Fetal magnetic resonance imaging: a valuable diagnostic tool

Advances in MR technology have facilitated MR imaging of the fetus. While MR will not replace antenatal ultrasound, it is proving to be a useful adjunct in antenatal imaging. This article provides an overview of the advantages of fetal MRI compared with ultrasound, the technique used and safety issues. The article outlines the main indications for fetal MRI, based on a recent review of clinical experience at Children's University Hospital, Temple Street, Dublin, over the last five years.

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Keywords

fetal; MRI; antenatal imaging

Key points

Robinson I. Fetal magnetic resonance imaging: a valuable diagnostic tool. *Infant* 2009; 5(4): 124-26.

1. Advances in MRI technology, particularly the development of fast imaging techniques, have facilitated MR imaging of the fetus.
2. While ultrasound is the mainstay of antenatal imaging, fetal MRI is proving to be a valuable adjunct.
3. Fetal MRI is primarily used to confirm the presence or absence of a sonographically suspected abnormality. In addition to characterising the abnormality, it may also detect additional findings not identified by ultrasound.
4. Fetal MRI has been shown to have an impact on patient counselling and may result in changes to pregnancy management.

The first published report of magnetic resonance imaging (MRI) in pregnancy was in 1983[1]. Initial experience mainly centred on maternal and placental diseases. As MR technology evolved, assessment of the fetus beyond simple volumetric measurements became practical, with the early focus on fetal neuroimaging. Over the course of the last 25 years, fetal MRI has become an important adjunct in antenatal imaging in a wide variety of circumstances[2,6,7].

Antenatal ultrasound versus MRI

The mainstay of antenatal imaging is and will remain ultrasound, which is cheap, safe, readily available, relatively quick and, in experienced hands, accurate and reliable. There are limitations to ultrasound however, particularly with respect to imaging the fetal brain. Low liquor volume, fetal position (particularly with the fetal head engaged in the pelvis), difficulty in obtaining sagittal views, impaired visualisation of the near field on transverse views of the brain and shadowing from the overlying calvarium, may all contribute to diagnostic uncertainty. To some extent new ultrasound technologies, for example 3D ultrasound with sagittal reconstructions, have improved ultrasound's diagnostic accuracy.

Fetal MRI, with its superior contrast resolution and true multiplanar imaging, has proven itself a useful additional tool in antenatal imaging. In assessing the fetal brain it provides evaluation of midline structures, sulcation and cortical definition greatly superior to ultrasound. It has been shown to detect sonographically occult abnormalities in up to 50% of cases, affect patient counselling and result in changes to pregnancy management in nearly half of cases[2]. In recent years, fetal MRI has successfully expanded beyond the realms of neuroimaging to imaging of the chest and abdomen.

The major limitation of fetal MRI is fetal motion, which severely restricted early imaging attempts. It was really only in the 1990s that this was overcome with the advent of fast imaging techniques.

Further potential limitations of fetal MRI relate to the small size of the fetus and the relatively large distance of the fetus from the receiver coil, which conspire to reduce signal-to-noise ratio. Recent advances, particularly in coil design, have led to improvements in signal-to-noise ratio although this can still be a factor in small fetuses.

Technique

A typical fetal MR examination will take 30 to 45 minutes. The mother lies supine or in the left lateral decubitus position. Patient discomfort and claustrophobia can be an issue although with careful attention to preparation and positioning these can be minimised. The mother may fast for four hours prior to the examination to reduce postprandial fetal motion. Fetal sedation, by maternal oral benzodiazepine administration, is used in some centres.

The single shot fast spin echo T2 sequence, where a single T2 weighted image may be obtained in less than one second, is the principal imaging technique. Axial, sagittal and coronal planes are obtained. Each image is acquired separately so that fetal motion during acquisition will

affect only that particular image. T1 imaging time is still significantly longer than T2 and therefore is more susceptible to motion artefact, but is particularly useful in the detection of fat, calcification or haemorrhage. Diffusion-weighted imaging and spectroscopy applications in fetal MRI are also being developed[2] but are not yet in widespread use.

Safety

Maternal safety in MRI is as for any patient and the standard MRI screening precautions apply. With respect to the fetus, two potential issues have been raised – teratogenicity and acoustic damage[2,7]. Studies following up children who were imaged as fetuses are limited but have not shown any adverse long-term effect[3,4]. There is a paucity of evidence regarding the safety of MRI in early pregnancy. The United Kingdom National Radiological Protection Board advises against MR imaging in pregnant women during the first three months of pregnancy. Practically, due to the reduced signal-to-noise ratio and increased fetal movement in small fetuses, it is preferable to wait until the second and third trimesters. Studies addressing the potential for acoustic damage due to the loud noises generated by the coils of the MR scanner have concluded that the risk of injury is negligible[4,5]. In summary, fetal MRI in the second and third trimesters is considered safe. Intravenous contrast is not recommended in fetal MR imaging[2,7].

Indications

Fetal MRI is primarily used to confirm the presence or absence of a sonographically suspected abnormality. In addition to characterising the abnormality it may also detect additional findings not identified by ultrasound. Fetal MR has been used in some centres where the fetus is considered to be at high risk (for example due to family history of genetic disorder) even in the presence of a normal ultrasound[6].

Early fetal MRI focused primarily on neuroimaging, and this remains the most common fetal MR study. A recent review of early clinical experience at Children's University Hospital, Temple Street, Dublin, revealed that over the last five years the majority of fetal MRI examinations have been of the fetal brain (79%), with the next most common being fetal thorax (8%) and fetal spine (6%).

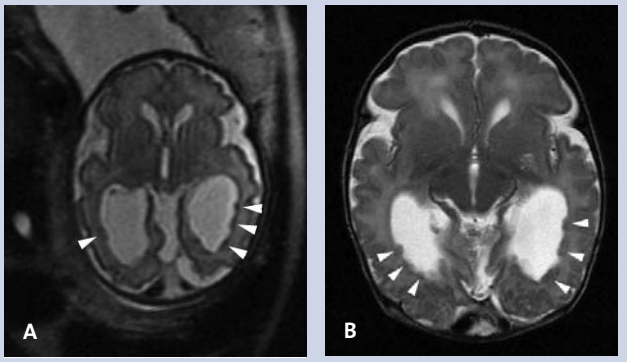


FIGURE 1a Fetal MRI axial SSFSE T2. Sonographically occult periventricular nodular heterotopia (arrowheads) in a fetus with ventriculomegaly.
FIGURE 1b Postnatal MRI axial T2. The postnatal MRI confirmed the fetal MR findings of periventricular nodular heterotopia (arrowheads).

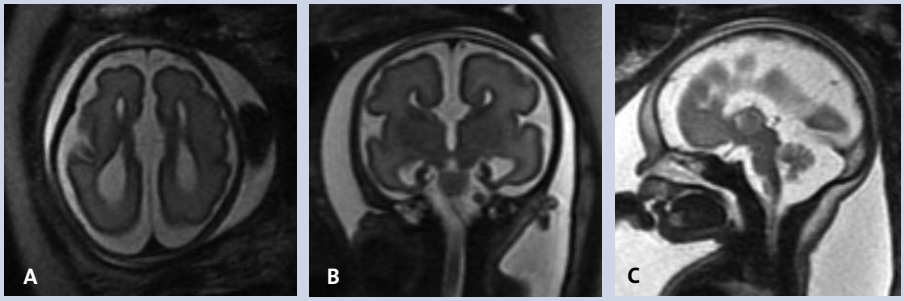


FIGURE 2a-c Fetal MRI axial, coronal and sagittal SSFSE T2. The multiplanar capability of MRI along with its improved contrast resolution allows for improved detection of agenesis of the corpus callosum.

MRI of the fetal brain

The three most common indications for MRI of the fetal brain were ventriculomegaly, abnormality of the corpus callosum and abnormality of the posterior fossa.

Ventriculomegaly

Forty-one per cent of fetal brain examinations were performed to assess sonographically detected ventriculomegaly. Between 15 to 35 weeks' gestation, the width of the atria of the ventricles is relatively constant and ventriculomegaly is defined on ultrasound as an atrial width greater than 10mm. A significant proportion of fetuses with ventriculomegaly may have an associated structural or chromosomal abnormality[7]. Many of the associated structural abnormalities, such as neural tube defects, Dandy-Walker syndrome and porencephaly, may be adequately assessed with ultrasound. However others such as agenesis of the corpus callosum, cortical malformations, periventricular nodular heterotopia (**FIGURE 1**), intracranial haemorrhage and holoprosencephaly spectrum are more accurately characterised with fetal MRI. The presence or absence of an associated abnormality has an important impact on prognosis as those with isolated ventriculomegaly have a better neurodevelopmental outcome[7].

Abnormalities of the corpus callosum

Ultrasound assessment of callosal abnormalities is often impaired as it is difficult to obtain a midline sagittal image to directly visualise the entire corpus callosum. A number of indirect signs such as lack of visualisation of the cavum septi pellucidi, parallel lateral ventricles, colpocephaly and high riding third ventricle may suggest the diagnosis. The multiplanar capability of MRI along with its improved contrast resolution allows for improved detection of abnormalities of the corpus callosum (**FIGURE 2**) and also provides an assessment of associated abnormalities which may have more of an impact on prognosis than the callosal dysgenesis itself.

Abnormalities of the posterior fossa

Fetal MRI may be used to assess posterior fossa abnormalities such as Dandy-Walker malformations, mega cisterna magna, arachnoid cyst, cerebellar haemorrhage and cerebellar hypoplasia/atrophy. With Dandy-Walker malformations, as with ventriculomegaly and callosal abnormalities, the incidence of associated abnormalities is high and may have a significant impact on prognosis.

MRI of the fetal thorax

In the fetal thorax MRI may be used to

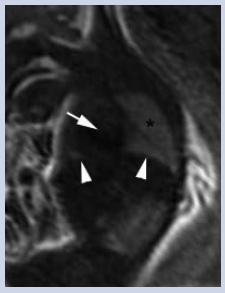


FIGURE 3a
Fetal MRI sagittal SSFSE T2 right hemithorax. Demonstrates normal lung (*) and diaphragmatic contour (arrowheads). The heart has been displaced into the right hemithorax (arrow).

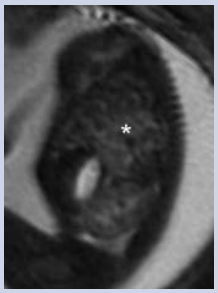


FIGURE 3b
Fetal MRI sagittal SSFSE T2 left hemithorax. Bowel (*) herniates through a large congenital diaphragmatic hernia into the left hemithorax.

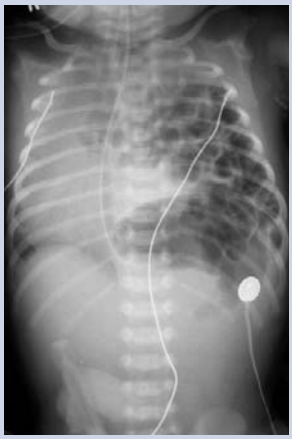


FIGURE 3c
Chest X-ray at birth confirms large left diaphragmatic hernia.

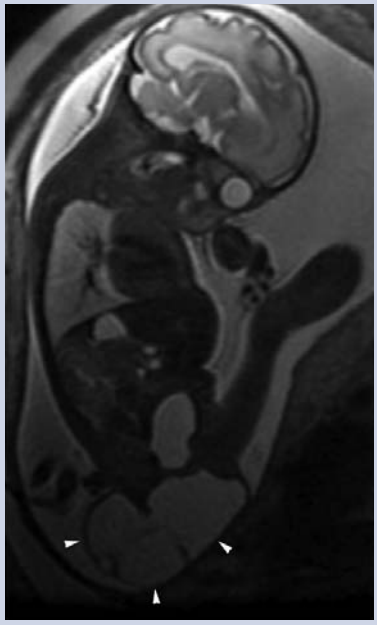
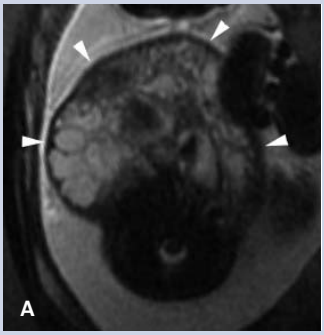


FIGURE 5
Fetal MRI sagittal SSFSE T2. A large predominantly cystic sacrococcygeal teratoma (arrowheads) with intrapelvic extension.

FIGURE 4a and 4b
Fetal MRI axial and sagittal SSFSE T2. A large multiloculated cystic hygroma (arrowheads) of the anterior neck intimately related to the trachea.



assess congenital diaphragmatic hernias, congenital cystadenomatoid malformations (CCAM) and pulmonary sequestrations. While ultrasound is relatively good at differentiating these entities, MRI is valuable in cases where there is diagnostic uncertainty. In cases of congenital diaphragmatic hernia (**FIGURE 3**), the position of the liver and degree of pulmonary hypoplasia, which are important prognostic indicators, are assessed. Differentiating CCAMs from sequestration can be difficult unless a visible feeding vessel from the aorta suggesting sequestration is seen[7].

MRI may also evaluate the fetal airway, for example in the case of a neck mass such as a cystic hygroma (**FIGURE 4**). This is particularly helpful when an EXIT (*ex utero* intrapartum treatment) procedure is being considered.

MRI of the fetal spine

Indications for MRI of the fetal spine include assessment of myelomeningocele and sacrococcygeal teratoma. The majority of cases of anomalies of the fetal spine are adequately assessed by antenatal ultrasound imaging. MRI is useful however in cases where ultrasound is limited by patient factors (for example large maternal body habitus or oligohydramnios). It is also used to assess the brain for associated abnormalities in cases of myelomeningocele[6]. The improved contrast resolution is helpful when assessing the degree of intrapelvic extension of a sacrococcygeal teratoma (**FIGURE 5**).

Conclusion

Over the past 25 years, fetal MRI has developed into a proven adjunct in antenatal imaging. It has been shown to detect sonographically occult abnormalities and affect patient counselling and pregnancy management[2]. While good quality ultrasound will always remain the mainstay of antenatal imaging, fetal MR is beneficial in a growing variety of clinical situations. Given the complex nature of many of these abnormalities and the different disciplines involved, good communication between fetal medicine physicians, neonatologists and radiologists is essential.

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Acknowledgement

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