Fetal MRI. Part I: Neuroimaging

- MRI may provide additional information and influence patient management when fetal ultrasound suggests a potential for abnormalities
- Ultrafast single-shot spin-echo MRI techniques are used to minimize artifacts due to maternal and fetal motion
- Fetal MRI can:
  - Confirm the presence of ventriculomegaly and sometimes determine the cause
  - Demonstrate subtle findings in disorders of cerebral formation (including the holoprosencephaly spectrum) that may be difficult to identify with ultrasound
  - Better define malformations of the corpus callosum and associated anomalies
  - Improve evaluation of spine abnormalities and posterior fossa malformations

Routine examination of the developing fetus typically includes an ultrasound evaluation of the fetal central nervous system, including the skull shape, lateral ventricles, choroid plexuses, cavum septum pellucidi, thalami, cerebellum, cisterna magna, and spine. Interpretation of these images may be challenging because fetal organs may be incompletely developed at the time of routine ultrasounds at 14 and 18 weeks. Therefore, if a routine ultrasound reveals suspicious findings or if there is an increased risk of fetal anomalies, patients may be referred to a specialist in fetal neurosonography for further evaluation. However, ultrasound may not provide sufficient information because of shadowing from the calvarium, fetal presentation, oligohydramnios, or maternal obesity. In these cases, MRI is an option for further evaluation if additional information could influence management of the pregnancy.

MRI provides contiguous images of the brain and spine with excellent image contrast, yielding anatomical detail of the developing central nervous system, including structures such as the corpus callosum, brain stem, and pons that may be difficult to see with ultrasound. The risk-benefit ratio of fetal MRI is considered favorable; no harm has been identified from the magnetic field or the exposure to radiofrequency signals. However, theoretical concerns remain regarding the acoustic noise experienced by the fetus during imaging, the potential biological effects of magnetism, and the specific absorption ratio (SAR, a measure of energy deposition), which results in a small (<0.5°C) increase in body temperature during imaging. For this reason, 1.5T imaging is typically preferred to 3T imaging. Although the 2007 American College of Radiology guidance document for safe MRI practices states that
gadolinium may be used if absolutely essential and the risks and benefits of gadolinium use are discussed with the patient and her referring physician, gadolinium is never routinely administered for fetal MRI.

Fetal neuro MRI is most often performed in the latter part of the second trimester, between 18-24 weeks of gestational age. Most central nervous system anomalies are detected on the 18-week ultrasound survey and, once diagnosed, parental concern and considerations of termination result in referrals for fetal MRI soon after the ultrasound.

To minimize artifacts due to maternal and fetal motion, a single-shot fast spin-echo imaging sequence is used. Specialized MRI techniques, such as diffusion-weighted imaging or proton magnetic resonance spectroscopy, have the potential to provide insight into mechanisms of injury to the fetal brain; these sequences are, however, typically limited by fetal motion.

**Ventriculomegaly**

An ultrasound finding of ventriculomegaly is one of the most common indications for MRI. Ventriculomegaly can be an isolated abnormality or it can be found in association with central nervous system malformations, such as callosal malformations. It can also be secondary to aqueductal stenosis, atrophy, infection, infarction, chromosomal disorders, or genetic syndromes. The cause of hydrocephalus can be determined by MRI in approximately 60% of cases and may provide further diagnostic information than that from ultrasound. In one study, MRI confirmed the ultrasound finding of isolated ventriculomegaly in the majority of cases but detected additional brain abnormalities in 17% (n=147) of cases, most commonly agenesis of the corpus callosum. Confirmation of isolated mild ventriculomegaly suggests that the neurological outcome has a high likelihood of being favorable, whereas the identification of other malformations increases the likelihood of neurological abnormalities and a low survival rate.

**Holoprosencephaly Spectrum**

Holoprosencephaly (HPE) refers to a spectrum of malformations that often involve ventral forebrain patterning. HPE defects range from complete lack of hemisphere separation (alobar holoprosencephaly) to mild basal forebrain anomalies (septooptic dysplasia). This condition is more common in miscarried fetuses than live births. Alobar holoprosencephaly is considered fatal. Fetal MRI can demonstrate subtle findings in the holoprosencephaly spectrum that are challenging to visualize by ultrasound, including continuity of the cortex across the midline, subtle anomalies of the frontal horns of the lateral ventricles, and fusion of midline structures.
**Callosal Malformations**
Malformations of the corpus callosum can be detected by ultrasound by 18-20 weeks gestation. The outcome depends on whether the malformation is partial or complete and can range from normal or minor developmental delays to severe disability. Fetal MRI can be useful to assess the degree of malformation and to detect associated anomalies, which may be helpful for prognostic counseling.

**Posterior Fossa Abnormalities**
Posterior fossa malformations include the the Dandy Walker malformation and cerebellar and brain stem dysplasias. The cerebellar vermis is better defined by MRI than by by ultrasound; it is best imaged in the sagittal plane, which is more easily obtained by MRI. Rotation of a normally formed, non-dysplastic cerebellar vermis is thought to be benign. Demonstration of a dysplastic, abnormally formed cerebellar vermis, in particular one associated with additional brain abnormalities, is thought to carry a worse prognosis.

The Chiari II malformation is characterized by a small posterior fossa and a herniation of the hind brain through the foramen magnum into the upper cervical canal. Fetal MRI in the midline sagittal plane is the best means of viewing this abnormality, which may be associated with ventriculomegaly. Chiari II malformation is also associated with myelomeningocele, the most severe form of spina bifida. Patients with this condition may be candidates for in utero surgical repair, which has been shown to improve the outcome for the fetus, even though it increases the risk for both maternal and fetal complications.

**Other Anomalies**
Fetal MRI can also provide addition information on other brain malformations, including lissencephaly and polymicrogyria. The former results from a neural migration defect and is characterized by a smooth-surfaced brain. In the latter, the brain surface has a characteristic pattern of many small convolutions or gyri.

**Fetal MRI Technique**
Fetal MRI is usually conducted with the mother in the supine position. However, in late pregnancy a left lateral decubitus position may be preferred to avoid compression of the maternal inferior vena cava by the gravid uterus. The scan begins by obtaining orthogonal and sagittal images of the mother, from which the radiologist can determine the position of the fetus. The remaining sequences are designed to obtain orthogonal views (axial, sagittal, and coronal) of the fetus, using a T2-weighted ultrafast single-shot turbo spin-echo sequence that minimizes artifacts due to fetal and maternal motion.

**Scheduling**
The Neuroradiology Division at Mass General and MassGeneral Hospital for Children consider it crucial that fetal neuroMRI be supervised directly by an attending pediatric neuroradiologist, and thus fetal neuroMRI is only performed on the Mass General main campus in Boston. Studies can be ordered online via the Radiology Order Entry (ROE) system (http://mghroe) or by calling 617-724-XRAY (9729).
Further Information
For more information about fetal neuroimaging, please contact Paul Caruso, MD, Pediatric Neuroradiology, Massachusetts General Hospital, at 617-726-8320.

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References


