

Ultrasound *vs* MRI in Diagnosis of Fetal and Maternal Complications

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ABSTRACT

Ultrasound is the screening modality of choice for the fetal imaging. However, there are circumstances in which an alternative imaging technique is needed for additional information regarding fetal anatomy and pathology as well as different maternal conditions.

Magnetic resonance imaging (MRI) is being increasingly used as correlative imaging modality in pregnancy because it uses no ionizing radiation, provides excellent soft-tissue contrast, and has multiple planes for reconstruction and large field of view, allowing better depiction of anatomy in fetuses with large or complex anomalies.

In this review, we attempted to identify strengths and weaknesses of each modality both from the literature and our own working experience, and to propose to some practical recommendations on when to use which imaging modality.

Both ultrasonography and MRI are operator-dependant and neither technique obviates the need for thorough knowledge of normal and abnormal anatomy. In early pregnancy, and where repeated assessment is needed, ultrasound has the obvious advantage. In circumstances where ultrasound examination is difficult, as in the obese patient or severe oligohydramnion, better images might be obtained by MRI examination. MRI might also identify early fetal ischemic lesions after an insult, such as maternal trauma or death of a monochorionic co-twin. From the published literature, it would appear that MRI may provide additional diagnostic information to that given by ultrasound in 25 to 55% of cases, which in turn may have influence on parental counseling and/or management of affected pregnancies. Individual circumstances and expertise influence the accuracy of both modalities. Ultrasound and MRI should be performed to the highest possible standard, and the final diagnosis should be made in a multidisciplinary setting.

Keywords: Ultrasound, MRI, Fetal imaging, Prenatal diagnosis.

INTRODUCTION

Ultrasonography (US) is the technique of choice for the screening of anomalies because it provides images in real time with excellent spatial resolution and presents no risks to mother or fetus. It is nonetheless an operator-dependent technique, which in some cases is limited by technical difficulties originating both from the mother and the fetus. Maternal size, image resolution, fetal position and amniotic fluid restriction can all affect the ability to establish an optimal imaging diagnosis. In addition, in complex fetal anomalies, US is not always able to provide sufficient diagnostic information in terms of management of the pregnant patient.

The growing number of cases of litigation brought against the gynecologist has led to the use of additional imaging techniques to complement US. Magnetic resonance imaging (MRI) can be used as a second-line technique and an adjunct to US in the study of obstetric disorders, and in particular to assess a number of pathologies affecting the fetus, the gravid uterus and the placenta.¹ Obstetric MRI is able to provide detailed information, thanks to the high spatial and contrast resolution

of latest-generation, ultrafast sequences and multiplanar capabilities. Whereas it is not strictly an operator-dependent technique, it's effective use is nonetheless conditioned by an excellent understanding of normal fetal anatomy. To date, it has not been shown that MRI is capable of causing damage to the fetus in fields lower than 1.5 T. The main international guidelines (Safety Committee of the Society of Magnetic Resonance Imaging), however, advise that the examination should be performed in the second or third trimester of gestation when a preliminary US examination proves inadequate or inconclusive.

MRI tissue contrast is influenced by the fat, water content and proton density of tissue. The signals can be enhanced or suppressed by manipulating the repetition time or echo time, or by using specific techniques to nullify the fat or water signal.¹ Fast, ultra-fast and real-time sequences have made fetal imaging possible without the need for fetal paralysis,² although sedation is still used sometimes.³ T2-weighted imaging is typically used to demonstrate fetal anatomy, while T1-weighted imaging is useful to depict hemorrhages, calcifications or lipomas,⁴ and

also cortical plate, brain stem and basal ganglia in late gestation. Diffusion-weighted imaging (DWI) is sensitive for the detection of hypoxic/ischemic brain lesions and useful for the identification of premyelinating structures, such as corpus callosum in early pregnancy.⁴

Numerous studies compared the use of ultrasound with MRI in the diagnosis of fetal anomalies. From the published literature, it appears that MRI may provide additional diagnostic information to that given by ultrasound in 25 to 55% of cases, which in turn would impact parental counseling and/or management of affected pregnancies.⁵⁻¹¹ MRI seems most consistently useful in characterizing fetal anomalies involving the central nervous system.^{5,6,8,12-14}

In general, fetal MRI is indicated after 18th gestational week, although subtle disorders might not be visible earlier than 23rd week. Due to these facts, the recommended time window to perform fetal MRI is between 23 and 32 weeks of gestations.¹⁵

With improved image acquisition by real-time ultrasound and the addition of 3D techniques, there is a continued need to evaluate when additional imaging, such as with MRI, will add value in the diagnosis of prenatally detected fetal anomalies.

Central Nervous System

MRI for evaluation of central nervous system (CNS) anomalies is indicated when there is suspicion of cerebral, cerebellar or spinal malformation, space occupying lesion, disorders of cortical development or possible hemorrhage. CNS anomalies occur with an estimated incidence of one per 100 birth, and accurate early diagnosis is imperative for counseling, management and adequate therapeutic choices. MRI has been useful in confirming abnormalities seen on ultrasound or determining the underlying cause of nonspecific sonographic abnormalities.¹⁶ A detailed MRI examination for possible CNS anomaly includes evaluation of the third, fourth and lateral ventricles, posterior fossa, corpus callosum, brain parenchyma, cerebral cortex and the degree of gyration, and the entire spine.

Ventriculomegaly represents the most frequent brain abnormality observed in fetuses. Its pathophysiology remains poorly understood and its etiology is quite variable. In about 60% of cases¹⁷ the ventriculomegaly is isolated and its prognosis depends for the most part on the scale of the ventricular dilatation and the presence of associated extracerebral or cerebral abnormalities.¹⁷ It is now accepted that MRI plays an important part in treatment of ventriculomegaly and the detection of associated cerebral abnormalities.¹⁸

When MRI is done at 21 to 37 weeks after the sonographic diagnosis of fetal ventriculomegaly, additional findings have included lissencephaly, holoprosencephaly, meningocele and evidence of intraventricular hemorrhage (Figs 1 and 2).^{8,19-21}

Conversely, ventriculomegaly has been ruled out in fetuses between 19- and 33-week gestation after an ultrasound exam has suggested mild asymmetrical ventriculomegaly.^{8,12,22,23}

Cerebellar and Posterior Fossa Abnormalities

Several authors have found MRI useful for the evaluation of the posterior fossa. Examples include providing additional



Fig. 1: Ultrasonography showing mild unilateral ventriculomegaly

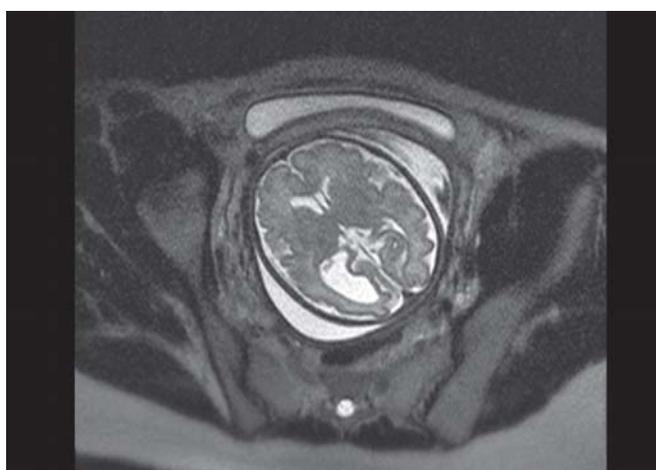


Fig. 2: MRI scan showing unilateral mild ventriculomegaly



Fig. 3: Ultrasonography indicating Dandy-Walker malformation

information⁸ on areas of hemorrhage in a tumor during the third trimester, excluding false-positive ultrasound findings,²⁴ diagnoses of posterior fossa cysts,²² or identification of pontine abnormalities²⁵ after 20-week gestation. MRI findings have also influenced the management of pregnancies in which the fetus has a posterior fossa cyst between 21 and 39 weeks,²² unilateral cerebellar deficiency at 25 weeks,²⁶ or Chiari malformation after

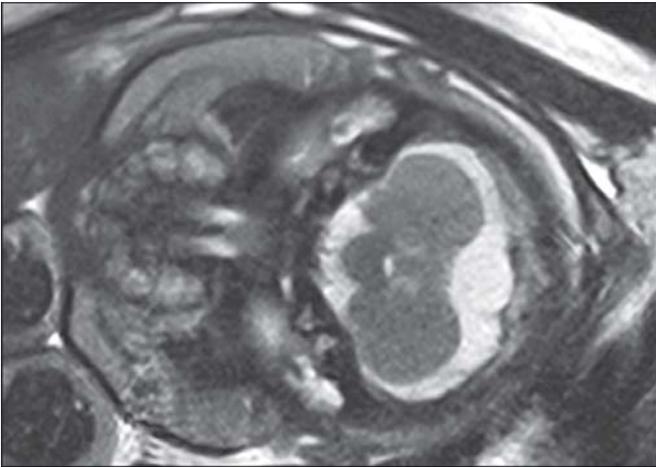


Fig. 4: Axial MRI scan of the same fetus showing mega cisterna magna

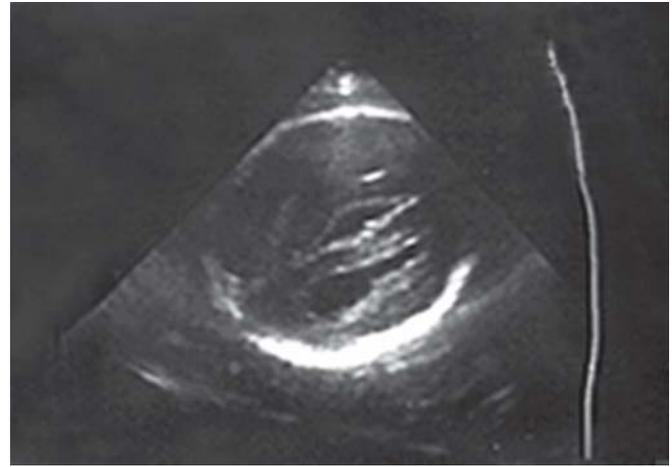


Fig. 5: Ultrasonographic scan showing agenesis of corpus callosum

24-week gestation.²⁷ The posterior fossa has remained an area where MRI excels (Figs 3 and 4).

Microcephaly

Microcephaly has traditionally been defined as a head circumference more than three standard deviations below the mean. In cases in which the head is not quite this small, it may be useful to assess the (relative) size of the frontal lobe²⁸ and to assess cerebral blood flow with Doppler ultrasound.²⁹

In severe cases of microcephaly, in which the acoustic window is very limited because of small fontanelles, MRI may be of use. Microcephaly, like ventriculomegaly, is anatomic finding rather than a diagnosis, and should prompt a search for the underlying cause.

Schizencephaly, Lissencephaly, Pachygyria, Polymicrogyria and Neuronal Heterotopias

MRI often adds to the diagnosis of malformations of cortical development between 21- and 32-week gestation.^{27,30-32} This might be partially because of an inherent advantage of MRI. Although it is feasible to evaluate cortical gyration and sulcation by means of either MRI or ultrasound in the second half of pregnancy,³³ myelination and migration can only be evaluated by MRI.³⁴

Myelination occurs predominantly after birth, but the protein and lipid signals of the white matter sheath can be seen by MRI 30 weeks onward, and the premyelinating formation of white matter tracts can be demonstrated antenatally with diffusion-weighted imaging.³⁴ The dynamic changes in the layered appearance of the cortex also help to confirm normal migration.³⁵ However, development as seen by MRI can lag behind anatomic studies by up to 2 weeks because of factors such as slice thickness or MRI planes that are not quite orthogonal.^{34,35}

Visualization of polymicrogyria may be age dependent, as such malformations may develop secondary to vascular problems and thus will not manifest before the end of the second

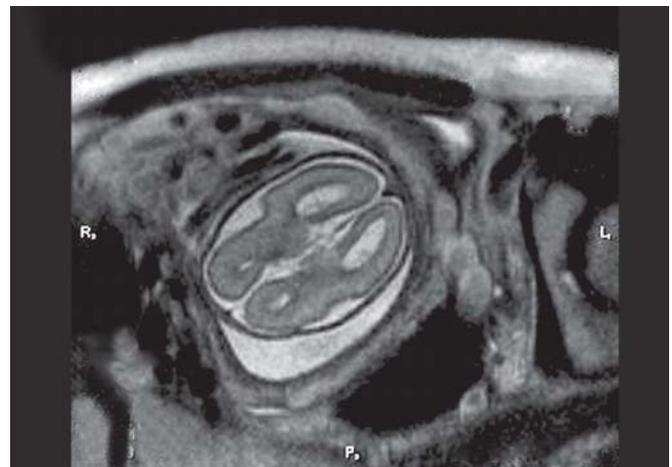


Fig. 6: Axial MRI scan showing agenesis of corpus callosum of the same fetus

trimester.³⁶ MRI may also be better than ultrasound for differentiating schizencephaly from other differential diagnoses prenatally (32-38 weeks) and postnatally.³⁷

Corpus Callosum

Ultrasound was shown to be as good³⁸ or better¹² than MRI for the diagnosis of corpus callosum abnormalities between 21 and 34-week gestation. In addition to indirect signs, such as colpocephaly, the corpus callosum can be visualized directly on multiplanar neurosonography to diagnose complete or partial absence of the corpus callosum.³⁸ Three-dimensional and Doppler ultrasound may also be of benefit for visualizing the midline structures and the pericallosal arteries (Figs 5 and 6).³⁸

Tumors

Fetal tumors represent a group of neoplasms in which teratomas are the dominant histologic type. Teratomas constitute the majority of both extracranial and intracranial neoplasms.¹⁶ While teratomas may be benign or malignant, they may prove fatal because of their location and size, leading to cardiac

overload and hydrops fetalis. The most common location in order of decreasing frequency is the sacrococcygeal region, head and neck, chest and retroperitoneum.¹⁶ CNS tumors represent only 10% of all antenatal tumors, however, intracranial teratoma accounts for approximately 50% of intracranial tumors. Fetuses with intracranial tumors may present with hydrocephalus or polyhydramnios.³⁹ The primary differential diagnosis for an intracranial tumor is hemorrhage, and differentiation between the two may be difficult secondary to the tendency of congenital brain tumors to bleed. The overall prognosis for fetal brain tumors is extremely poor.

Doppler ultrasound can identify tumors with increased blood flow at 35 weeks.³⁹ Hemorrhage into a tumor has also been suggested by a sudden increase in tumor size or the development of a mass within the mass at 39-week gestation.³⁹ MRI can be used to determine cellularity,⁴⁰ exclude areas of hemorrhage or necrosis, distinguish tumors from hematomas, and confirm the presence of fat in lipomas.⁴⁰ The intracranial nodules of tuberous sclerosis have been consistently found with greater sensitivity by MRI, both antenatally between 20- and 32-week gestation or postnatally, usually in fetuses in whom an intracardiac mass indicative of a rhabdomyoma was found (Figs 7 to 10).⁴¹

Brain Vascular Malformations

Brain vascular malformations are rarely diagnosed in fetuses. The most common is the vein of Galen aneurysm. The vein of Galen aneurysm (VGM) is a vascular malformation of the choroid plexuses that drains into the vein of Galen. Because of the high flow the vein dilates and resembles an aneurysm. Other malformations are not usually seen as the draining veins are smaller and therefore not detected by ultrasound.

The diagnosis is suspected during the third trimester ultrasound examination when a cyst-like structure is seen in the region of the posterior fossa.⁴² The Doppler ultrasound and in particular the color Doppler makes the diagnosis by showing high flow in the structure.

The vein of Galen can be treated postnatally and have a good outcome if some conditions are respected, but a large vascular malformation of the brain in this region carries a much more severe prognosis. For this reason, prenatal MRI will be necessary in most cases to evaluate the exact nature of the malformation. The MRI must include T2-weighted sequences in axial, sagittal and coronal planes. MR angiography can be done as well, if necessary.



Fig. 7: Ultrasonographic scan showing fetal cystic intracranial lesion



Fig. 9: Ultrasonographic scan showing tumor of the fetal neck

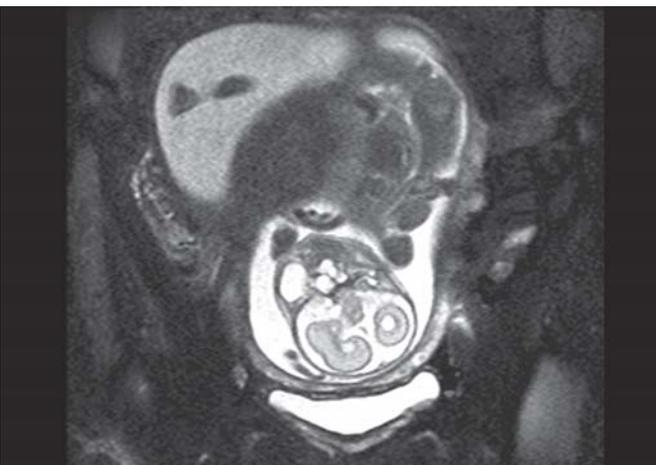


Fig. 8: Axial MRI scan of the same fetus showing teratoma of fetal brain

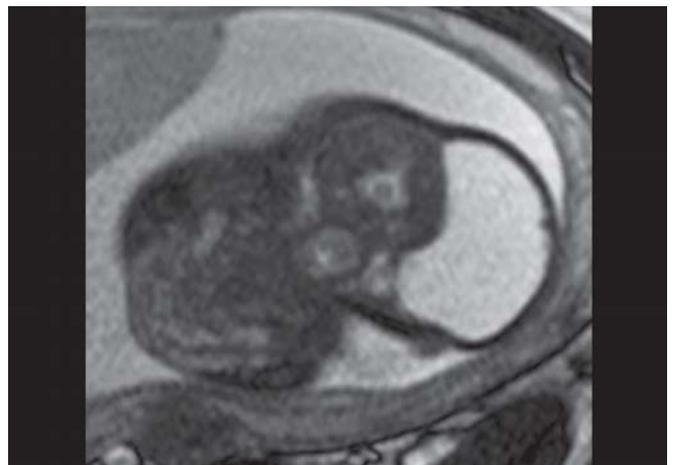


Fig. 10: Axial MRI scan of the same fetus showing lymphangioma of the neck

Acquired Lesions

Ischemia

Ischemia might be demonstrated by MRI, minutes to hours after an insult in the third trimester, if it results in a hyperintense DWI signal and reduced apparent diffusion coefficients (ADC).⁴³ Chronic changes are more commonly seen, and appear as increased T2WI and decreased T1WI signals because of subcortical leukomalacia.⁴⁴

In cases of fetal stroke, MRI has demonstrated hemorrhagic lesions in 90% and porencephaly in 13% of affected fetuses.⁴⁵ In a severe case, a combination of cardiotocography, Doppler ultrasound and MRI made it possible to diagnose fetal brain death at 23-week gestation.⁴⁶ MRI has also added to the clinical information about fetuses with a sonographic diagnosis of porencephaly, schizencephaly, periventricular leukomalacia, and other lesions of the brain parenchyma between 21 and 34 weeks (Figs 11 and 12).^{8,19,20,31}

Infections

Intrauterine infection with cytomegalovirus can lead to microcephaly, ventriculomegaly and porencephaly, which are



Fig. 11: Ultrasonographic finding inconclusive

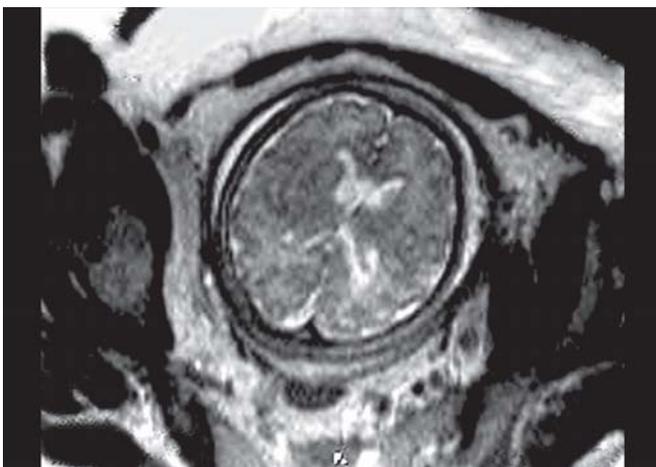


Fig. 12: Axial MRI scan showing cerebrovascular insult of the same fetus

easily seen by ultrasound at 29-week gestation.⁴⁶ More subtle signs of infection include borderline ventriculomegaly with focal areas of increased echogenicity and small cysts that are situated symmetrically in the lateral periventricular areas at 22 to 29-week gestation.⁴⁷ The combination of this typical ultrasound finding with an MRI study showing hyperintense germinal matrices bulging into the lateral ventricles at 33 to 35 weeks is very specific to the diagnosis of congenital cytomegalovirus infection,⁴⁸ and is another example of how ultrasound and MRI can complement each other. Results of current studies show that an important proportion of CMV-infected fetuses have normal prenatal ultrasound and MRI scans.^{49,50} These children usually have good outcome without long-term disabilities. Diffusion-weighted imaging might be useful for the detection and monitoring of brain abscesses and herpetic encephalopathy from 35 weeks onward.⁵¹

Fetal Evaluation of Spine Dysraphism

Spinal dysraphism (SD) or neural tube defects (NTD) encompass a heterogeneous group of congenital spinal anomalies that result from the defective closure of the neural tube early in gestation with anomalous development of the caudal cell mass.⁵² The incidence is 1 to 2 per 1,000 births.⁵² Advances in US and MRI have dramatically improved the diagnosis and therapy of spinal dysraphism both prenatally and postnatally. Prenatal US can identify spinal abnormalities, associated central nervous system (CNS) and non-CNS anomalies (cardiac, skeletal), as well as assess fetal growth and well-being.⁵³ MRI is a complementary tool that can further evaluate the spinal anomaly and associated central nervous system (CNS) and non-CNS anomalies, that may impact on prognosis.⁵⁴ Three-dimensional CT is now being used to assess fetal skeletal dysplasia in the third trimester and can also be useful in the assessment of more complex spinal anomalies.⁵⁴

In this era of fetal surgery, differentiating among the various forms of spinal dysraphism prenatally becomes critical. If fetal surgery is shown to improve long-term outcome of myelomeningoceles, advanced techniques including fetal MR and 3D US may be required routinely to accurately classify these spinal dysraphisms (Figs 13 to 16).

Fetal Chest

The most common thoracic abnormalities that affect fetus are congenital diaphragmatic hernia, cystic adenomatoid malformation and bronchopulmonary sequestration. Adequate lung development *in utero* is the major determining factor of neonatal survival in a fetus with a chest mass. Pulmonary hypoplasia can occur in a variety of settings but is most common when a space occupying lesion is present. MRI can easily distinguish among liver, lung and bowel. Allowing differentiation of thoracic space occupying lesions, determining liver position in congenital diaphragmatic hernia, and estimating lung volume.¹⁶ In isolated congenital diaphragmatic hernia, fetal lung



Fig. 13: Ultrasound scan showing lumbosacral spina bifida

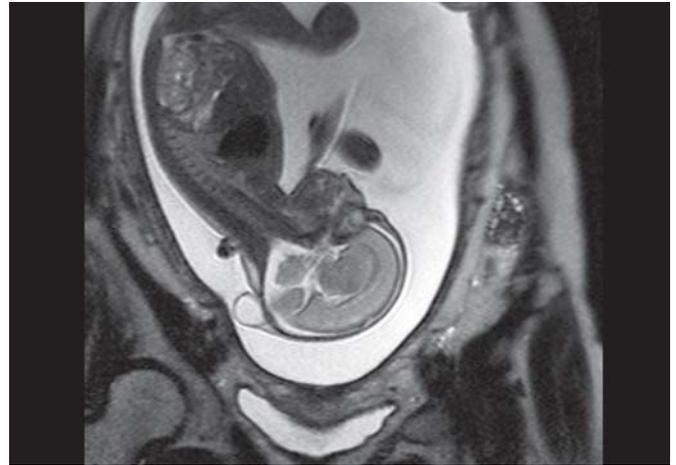


Fig. 16: Sagittal MRI scan showing fetal meningocele



Fig. 14: Sagittal MRI scan of the same fetus showing spina bifida



Fig. 17: Ultrasongraphic scan indicating diaphragmal hernia/CCAM



Fig. 15: Ultrasongraphic scan showing meningocele



Fig. 18: MRI scan of the same showing CCAM of the lungs

volume measurement by MRI can be used in clinical practice and is a good predictor of postnatal outcome, i.e. of pulmonary hypoplasia. The measured/expected FLV ratio was significantly lower in infants with congenital diaphragmatic hernia who died compared with those who survived (Figs 17 to 20).⁵⁵

Fetal Heart

Fetal echocardiography represents the imaging modality of choice for screening evaluation of cardiac anatomy and prenatal diagnosis of congenital heart malformations, since it is able to provide real-time images with high resolution and it is not



Fig. 19: Sonographic scan showing left-sided diaphragmatic hernia with displacement of the heart to the right



Fig. 20: MRI coronal scan showing left-sided diaphragmatic hernia

detrimental to the mother and the fetus.⁵⁶ The usual timing of fetal echocardiography for the diagnosis of congenital heart disease is approximately 18 to 20 weeks of gestation although the quality of cardiac images is best between 24 and 28 weeks of gestation.

During the latest phases of gestation, some limitations (relative reduction of the amniotic fluid volume, intensification of calcification in the ribs, and so on) may occur and impair the quality of the examination.⁵⁷ Notwithstanding the importance of ultrasonography in fetal heart analysis, echocardiography remains an operator-dependent technique and in certain circumstances it is indicative, but not conclusive, for patient counseling and patient care, especially in cases of complex fetal anomalies.⁵⁸

Even if fetal cardiac MRI image quality needs improvement, preliminary results demonstrates the feasibility to visualize the fetal heart with routine fetal MRI protocols. The most efficient technique to characterize the fetal cardiac anatomy appears to be T2- weighted true FISP sequence, whereas the most suitable technique to evaluate the fetal cardiac dynamic and function is real-time cine-MRI.⁵⁹ This preliminary evidence, even if requiring further studies within a larger population and additional quantitative assessment of cardiac structures, makes MRI a potential second-level tool in the diagnosis of congenital heart disease, diagnosed by fetal US.

Fetal Abdomen

Abnormalities involving the fetal abdomen include abdominal wall abnormalities, gastrointestinal tract abnormalities, and pathology involving the genitourinary tract. The spectrum of abdominal wall abnormalities consists of omphalocele, gastroschisis, pentalogy of Cantrell, limb-body wall complex and bladder exstrophy. MRI delineates anatomic detail of complex anomalies, and can detect additional anomalies, allowing for accurate prenatal diagnosis and more precise prenatal counseling.¹⁶ Gastrointestinal abnormalities include atresias/obstruction of the esophagus, duodenum, and small bowel, meconium peritonitis, anorectal malformations and megacystis-microcolon-intestinal hypoperistalsis syndrome. MRI has been able to demonstrate intestinal dilatation with suggestion of approximate location of an obstruction. A knowledge of normal fetal bowel MRI pattern is essential in detecting abnormalities of the gastrointestinal tract. The rectum demonstrates a high T1 and low T2 signal secondary to accumulation of meconium after 20 weeks' gestation.⁶⁰ Small bowel shows characteristic high T2 signal. MRI can detect abnormal fluid content within the rectum, suggesting a urorectal communication. Additionally, MRI has been useful in differentiating enteric cysts from meconium pseudocyst based on signal characteristics on T1-weighted images with low T1 signal intensity seen in an enteric cyst and intermediate T1 signal seen in a meconium pseudocyst (Figs 21 and 22).¹⁶

As a complementary examination, MRI combined with US may be helpful in studying antenatal occlusive pathologies. However, the contribution of MRI is subject to criticism in terms of its efficacy in locating the occlusion.⁶¹ Genitourinary tract abnormalities account for approximately 30% of antenatally detected anomalies. They can occur in isolation or as part of syndrome or chromosomal abnormality.⁶² MRI provides anatomic detail of the renal and bladder regions at any gestational age, regardless of the presence or absence of amniotic fluid. Renal morphology, obstruction, duplication, position and agenesis can be well-demonstrated by this technique.¹⁶ It can also provide valuable information about the origin and nature of a fetal abdominal mass, allowing differentiation of a solid mass from simple enlargement of the kidneys and helping to distinguish a renal mass from an extrarenal mass (Figs 23 and 24).⁶³



Fig. 21: Oblique sagittal sonographic scan reveals a hypoechoic area anteriorly and single loop bowel dilatation



Fig. 24: MRI coronal scan showing two cystic formation on the right fetal kidney

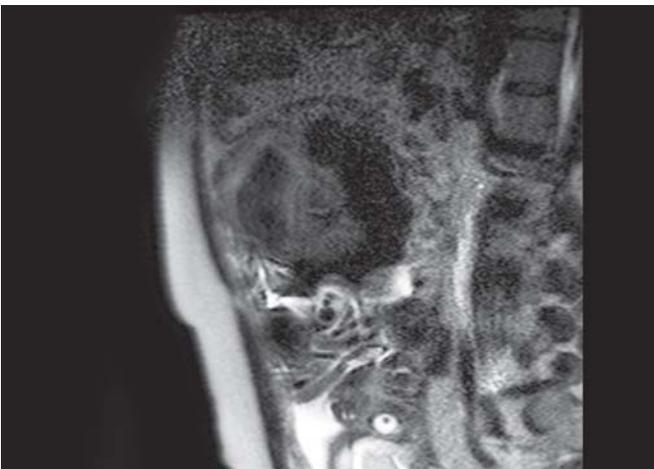


Fig. 22: MRI coronal scan of the same fetus showing dilatation of colon/suspected anal atresia



Fig. 23: Ultrasound scan showing cystic lesions in fetal kidney

Fetal MRI is a useful complementary tool in the assessment of sonographically diagnosed fetal urinary tract anomalies; and in a small percentage of cases, it can have a substantial impact on obstetric management.⁶⁴

Abnormal Placentation

In placenta accreta, the anchoring placental villi attach to the myometrium. In placenta increta there is invasion of the chorionic villi into the myometrium. Placenta percreta refers to penetration of chorionic villi through the uterine serosa, with possible invasion of neighboring structures.

Diagnostic criteria for placenta accreta on MRI include thickened dark nodular contour of the placenta–uterine interface with extensions of the dark bands within the placenta; mass effect of the placenta on the uterus causing an outer bulge; heterogeneous placental signal on the T2-weighted images with large placental lakes or vessels.¹⁶

Suspicion for placenta accreta has enabled appropriate preparation for delivery with the support of anesthesia, experienced surgeons and interventional radiology. Potential life-threatening hemorrhage is the major risk factor in placenta accreta.

Antenatal diagnosis has diminished blood loss and morbidity in cases of placenta accreta regardless of management.

Early fetal MRI can clearly identify a placental pathology in symmetrical extreme early onset IUGR.⁶⁵ The identification of subchorionic cysts within an abnormal placenta must prompt a very close fetal surveillance program, as well as a multidisciplinary discussion regarding optimal timing of delivery.⁶⁵ Early fetal MRI, therefore, helps to accurately determine the prognosis for the fetus, facilitates the prenatal care for the obstetrician and informs difficult decision-related processes for parents.

MATERNAL MRI

Adnexal Masses

One of the more common indications for MRI in pregnancy is to assess complex adnexal masses. The majority of masses less than 6 cm detected in the first trimester are corpus luteum cysts

that will resolve spontaneously as well as 25% of second-trimester adnexal masses. A total of 2 to 5% of adnexal masses that are removed during pregnancy are malignant.⁶⁶ Ultrasonography can usually give an accurate description of the size and character of adnexal masses. However, when a patient is considering having surgery for an adnexal mass in pregnancy, it has been shown that MRI correctly identifies the origin and nature of the mass to decrease the need for surgery during pregnancy.⁶⁶ Ovarian masses in pregnancy are typically asymptomatic unless they enlarge rapidly, rupture or torsion. Torsion can be a difficult diagnosis on ultrasound since blood flow may be present (due to the dual blood supply of the ovaries from the ovarian artery and ovarian branch of the uterine artery). In addition, many pregnant patients with ovarian hyperstimulation will have ovarian torsion; it may be difficult to distinguish between enlarged ovaries from hyperstimulation and torsion in these cases. In complicated cases in which the sonographic diagnosis is unclear, MRI can demonstrate suggestive features of torsion, such as enlarged edematous ovary with high signal intensity stroma on T2-weighted images.⁶⁷

Gestational Trophoblastic Disease

Gestational trophoblastic disease (including hydatidiform mole, invasive mole, choriocarcinoma and placental site trophoblastic tumor) is typically diagnosed and followed with sonography. The main role of MRI is in the evaluation of the extent of its complications.⁶⁶ Because of the high association between molar pregnancy and choriocarcinoma, patients need surveillance after this diagnosis is made.

Abdominopelvic Pain

Assessment of abdominal and pelvic pain in pregnancy can be difficult since the pain can be due to such varied causes as ligamentous laxity, miscarriage, a hemorrhagic corpus luteum cyst, abruption, preterm labor, ectopic pregnancy, uterine dehiscence, choledocholithiasis, nephrolithiasis, fibroid degeneration, ovarian torsion, gastroenteritis and appendicitis.

Ultrasound is the primary imaging modality for these patients. When ultrasound is not sufficient for a diagnosis, MR can be helpful.⁶⁶ Acute appendicitis is the most common nonobstetrical surgical condition of the abdomen complicating pregnancy. The incidence of appendicitis in pregnancy (0.05-0.07%) is similar to that in the general population, but pregnant patients are more likely to present with perforation (43% vs 4-19% in the general population) since diagnosis tends to be delayed.⁶⁶ Anatomic and physiologic changes that may disguise and delay the diagnosis of acute appendicitis include: (1) Cephalad displacement of the appendix from the right lower quadrant by the enlarged uterus; (2) increased leukocyte count in pregnancy; and (3) physiologic increase in maternal blood volume that diminish the woman's ability to demonstrate tachycardia or hypotension.

Ultrasonography with graded-compression is valuable for detecting acute appendicitis in pregnant women. In cases where a normal appendix is not visualized sonographically, MRI can be used to visualize the appendix.⁶⁸ The normal appendix is seen on MRI as a tubular structure of less than 6 mm in diameter. MRI findings in appendicitis include an enlarged fluid-filled appendix with or without increased signal intensity in the periappendiceal fat on T2-weighted imaging representing periappendiceal inflammatory changes.⁶⁸

Endometrial Carcinoma

Endometrial carcinoma is the most frequent female pelvic malignancy and the seventh most common neoplasm world wide, with the highest incidence in North America and Europe. It is reasonable to expect a further rise in its incidence owing to increases in life expectancy. Endometrial cancer is staged according to a surgical system because clinical estimation is incorrect in over 20% of cases.⁶⁹ However, accurate preoperative staging of the disease would assist in planning the optimal course of treatment. In particular, the ability to distinguish between patients with deep, and those with no or < 50% myometrial invasion (FIGO stage Ic vs stage Ia or Ib).

Several techniques have been studied as tools for preoperative staging of endometrial carcinoma. Magnetic resonance imaging (MRI), computed tomography (CT) and transvaginal sonography (TVS) have all been proven to be accurate in the assessment of depth of myometrial infiltration.⁶⁹ The diagnostic accuracy of the three imaging modalities has been compared in a large-scale meta-analysis,⁷⁰ which demonstrated that the CT, sonography and MRI were of similar accuracy, although MRI showed a trend toward better results. In particular, it has been demonstrated that contrast-enhanced MRI performs better than helical CT in the preoperative staging of endometrial cancer.⁶⁹ However, MRI is costly, time consuming and has limited availability, and so may not be appropriate for all patients.⁷¹

Contrast-enhanced MRI and TVS perform equally well in the evaluation of myometrial invasion, whereas TVS shows a trend towards better performance in the detection of cervical tumor spread. Therefore, TVS could potentially be proposed as the first-line imaging modality in patients with endometrial carcinoma. On the other hand, MRI, which is more expensive and time consuming, could be employed as a second-line imaging technique in patients in whom TVS gives images of poor quality and if precise preoperative staging is crucial (e.g. for determining the type of surgery in polymorbid patients).⁶⁹

Magnetic Resonance Imaging (MRI) in Urogynecology and Female Urology

MRI provides the opportunity to examine the soft tissue structures of the pelvic support apparatus in the two. It is noninvasive, has excellent soft tissue contrast resolution without

exposure to ionizing radiation and allows the study of function of pelvic floor structures under different dynamic conditions, such as increased abdominal pressure during Valsalva.⁷² Several anatomical landmarks used for pelvic measurements are also easily identified in MRI and most measurements are thus highly reproducible.

Currently, the clinical value of these examinations is still under investigation with its impact on therapeutic decisions not yet fully evaluated.

Possible measurements using MRI in urogynecology and female urology:⁷³

- a. Bladder neck and cervical descent/mobility: Position of bladder neck and cervix at rest and on Valsalva.
 Pubococcygeal line: A line extending from the inferior border of the pubic symphysis to the last joint of the coccyx. Bladder neck or cervical descent > 2 cm below this line with straining indicates weakness of the pelvic floor. If alternative landmarks are used in scientific papers they should be clearly described.
- b. Intercurrent pelvic pathology: For example, fibroids, ovarian pathology.
- c. Uterine version: Anteverted or retroverted; flexion at the isthmus⁴⁷
- d. Bladder abnormalities: For example, tumor, foreign body.
- e. Urethral abnormality: For example, diverticulum.
- f. Postoperative findings: For example, bladder neck mobility.
- g. Pelvic floor measurements/levator defects: Assessment of the configuration of pelvic floor muscles, in particular, the levator ani.
- h. Descent.

Diagnostic ability may be enhanced by the use of 3D MRI. New techniques with high speed sequence of pictures allow a functional MRI.⁷³

CONCLUSIONS

The utility of MRI imaging for fetal and maternal evaluation has evolved considerably in recent years. With advent of shorter acquisition times, fetal MRI has become more valuable and its role is still expanding.

MRI provides valuable information about the fetus particularly in the evaluation of anomalies of the brain (Table 1). The corpus callosum and vermis can be difficult to image in the second trimester with ultrasound, yet these structure are often clearly visualized with MRI. MRI has also provided useful information in the evaluation of ischemic lesions of the cerebral cortex.³

Fetal anatomy is well-visualized by MRI, in part because of large amounts of amniotic fluid, as well as fluid within the fetal lungs, gastrointestinal tract, kidneys, bladder.⁴ The multiplanar abilities of MRI may be helpful in determination of the origin and extent of fetal abnormalities. MRI is not limited by fetal position or maternal body habitus, but it is limited by fetal motion and as US, by severe oligohydramnions.⁹

MRI can be considered safe for fetal evaluation after the first trimester, but its use should be limited to cases in which complex anomalies are suspected, and the US findings are equivocal or incomplete.

Although MRI is a valuable source of information in prenatal diagnosis and treatment, it should not replace US for routine screening of the fetal anomalies. MRI has limited capabilities in the evaluation of fetal cardiac anomalies because of rapid motion of fetal heart. Unlike US, MRI cannot be used to evaluate fetal movement, which is clinically important part of fetal biophysical profile.

MRI could have potentially even greater significance as a diagnostic procedure in the future as fetal surgery emerges as a new field in perinatal medicine. Preoperative planning with fetal MRI, specifically for central nervous system malformations and masses of the neck may greatly enhance treatment for these selected life threatening conditions. In addition, MRI could have role in the evaluation of fetal lung volume and possible pulmonary hypoplasia.⁵⁵

Table 1: Comparison of ultrasound (US) and magnetic resonance imaging (MRI) findings in cases in which MRI added no information and for those in which MRI added information to final diagnosis (Frates et al, Radiology 2004)

<i>Ultrasound and MRI correct, MRI imaging added no information</i>	<i>Ultrasound and MRI correct, MRI imaging added information</i>
Bordeline ventriculomegaly	Dandy-Walker variant suspected at US confirmed at MRI
Ventriculomegaly	Encephalocele (US, MRI)
Ventriculomegaly and hemorrhage	Corpus callosum agenesis (MRI)
	Midline CNS cyst and fetal hypotonia (US)
	enlarged cavum septum pellucidum, pontine cerebellar degeneration (MRI)
Dandy-Walker variant	Complex facial cleft (MRI)
Chiari malformation	Cervical teratoma (US, MRI), location or status of trachea (MRI)
Posterior urethral valves	Sacrococcygeal teratoma (US, MRI)
	earlyly hydrops
Multicystic displastic kidney, bilateral	Vein of Galen aneurysm (US, MRI), feeding or draining vessel evaluation (MRI)

In conclusion, ultrasound continues to be the screening modality of choice in the evaluation of the pregnant patient due to its relatively low cost and real-time capability. However, MRI is increasingly being utilized in pregnant patients as a problem-solving tool.

Advantages of MRI include enhanced tissue contrast, larger field of view and multiplanar capability. Additionally, MRI has been shown to be useful for a variety of maternal indications, owing to the lack of ionizing radiation, global field of view and high intrinsic soft-tissue contrast.

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