnosing fetal brain pathologies. Historically, sonography was the sole diagnostic tool for evaluating fetal brain pathology.[1] However, fetal MR imaging has become a valuable adjunct to evaluate fetal brain anatomy, and substantial advancements made since its introduction in the late 1980s have made it possible to evaluate fetal anatomical structures and brain development to confirm pathologies that might be undetectable by other prenatal imaging methods.[2] Fetal MR imaging is not available widely, and there is a lack of expertise in this type of imaging. Although some components of fetal MR imaging need to be investigated, there is ample research that contributes to its development.[3,4] MR imaging applications are noninvasive and provide advanced information on anatomy, function, and pathologies without the use of ionizing radiation. In addition, fetal MR imaging allows the medical team to accurately diagnose brain pathologies to help devise a plan for intervention. MR imaging is a great way to evaluate a variety of different symptoms that people might have, and it has strong imaging capabilities.

Technical Aspects

Several aspects must be considered when a fetal MR imaging examination is ordered. First, the appropriateness of MR imaging for the patient should be determined. In addition to considering the risks and benefits of the procedure, the patient should be screened for ferrous materials. Furthermore, obtaining written informed consent is necessary for pregnant patients.[3] After the patient is deemed appropriate to scan, technical aspects are considered, including positioning, gradient field strength, and sequences.[3,5]

Positioning

Positioning of patients typically is supine, but a semidecubitus position might be preferred to avoid compression of the vena cava.[5,6] Because fetal MR imaging commonly is performed after 17 to 18 gestational weeks, certain positions might be uncomfortable for the patient during the second and third trimesters.[3] Choice of positioning is dependent on the patient's ability to comfortably lie in a position where they can remain still for a specified period.

Gradient Field

In most examinations, fetal MR imaging is performed using a 1.5 T superconducting magnet.[1,6,7] However, research has indicated that 3 T magnets allow better delineation of anatomy.[5,8] Additional safety concerns and increased image artifacts associated with a higher field strength might be why fewer facilities are using a 3 T magnet.

Sequences

Fetal MR imaging typically uses parameters for fast sequences because of the chance for fetal motion. Sequence parameters and protocols can vary

substantially between different facilities, magnets, and manufacturers; however, there are standard sequences that are performed in fetal MR imaging. Initially, localizers are acquired in the maternal coronal plane to locate the fetal anatomy, followed by a T2-weighted fast spin-echo sequence. A T2-weighted fast spin-echo sequence is imaged on coronal, sagittal, and axial planes to evaluate cerebral anatomy, as well as to identify potential fetal brain malformations.[5,6,9] Manganaro et al indicate that breath-hold gradient-echo sequences are employed frequently and are useful in cases of artifacts caused by excessive motion.[5] Another common sequence is diffusion-weighted imaging, which is useful in displaying information about water motion and tissue microstructure.[1,9] Diffusion-weighted imaging allows the assessment of brain development and can detect focal areas of injury. In addition, T1-weighted sequences, such as gradient echo, also can be performed to demonstrate fat, calcification, and hemorrhage.[2] Each sequence used contributes helpful information to radiologists to provide conclusive and accurate diagnoses.

Safety Aspects

Although there is no evidence of harmful effects associated with fetal MR imaging, there is a lack of consensus on whether it is safe. The American College of Radiology states that pregnant patients can undergo MR scans during all stages of pregnancy, and there are no concerns whether imaging with a 1.5 T or a 3 T magnet.[10] Conversely, the Canadian Task Force on Preventive Health Care indicates that MR imaging is safe during the second and third trimesters at 3 T and below.[11] Although imaging is permitted, the literature shows that the potential risks and benefits should be weighed before deciding whether to proceed. Interpretation of evidence related to fetal MR imaging safety is challenging because of limiting factors such as inconclusive results, small population samples, and overall lack of research.[4,10,12]

Administering Contrast Agents

The administration of contrast agents during pregnancy is decided on a case-by-case basis but generally is not recommended because of a lack of knowledge and research on the effects. Research has not demonstrated a clear understanding of risks to the fetus associated with gadolinium.[1] Gadolinium-based agents enter the placenta and travel through the fetal circulation into the fetal kidneys and are excreted in the amniotic fluid.[4,10] Research indicates that whether the presence of these gadolinium ions in the amniotic fluid can cause adverse effects is unknown.[1,10] Ray et al concluded that the administration of contrast during any point in a pregnancy resulted in an increased risk of infiltrated skin conditions, rheumatological problems, and inflammatory issues.[13]

Fetal MR Imaging at 3 T

Less is known about imaging at 3 T compared with 1.5 T. Effects involving the gradient and radiofrequency magnetic field on a fetus are inconclusive. Most research has been conducted at 1.5 T; data regarding potential risks of MR imaging at 3 T are limited.[3,13] The findings of 2 studies suggest that there are no associated adverse effects when imaging a fetus at 3 T.[12,14] A conclusion regarding the safety of fetal MR imaging performed at 3 T is unknown because of the lack of definitive research.

Clinical Conditions

Fetal MR imaging often is performed to further investigate a suspected or inconclusive pathology demonstrated on prenatal sonography.[1,8] Bekiesińska-Figatowska et al stated that MR imaging likely is able to confirm occult abnormalities suspected on sonography because of its ability to depict tiny structures such as optic nerves and hypophysis.[15] The main disorders of the brain assessed by fetal MR imaging include ventriculomegaly, corpus callosum malformations, posterior fossa malformations, and holoprosencephaly.

Ventriculomegaly

The most common diagnosis and indication for fetal brain MR imaging is ventriculomegaly, which is defined as ventricular atrial enlargement greater than 10 mm in the posterior area of the choroid plexus.[3,16] Prevalence of ventriculomegaly is less than 2.5 per 1000 pregnancies.[17] Masselli et al proposed that the underlying etiologies of ventriculomegaly could include certain malformations, obstructions, or overproduction of

cerebral spinal fluid.[2] Research has shown that anomalies such as those were detected in 80% of fetal MR imaging of ventriculomegaly.[1] Severity of ventriculomegaly is the main factor that influences neurological outcome and survival rate. Survival rate of patients experiencing mild ventriculomegaly is 93% to 96%, whereas the survival rate of patients with severe ventriculomegaly can be as low as 28%.[2] Previous studies infer that most mild cases are likely to resolve on their own with no adverse effects, but more severe cases could affect brain development.[5,9]

MR imaging is an excellent tool to evaluate ventriculomegaly because of its ability to visualize the ventricular size of the fetal brain and because it allows for better tissue contrast. Fetal MR imaging techniques also allow the medical team to plan postnatal intervention as warranted. The disorder is best visualized and measured using a midthalamic axial plane.[3]

Corpus Callosum Malformations

The corpus callosum is the longest commissure and structurally connects the 2 cerebral hemispheres. In a typical fetus, the corpus callosum completely develops between 10 and 20 weeks of gestation.[2,6] The most common disorders of the corpus callosal that occur during gestation include hypogenesis, dysgenesis, and hypoplasia, and agenesis.[1] The incidence of anomalies associated with the corpus callosum is difficult to ascertain because of the selection bias in reported studies. However, a larger population study conducted by the California Birth Defects Monitoring Program found that cases of hypoplasia and agenesis of the corpus callosum were reported in 630 out of 3.4 million live births (0.019%).[18] Postnatal symptoms of corpus callosum disorders are largely dependent on the severity of the malformation. Research reports that children experienced varying symptoms such as motor control impairment, coordination difficulties, language problems, and impaired cognitive status.[19]

The malformations are best visualized and assessed in fetal MR imaging using a T2-weighted midline sagittal plane.[3] Hypogenesis is easily diagnosed on an MR image by identifying a diffusely thin corpus callosum.[2] Dysgenesis and hypoplasia are associated with parallelization of the lateral ventricles, a high third ventricle roof, and colpocephaly.[2,5] Fetal MR imaging helps radiologists to accurately diagnose and assess the severity of the corpus callosum malformation.

Posterior Fossa Malformations

Fetal MR imaging can provide a detailed analysis of the posterior fossa and surrounding structures, including the vermis, cerebellar hemisphere, and brainstem. In addition to ventriculomegaly, posterior fossa malformations are another common indication for fetal MR imaging.[1,3] A study that included 94 neurology consults for fetal brain pathologies found that 20% had posterior fossa malformations.[20] MR imaging is useful especially in imaging posterior fossa malformations; during the third trimester, posterior fossa structures can be difficult to evaluate using other imaging methods because of the ossification of the skull. Imaging at younger gestational ages (< 20 weeks) can result in reduced specificity; therefore, frequent practice is to perform follow-up imaging at a later gestational age or postnatally.[1,21] Symptoms resulting from posterior fossa malformations range substantially depending on the severity of the malformation, but brain development issues can occur.

Fetal MR imaging can help evaluate and diagnose specific diseases directly associated with the posterior fossa. Dandy-Walker malformation is a common example. Criteria for diagnosis of Dandy-Walker malformation are agenesis of the cerebellar vermis, hypoplasia of an upward vermin axis, and cystic dilation of the fourth ventricle.[1] Evaluating the supratentorial structures when looking for indications of Dandy-Walker malformation also is important because it is associated with many supratentorial conditions such as corpus callosum agenesis, polymicrogyria, and occipital encephalopathy.[21]

Holoprosencephaly

Holoprosencephaly represents a spectrum of brain malformations but typically is characterized by an incomplete separation of the cerebral hemispheres.[22] Statistics from studies related to prevalence of holoprosencephaly vary. Some studies demonstrated that holoprosencephaly occurred in 1 in 16 000 live births,[23,24] whereas other research indicated that the

prevalence was 1 in 10 000.[5,22] Research concluded that holoprosencephaly occurred in 1 in 250 pregnancies, which indicates that only a small percentage of fetuses with holoprosencephaly reach live delivery.[5,22,23] Holoprosencephaly usually originates from chromosomal disorders; trisomy 13 and trisomy 18 are the most frequently reported.[2]

Fetal MR imaging aids in visualizing 3 types of holoprosencephaly (listed in decreasing order of severity): alobar, semilobar, and lobar.[3,22] Riddle et al described alobar holoprosencephaly as a failure of the cerebral hemispheres to separate completely that is accompanied with an absence of the falx cerebri on imaging.[22] Although a variety of explanations for the differences between lobar and semilobar holoprosencephaly are found in the literature, evidence concludes that semilobular holoprosencephaly is an incomplete separation of the frontoparietal lobes and failure of transverse cleavage into diencephalon and telencephalon.[3] Lobar holoprosencephaly is defined as an incomplete separation of only the frontal lobes.[3,22] Research shows that MR imaging is able to detect these disorders by visualizing the sagittal and axial planes to locate incomplete formations of anatomical structures.[3]

Limitations of Fetal MR Imaging

Compared with other imaging methods, MR imaging is more expensive, which can limit the number of patients able to afford the examination. Fetal MR imaging is not widely available to patients, and many facilities do not perform fetal MR imaging because of a lack of training, expertise, and equipment.[4] In addition, ferrous implants and pacemakers are a contraindication that could prevent a patient from being scanned, because of the magnetic field of the scanner.[10] Claustrophobia might be a limiting factor in proceeding with the procedure as well, since the bore of the MR scanner typically is a tunnel shape that is not much bigger than the patient. These limitations might contribute to a smaller number of fetal MR examinations being performed.[10]

Conclusion

Fetal MR imaging has become a primary technique in prenatal evaluation of brain malformations and can be crucial for identification and characterization of pathologies, especially in instances where other modalities have insufficient capabilities. Technical considerations, safety, clinical diagnoses, and limitation factors all have a role in the decision to use fetal MR imaging. Fetal MR imaging is not widely available. In addition, evidence regarding safety aspects regarding the fetus have not been conclusive, which outlines an area for future study. Continued advances in research and techniques of fetal MR imaging will contribute to new possibilities and fewer limitations.

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