Review Article

Foetal MRI: advances in the evaluation of the developing foetus

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Abstract

MRI assessment of the foetus has been around for 25 years although in routine practice only for the last few years. The tackling of the main challenge of foetal movement was paramount and with this aside the use of the technique has grown exponentially. Arguments related to safety and availability are often used against its routine implementation. However, for a number of specific indications, foetal MRI has been shown to be far better than ultrasound (U/S) and to make a difference in patient management. The role of the modality should be as a problem solver in foetal assessment.

Key words

Foetus, MRI, ultrasound

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Introduction

The first report in the literature describing 6 cases of foetal assessment by MRI originated from Aberdeen, Scotland and dates way back to 1983.[1] The fact that MRI, in a similar manner to Ultrasound (U/S), does not employ ionising radiation lends itself to examining the developing foetus and research on the matter has been performed ever since. Challenges mostly related to foetal movement limited its use but advances over the last 10 years have seen MRI grow exponentially in obstetric evaluation.

Practical issues

T2 weighted images are provided by Single Shot Fast Spin Echo (SSFSE) sequences whilst Fast Multiplanar Spoiled Gradient-Recalled imaging provides T1 weighted images.[2-4] The important difference is that these sequences allow the scanner to obtain images rapidly and individually.[5] This is unlike the standard MR sequences where movement during sequence acquisition, which normally takes a few minutes, results in suboptimal imaging of the whole series of images. Previous methods relied on decreasing foetal movement by maternal sedation or injection into the umbilical cord.[6] Such methods are now obsolete[7] and this made the test more safe and justifiable.

In practice, image acquisition in a foetal scan, often results in trial and error with repeatedly orienting the imaging parameters and planes to new positions adopted by the foetus as the scan is undergone. Estimating the exact time of duration of such a scan is therefore difficult and often a practical issue when running a busy list. These foetal scans are generally fitted amongst paediatric patients and with small children requiring sedation or general anaesthesia for MR scanning, timing of the duration is of considerable importance. In practical terms, in a busy paediatric radiology setting, these scans are best timed to be last on the list.

Although the recently developed single shot sequences shorten time consumption by decreasing the number of non diagnostic attempts secondary to movement, the average time of a scan is still 45 to 60 minutes making the investigation very costly. Such a scan time is dependant by the area of the foetus one is focussing on and the question to be answered. Often the scan is targeted on one part of the body (brain/chest/abdomen) where a potential abnormality was seen on U/S. It is however still recommended to evaluate the whole foetus due to the possibility of associated anomalies.[2] Time constraints and

availability make this a difficult target. Therefore, planning is vital. A multidisciplinary team meeting approach with involvement of the physicists, radiographers and radiologists is recommended.[8]

Recognised indications

Obstetric U/S has a number of areas where appropriate visualisation is deficient due to due limitations of the modality itself. MRI lends itself here as a problem solver.

- The majority of initial research and literature concentrated on visualising the brain. U/S travels poorly through bone. Parts of the cranium, mostly the posterior fossa, can be challenging to visualise in detail.[9] Whitby *et al*. reported a 47% difference in findings between U/S and MRI in foetuses thought to have brain abnormalities on U/S. Where concordant with the U/S findings, MRI detected additional findings in 25% of the cases scanned.[10]
- Bone is again a barrier in cleft lip cases. The hard palate prevents obtaining detail of the soft palate in such cases on U/S. Evaluation by U/S is also dependant on amniotic fluid volume, foetus position and maternal stature. MRI can give further detail and confidence in the diagnosis.[11]
- Lung abnormalities are also shown to be far better evaluated by MRI. Lung volumes can be estimated in cases of diaphragmatic hernia. Inter observer variability has been found to be significantly less when estimating lung volumes by MRI rather than by U/S.[12] Elevation of the liver into the chest can be confirmed or refuted with confidence. This additional information has significant predictive survival correlation and allows early surgical planning.[13]
- When potential airway compromising abnormalities, such as cystic hygromas are detected on antenatal U/S, MRI allows further detail and higher diagnostic confidence allowing improved delivery choices and immediate post natal decision planning.[14-15]

Objections

MRI table time is very expensive. One may argue that foetal MRI is time consuming and when compared to a good detailed obstetric scan yields little more information. A similar argument often presented is that little change in management results with the extra information the MRI scan offers compared to obstetric U/S. Therefore, it would make more sense to limit MRI use in pregnancy, focus on better U/S scanners and skills and allow more MRI time to be freed for other indications.

Whilst some of the above is true, and consequently routine foetal MRI is not justified, MRI, as outlined above, can be far superior in the evaluation of certain anomalies. US scanners are freely available, small, mobile and many medical and allied specialists are highly trained in the field. Therefore, experience and confidence is relatively easy to obtain. MRI, on the other hand, is limited by place, time and particularly with foetal cases, availability of experienced MR radiographers.

Interpretation poses another challenge. The ultrafast sequences required during foetal assessment have been reported to have a sensitivity of 78% and a specificity of 98% when compared to the standard techniques available postnatally.[16] Although not as detailed as the standard MRI sequences, the neurological information, especially in later pregnancy, is similar and apart from the depth of pathologies this opens itself to, one has to individually develop a database of normal appearances throughout the gestational age of the developing foetus. The latter was definitely the hardest challenge in the expansion of the modality and the main focus of research for the last few years.[17] This is particularly more relevant with imaging the developing brain.

Safety

Primum non nocere is the foremost rule of every health professional. This is particularly vital with the developing foetus and a point of discussion in arguments against routine scanning particularly early in pregnancy. Apart from the standard risks the MRI scanner can pose to the mother, the additional potential risks to the foetus are two fold: a potential teratogenic risk and damage to hearing from the acoustic insult during the scan.[4]

The foetus is more sensitive to heat changes and elevated body temperature in the mother or foetus has been shown to be teratogenic in animal studies.[18] The central nervous system is thought to be particularly sensitive to heat. A series of studies on children who had undergone MRI *in utero* have reported this to be safe. Or rather, to date there has been no published evidence that the energy levels presently in use pose a risk to the foetus.[4,19-22] With a small number of studies showing potential risk in animal studies, the National Radiology Protection Board (NRPB) in the UK still advises the use of *in utero* MRI to be limited to the second and third trimester.[23]

Conclusion

Foetal MRI has been shown to be safe in later pregnancy. In recognised scenarios it provides invaluable information which results in significant changes in patient management. In the adequate provision of foetal assessment, it has become an indispensable problem solving adjunct to U/S.

References

1. Smith FW, Adam AH, Phillips WDP. NMR imaging in pregnancy (Letter). Lancet 1983;1:61-6.
2. Prayer D, Brugger P, Prayer L. Fetal MRI: techniques and protocols. Pedatric radiology. 2004;34:685-93.
3. Huppert B, Brandt K, Ramin K, King B. Single shot fast spin echo imaging of the fetus-a pictorial review. Radiographics 1999;19:215-27.
4. Coakley FV, Glenn OA, Qayyum A, Barkovich AJ, Goldstein R, Filly RA. Fetal MRI: A developing technique for the developing patient. AJR 2004;182:243-52.
5. Glastonbury CM, Kennedy AM. Pictorial Essay: Ultrafast MRI of the fetus. Australasian Radiology. 2002;46:22-32.
6. Girard N, Reybaud C, Dercole C, Boubli L, Chau C, Cahen S *et al. In vivo* MRI of the fetal brain. Neuroradiology 1993;35:431-6.
7. Levine D. Fetal Magnetic Resonance Imaging: Editorial. Topics in Magnetic Resonance Imaging 2001;12:1-2.

8. Morris J, Whitby E, Paley M. Magnetic Resonance Imaging of the Fetus: Physicists', Technologists' and Radiologists' Perspectives. Imaging Decisions MRI 2005;9:2-7.
9. Levine D, Barnes PD, Madsen JR, Li W, Edelman RR. Fetal central nervous system anomalies: MR imaging augments sonographic diagnosis. Radiology.1997;204:635-42.
10. Whitby E, Paley MN, Davies N, Sprigg A, Griffiths PD. Ultrafast magnetic resonance imaging of central nervous system abnormalities in utero in the second and third trimester of pregnancy: comparison with ultrasound. International Journal of Obstetrics and Gynaecology. 2001;108:519-26.
11. Stroustrup Smith A, Estroff JA, Barnewolt CE, Mulliken JB, Levine D: Prenatal diagnosis of cleft lip and palate using MRI. AJR 2004;183:229-35.
12. Paek BW, Coakley FV, Lu Y, Filly RA, Lopoo JB, Qayyum A *et al*. Congenital diaphragmatic hernia: prenatal evaluation with MR lung volumetry – Preliminary experience. Radiology 2001;220:63-7.
13. Walsh DS, Hubbard AM, Olutoye O, Howell LJ, Crombleholme TM, Flake AW *et al*. Assessment of fetal lung volumes and liver herniation with magnetic resonance imaging in congenital diaphragmatic hernia. American Journal of Obstetrics & Gynecology. 2000;183:1067-9.
14. Kathary N, Bulas DI, Newman KD, Schonberg RL. MRI imaging of fetal neck masses with airway compromise: utility in delivery planning. Pediatric Radiology. 2001;31:727-31.
15. Morof D, Levine D, Grable I, Barnewolt C, Estroff J, Fishman S. *et al*. Oropharyngeal teratoma: prenatal diagnosis and assessment using sonography, MRI and CT with management *Ex Utero* intrapartum treatment procedure. AJR 2004;183:493-6.
16. Singh RK, Smith JT, Wilkinson ID, Griffiths PD. Ultrafast MR Imaging in Pediatric Neuroradiology. Acta Radiologica 2003;44:550-7.
17. Garel C, Chantrel E, Elmaleh M, Brisse H, Sebag G. Fetal MRI: normal gestational landmarks for cerebral biometry, gyration and myelination. Child's nervous system. 2003;19:422-5.
18. National Radiological Protection Board. Review of Scientific evidence for limiting exposure to electronic fields: Documents of the NRPB. 2004;15(3). London England: H.M. Stationery office.
19. Clements H, Duncan KR, Fielding K, Gowland PA, Johnson IR, Baker PN. Infants exposed to MRI in utero have a normal paediatric assessment at 9 months of age. BJR. 2000;73:190-4.
20. Levine D, Zuo C, Faro CB, Chen Q. Potential heating effect in the gravid uterus during MR HASTE imaging. J Magn Reson Imaging.2001;13:856-61.
21. Levine D. Fetal MRI: MRI safety and informed consent. Atlas of fetal MRI. Available from: http://bidmc.harvard.edu/content/bidmc/departments/radiology/files/fetalatlas/appendicies/safety/safety.html (accessed on 5th November 2007).
22. Baker PN, Johnson IR, Harvey PR, Gowland PA, Mansfield P. A three-year follow-up of children imaged in utero with echo-planar magnetic resonance. Am J Obstet Gynecol. 1994; 170:32-3.
23. National Radiological Protection Board. Principles for the protection of patients and volunteers during clinical magnetic resonance diagnostic procedures: Documents of the NRPB. 1991;2. London, England: HM Stationery Office.