

Review Article

Fetal MRI: an essential step in interpreting complex ultrasound findings

Ian Baldacchino, Isabelle Saliba, André Stefan Gatt

Abstract

Background: Fetal magnetic resonance imaging (MRI) allows for the interpretation of complex fetal anomalies detected on ultrasound (US). Locally it has been available since 2013 but has remained underused.

Method: In this paper we report the US and MRI findings of all cases of fetal MRI that were taken to date locally and how MRI can contribute to the clarification of malformations, management, counseling, evaluation of prognosis and ruling out of other possible malformations.

Results: The cases reported were: two cases of hydroureter; gastroschisis; ventriculomegaly; intracranial haemorrhage; splenic cyst; Arnold Chiari II malformation. In all seven cases MRI was able to add to or change the diagnosis.

Conclusion: Fetal MRI acts as an adjunct to US in interpreting abnormal fetal development. It is a safe non-invasive method of imaging that allows the clinician to take more informed decisions and better parental counselling.

MeSH terms

Child, Counseling, Magnetic Resonance Imaging, Pregnancy, Prognosis.

Introduction

Locally fetal magnetic resonance imaging (MRI) has been available since 2013. This allows for the possibility of interpreting fetal anomalies detected on ultrasound (US). In this paper we report all fetal MRIs taken to date locally.

Routine US is first line in detecting fetal anomalies being fast, safe, inexpensive and avoiding any form of ionizing radiation. It cannot however give more subtle information when attempting to focus on a specific organ or region of fetal anatomy and is limited by the experience of the user, maternal obesity and oligohydramnios.^{24,27} MRI also has its downfalls being hindered by fetal movements, requiring a long scan time of 50-60 minutes and fasting period of two hours.

Fetal US

Fetal US employs high frequency pulsed sound. The propagating waves encounter different tissues and are reflected back to be picked up by a transducer. The waves are then depicted on a screen which allows the interpreter to see the strength of the signal and its position. Safety during the first trimester is ensured by employing lower power output devices and ensuring a short 'dwell time' over a particular target.²⁹ US in pregnancy is indicated for two main reasons: routine US screening; diagnostic examination following identification of abnormal growth, complications during pregnancy and risk factors for fetal malformation. Early first trimester US (<24 weeks) aims at planning the pregnancy by giving a better evaluation of gestational age and identifying multiple pregnancies and has demonstrated a reduction in the rates of medical inductions. Routine US in later pregnancy is not recommended.⁸

Ian Baldacchino M.D.*

Specialist Training Programme in Family Medicine,
Malta
ian.baldacchino@gov.mt

Isabelle Saliba M.D., F.R.C.O.G.

Department of Obstetrics and Gynaecology,
Mater Dei Hospital, Malta

André Stefan Gatt M.R.C.S., F.R.C.R.

Medical Imaging Department,
Mater Dei Hospital, Malta

*Corresponding Author

Fetal MRI indications

The decision to undertake fetal MRI is dependent on the following care decisions:

1. The decision about treatment, mode of delivery, eventual prognosis and parental counselling, can be clarified further when US is not enough to confirm diagnosis
2. When the abnormality detected on US appears complex and the physician wishes to make more better informed decisions about patient care
3. There is a considerable risk for abnormality of the fetus even if US scans are normal.¹³

More specific indications are listed in Table 1 but each case merits its own individual attention.

Fetal development in MRI

Fluid filled organs including the oesophagus, bowels and bladder appear hyperintense on T2-weighted MRI and hypointense on T1-weighted MRI containing mineral and protein rich meconium produced after 13 weeks gestation (WG). Therefore bowel situated outside the body will transmit these appearances respectively.¹² The liver similarly is rich in iron as well as other minerals such as zinc and will show alike T1- and T2- appearances. It has a characteristic moderately dark structure on T2-weighted MRI.^{22,26} A homogenous signal can be detected on T2 weighted images when assessing for the spleen after 20WG appearing hypointense on T1- and hyperintense on T2- weighted images.²² Renal abnormalities may account up to 14-40% of prenatal abnormalities and is often accompanied by deficiencies in liquor volume. MRI can be useful in clarifying the severity of disease and confirm the presence or absence of structures.^{1,5-6,10} Therefore the diagnosis and management of cases can be changed as MRI was more adequate in assessing the size and degree of hydronephrosis identified by higher signals on balanced fast field echo (bFFE) and single shot sequences.^{10,21}

Fetal brain anomalies identified on ultrasound often still remain indeterminate in nature. Also ultrasound reverberations onto the more anterior hemisphere from overlying bony structures interferes with optimal visualisation allowing only the more distal hemisphere to be visualized. Later on the ossifying calvaria make fetal MRI a more

tempting alternative.^{15,27} Ventriculomegaly is the commonest non-specific finding on fetal central nervous system (CNS) ultrasound which can indicate other conditions that can be diagnosed by MRI.³ Prenatal sonography can then go on to interpret other findings in 80% of cases associated with other syndromes such as Dandy-Walker complex, lissencephaly etc however cortical abnormalities such as agenesis of the corpus callosum, cortical malformations, intraventricular haemorrhage etc still remain sonographically occult, being identified only on MRI.^{16-17,27}

MRI preparation

Fetal MRI predominantly applies T2-weighted imaging. Single shot fast spin-echo (SSFE) is the most useful modality providing T2-weighted images that capture cross-sectional segments which may be disrupted by fetal movements.²⁴ When required, Fast Multiplanar Spoiled Gradient-Recalled imaging provides T1-weighted images for identification of fat, haemorrhage and calcification.^{9,18,23,28}

Fetal MRI images were obtained on a 1.5 Tesla scanner (GE Healthcare, Milwaukee, Twin Speed version HDX). The patient is asked to fast for two hours to minimise fetal movement artefacts and then positioned supine wearing an 8 channel torso coil. A 3 planar localizer is used. Calibration: Coronal SSFSE ARC; Sagittal SSFSE ARC; Axial SSFSE ARC.

Fetal MRI ethics

The pediatric society of radiology recommends that fetal MRI be performed after 18 weeks gestation (WG). Effects on the developing fetus are still unknown. The use of contrast is also not recommended for its safety during pregnancy has not yet been adequately studied. So far however there have been no reported adverse effects on fetal and maternal outcomes during pregnancy in this aspect or on human tissue.^{13,25} Other recommendations specify waiting till at least 22WG as knowledge on the subject is still lacking, also small size and excessive motion of young fetuses make imaging difficult to interpret.¹⁶

Table 1: Indications for fetal MRI ^{4,20}

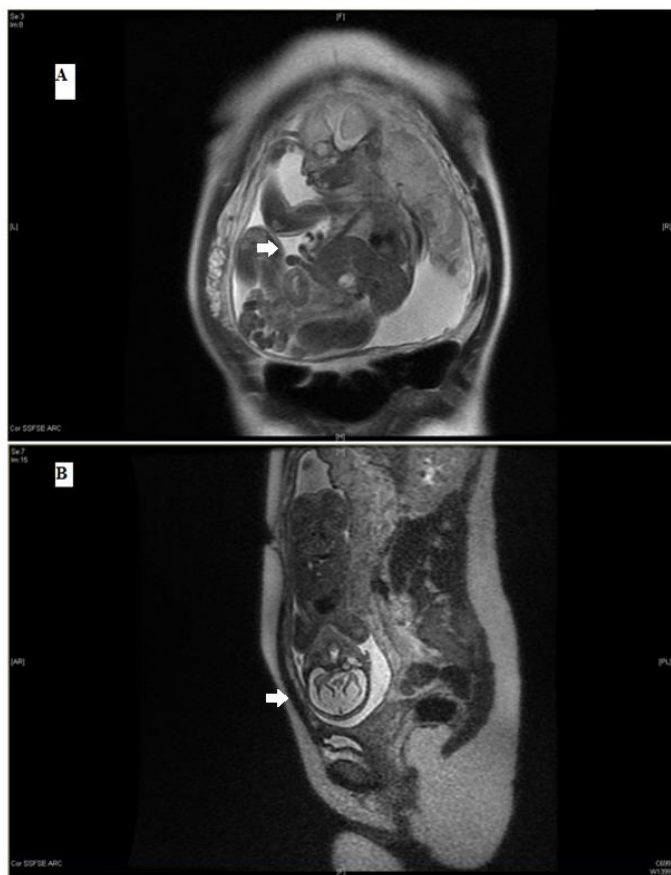
System	Main indication category.	Subcategory
Central nervous system.	Brain development.	cell density, myelination.
	Vascular anomalies.	haemorrhage, ischaemic lesions, mono chorionic twin pregnancy complications
	Screening fetuses with a family risk of brain anomalies.	Tuberous sclerosis, corpus callosum developmental anomalies.
Fetal oropharynx and face.	Airway patency.	Reviewing compromise by masses, mandibular or facial malformations.
	Confirm or diagnose isolated cleft of the posterior palate.	
	Other anomalies.	Atypical facial clefts, retrognathia, micrognathia, craiosynostosis, cephaloceles, vascular anomalies, tumours, microphthalmia, other ocular and orbital anomalies.
Neck.	Masses relative to fetal airway.	Assist in managing delivery, assess fetal goiter and thyroid neck masses.
Thoracic anomalies.	Provide more information for counselling and management on malformations.	Bronchopulmonary sequestration, congenital pulmonary adenomatoid malformation, oesophageal atresia.
	Congenital diaphragmatic hernia.	Evaluate lung volume and presence of liver and intra-abdominal organs in the thorax. Assess lung growth.
Fetal heart.		Fetal echocardiography remains the method of choice for screening and evaluation of anomalies.
Intra-abdominal anomalies.	Masses.	Reserved for when US cannot provide information for adequate counselling or management. Review of cystic or solid masses including tumours.
	Urogenital tract.	Readily visualized on US however low liquor volume, fetal position may distort adequate assessment. MRI can help in this situation.
Extremities and Bone.		US is imaging of choice however MRI sequences have also been developed.
Spine.	Congenital anomalies.	US is modality of choice to screen for neural tube defects. Suspected anomalies can be confirmed on MRI including neural tube defects, sacrococcygeal teratomas, vertebral anomalies.
Complications of mono chorionic twins.		Assess vascular anatomy; review co-twin for morbidity; review anatomy in cojoined twins.

Case reports

Case 1: 28WG with confirmed gastroschisis on ultrasound showing a 7mm defect on the right side of the umbilicus. On fetal MRI the defect was evidently much larger. It was able to also detect partial herniation of the right lobe of the liver and right kidney as well as herniation of multiple small bowel loops and the dome of the urinary bladder. Diaphragmatic hernias and pulmonary dysplasia were excluded. Perinatal care was planned for. (Figure 1A)

Case 2: A 23WG investigated for the demise of one twin which was accompanied by ventriculomegaly in the second twin on US. MRI confirmed ventriculomegaly as well as enlargement of the extra-axial spaces. There was also however marked thinning (perceived absence) of large areas of the supratentorial cortex which represented extensive cortical loss through infarction. (Figure 1B)

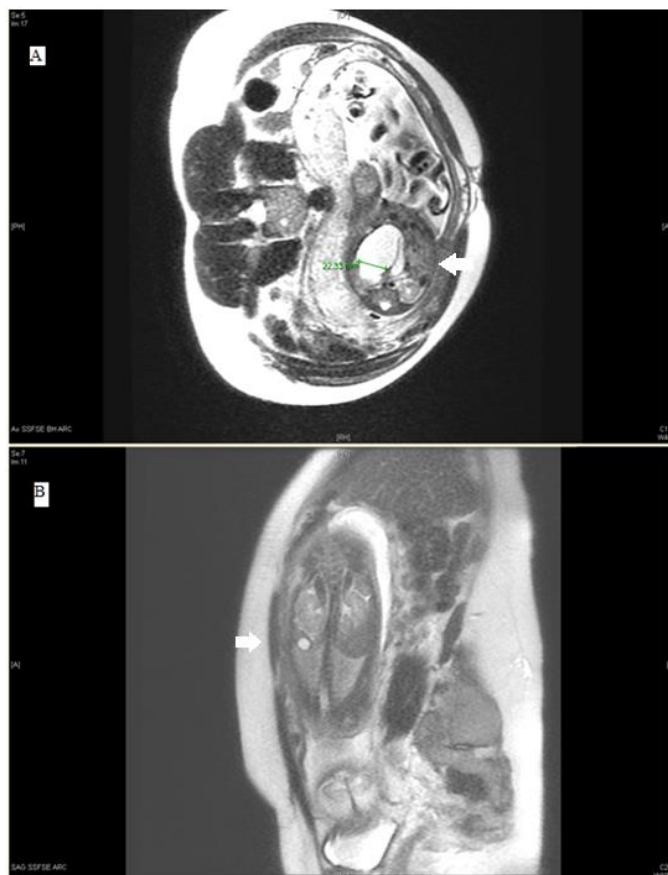
Figure 1(A): *Gastroschisis depicting herniation of multiple bowel loops and dome of urinary bladder*
(B): *Ventriculomegaly and thinning of the cerebral cortex consistent with infarction*



Case 3: 24WG identified with an enlarged right sided kidney and findings indicative of obstruction. The MRI was able to confirm the diagnosis the degree of hydronephrosis (Figure 2A). The size and orientation of the kidneys was confirmed as well as the architecture of the right kidney.

Case 4: A cystic lesion was identified behind the stomach on US however the exact detail as to which organ was involved was inconclusive. Fetal MRI corroborated this with a 10mm cyst lying in the upper pole of the spleen consistent with a simple splenic cyst. It was also able to rule out other organs being involved and confirmed the benign nature. (Figure 2B)

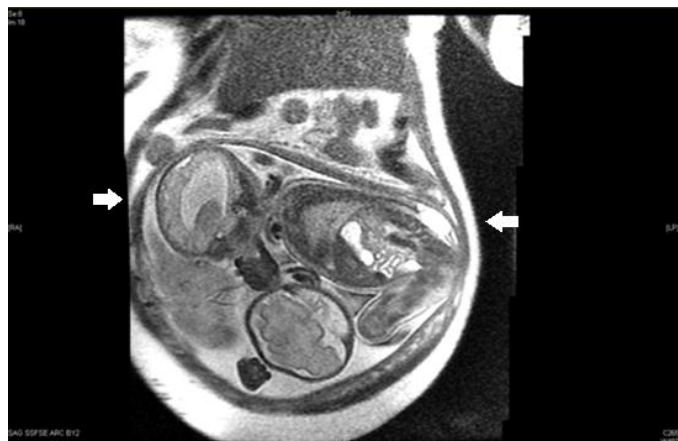
Figure 2: (A) *Marked hydronephrosis of the right kidney* **(B)** *Splenic cyst*



Case 5: A lower lumbar lesion was identified on a twin consistent with spina bifida. MRI demonstrated a lumbosacral myelomeningocele and meningeal sac as well. It also added that there was associated hydrocephalus and cerebellar tonsillar herniation diagnosing a Chiari II malformation (Figure 3A). No abnormalities were identified in the other twin. The anomaly was confirmed at birth and

the twin transferred to a more supportive unit.

Figure 3: Sagittal view depicted hydrocephalus and cerebellar tonsillar herniation – Chiari II malformation and myelomeningocele



Case 6: 23WG presented with sudden increase in biparietal diameter (BPD) which was reported as fetal hydrocephalus on ultrasound with skull bossing. An anechoic cystic structure in the cerebellum possibly obstructing the fourth ventricle was also identified. MRI was able to confirm a right sided haemorrhage associated with smaller blood products in the contralateral ventricles suggesting a communicating hydrocephalus secondary to blood products (Figure 4A and 4B). The diagnosis was changed as well as the management of the case.

Case 7: 26WG referred in view of dilatation of both kidneys on ultrasound. The right renal collecting system was however reported as normal on MRI however the left side was only mildly dilated. The prognosis of the case therefore improved and ruled out obstructive pathology involving the bladder and ureters. The case required simple follow up.

Discussion

In the seven cases presented all had an initial anomaly that was identified by US. In all cases MRI was able to add to or change the diagnosis.

In the first case US was only able to report a small defect of 7mm. MRI however confirmed a more appropriate 7cm opening along with several viscera herniating outside the abdominal cavity. This anomaly arises from a discrepancy in the space allocated for the viscera and the viscera in the abdominal cavity, and can also be associated with other respiratory complications.

Figure 4: (A) Axial view showing left sided brain dilatation pushing against the skull vault (B) Sagittal view showing extent of haemorrhage

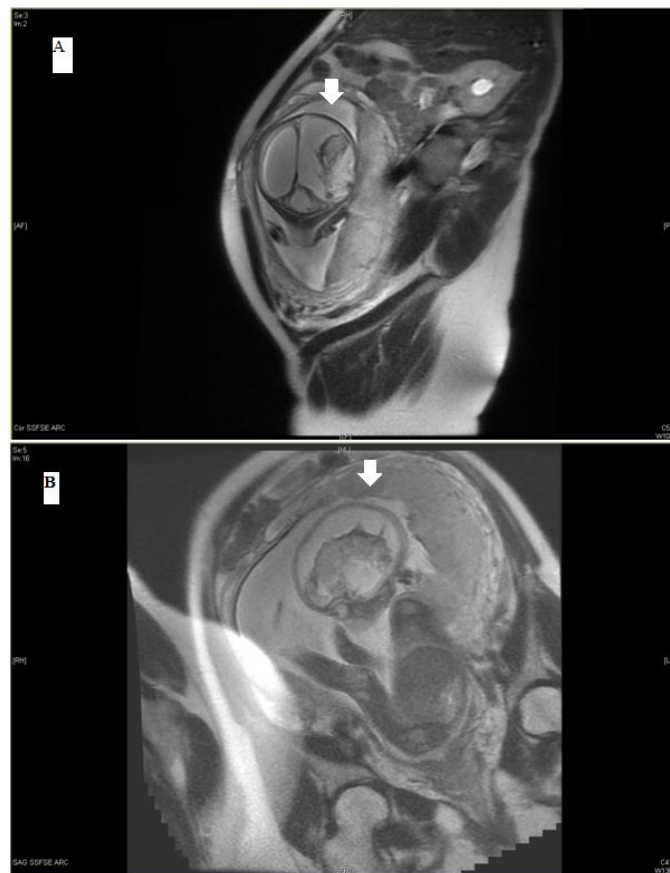
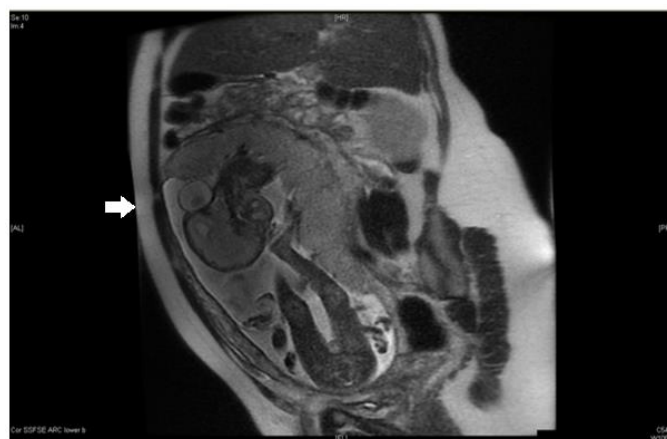


Figure 5: Meningoencephalocele containing part of the cerebellum



Gastroschisis is a defect which affects all the layers of the abdominal wall (in contrast to omphalocele where the abdominal organs fail to return into the abdominal cavity at 11WG). At birth the main concerns are the stabilization of the patient and the exclusion of other congenital anomalies.¹⁵ In the UK the preferred means of correction is by silo followed by surgical corrective means. The size

of the defect, presence of intestinal atresia, intestinal necrosis or perforation which are usually evident at birth and are associated with gastroschisis influence which method, be it surgical or silo repair, be undertaken.⁷ The latter were evaluated for by MRI.

Cases 2 and 7 displayed abnormal renal findings. The 'Multidisciplinary consensus on the classification of prenatal and postnatal urinary tract dilatation' reports that the anterior – posterior renal pelvis diameters (APRPD) are reported as abnormal if ≥ 4 mm in the second trimester and ≥ 7 mm at 32WG. If the APRPD is ≥ 7 mm at 32WG there was a general consensus recommending postnatal radiological evaluation. If the APRPD ≥ 10 mm after 48 hours postnatally it was considered as abnormal. Milder degrees of dilatation may still require follow up even later on in life with a diameter of 3mm being normal for a one year old and 6mm for a six year old (values based on MRI measurement). It was also observed that progressive urinary tract dilatation during pregnancy (rather than lack of regression) was more associated with uropathies. The management would then include follow up ultrasonography and consideration of surgical or medical intervention (ex antibiotic prophylaxis).¹⁹

Central nervous system and spinal anomalies such as Arnold Chiari malformations and cerebral haemorrhage are confirmed via MRI. Echogenic structures such as blood clots (referring to case 6) could be interpreted for cystic structures and are clarified on MRI. MRI is clearer in cases of intracranial haemorrhage and more accurate than US with worse grading after MRI was performed.¹¹ In this way expecting parents are counseled about the possible outcomes, management available and prognosis. Specialised obstetric care and birth management can be planned ahead. Nearly all myelomeningoceles have the Arnold-Chiari II malformation which is associated with other antenatal anomalies and long term disability. Options include prenatal or postnatal correction of the meningocele. The former has to be balanced against the risk of preterm delivery and maternal morbidity.² Case 6 was then confirmed to be a case of intracranial haemorrhage, shifting the diagnosis from a structural cause. Drug exposure, viral infection and thrombotic causes were excluded eventually leading to the detection of severe fetal thrombocytopenia when fetal blood sampling was carried out.

Conclusion

Fetal MRI acts as an adjunct to US in interpreting abnormal fetal development. It is a safe non-invasive method of imaging that allows the clinician to take more informed decisions and better parental counselling.

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