

# Fetal Magnetic Resonance Imaging: A Problem Solving Tool in Antenatally Detected Fetal Anomalies and Abnormalities

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## Abstract

**Background:** A study was conducted to confirm findings of antenatal ultrasonography (US) by magnetic resonance imaging (MRI) and to understand the role of fetal MRI in decision making for better parental counseling in case of central nervous system (CNS) anomalies.

**Methods:** The study was conducted in Department of Radiology, Manipal Hospital, over 24 months including all pregnant women with suspected fetal CNS anomalies on the US.

**Results:** A total of 29 patients underwent fetal MRI examination on GE 1.5 Tesla TWIN SPEED, HDX machine. 2/29 cases were twin pregnancies. In 1/2 twin pregnancy feto-reduction of a fetus was done. In 26/31 fetuses, comparison of US and MRI reports was made. MRI provided supplementary information to US in 35% (9/26) and it was concordant with US in 46% (12/26) while discordance observed in 19% (5/26). In 23% (6/26) US provided additional information over MRI. Ventriculomegaly was noted in 12/30 live fetuses (40%), in 2/12 (17%) it was severe, and in 6/12 (50%) associated CNS anomalies were found. In 6/29 fetuses (21%) corpus callosal abnormality was suspected on the US. In 5/6 (83%) MRI confirmed while in rest, it disproved US diagnosis. 5/30 (17%) fetuses had posterior fossa malformations. 1/30 had schizencephaly. 1/30 had tuberous sclerosis and single fetus showed unilateral deep asymmetric calcarine sulcus.

**Conclusions:** MRI allows detailed visualization of the fetal CNS. Additional findings provided by MRI are helpful in understanding severity of the abnormality and in decision making. The US is useful for initial screening and follow-up.

**Key words:** Fetal MRI, Central Nervous System anomalies, US correlatrion

## INTRODUCTION

Ultrasonography (US) is the primary screening modality for fetal imaging because of its relatively low cost, lack of harmful effects, easy availability, and real-time imaging. However, there are limitations, including small field of view, limited soft tissue acoustic contrast, beam attenuation by adipose tissue, poor image quality in oligohydramnios and limited visualization of posterior fossa in advanced gestational age, because of calvarial calcification.<sup>1-3</sup>

Magnetic resonance imaging (MRI) is a valuable complement to the US when additional information is needed to confirm diagnosis during pregnancy. Recently, MRI with fast sequences has allowed images to be obtained during maternal breath-holding, without fetal or maternal sedation. It gives superior soft tissue contrast resolution, because of which we are able to distinguish individual fetal structures such as lung, liver, kidney, and bowel.<sup>4</sup> Moreover, it provides multiplanar imaging as well a large field of view, facilitating examination of fetuses with large or complex anomalies, and visualization of the lesions within the context of the entire fetal body.<sup>5</sup> It allows better fetal imaging in situations such as maternal obesity and oligohydramnios, where it may be difficult to obtain clear images by the US due to technical limitations.<sup>6</sup>

MRI has also proved to be useful for a wide variety of disorders, mainly those involving the central nervous

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system (CNS); especially in late gestation when the ossification of the calvarium limits a good visualization of the encephalic structures. However, fetal MRI study may give limited diagnostic information in early gestational age due to the small size of the fetus and fetal movement.<sup>7</sup> Safety is important in evaluating the fetus. MRI is a non-invasive that does not involve ionizing radiation with no known associated side effects or reported delayed sequels.<sup>8</sup> No known harmful effects to the developing human fetus have been documented at 1.5 Tesla or less. However, safety has not been dogmatically proven. *In-utero* MRI has not shown any effect on fetal growth.<sup>9</sup> A 2 years follow-up study of children who underwent imaging *in-utero* showed no demonstrable increase in disease occurrence.<sup>10</sup>

The American College of Radiology (ACR) states that fetal MRI can be done at any stage of pregnancy if the risk-benefit ratio to the patient warrants the same<sup>11</sup> and only if the US is inadequate. However, it is wise to wait until 17-18 weeks of gestation because of the potential risk to the developing fetus and excessive motion of younger foetuses.<sup>12</sup> A written informed consent is usually required from the pregnant woman before fetal MRI.

## METHODS

The study was conducted in the department of radiodiagnosis and imaging Manipal hospital Bengaluru, a 800 bedded multispecialty tertiary care hospital, over a period of 24-month from July 2012 to July 2014. All pregnant women with suspected fetal anomaly on ultrasound scan and above 18 years of age; pregnant women with previous history of fetal congenital anomalies; and pregnant women with confirmed diagnosis of congenital anomalies of fetus *in-utero* who are <18 weeks and are scheduled for termination were included in the study. Pregnant women having a history of claustrophobia, metallic implants insertion, cardiac pacemakers, and metallic foreign body were excluded from the study. MRI was also avoided in pregnant women who require sedation. A total of 29 patients underwent fetal MRI examination in our hospital during the study period.

GE 1.5 Tesla TWIN SPEED, HDX MRI machine was used. The non-imaging data were collected in prescribed format. 12 channel body coil was used with small field of view as possible. 3-5 mm thick slices were taken. Multiple sequences were taken predominantly T2 single shot fast spin echo (SSFSE) in 3 orthogonal planes. The mother was kept NPO for 4 h prior to the MRI exam to reduce fetal motion. Written informed consents were obtained before study in all cases. The mother lied supine during the course of the exam in comfortable position possible

during the MR exam to minimize fetal motion. MRI exam can be performed with the mother lying on her left side although this results in lower image quality.

Most fetal MRI is primarily performed using an initial localizer obtained in 3 orthogonal planes with respect to the mother, using 6-8 mm thick slices with a 1-2 mm gap and a large field of view. The localizer is used to visualize the position of the fetus and determine fetal sidedness, as well as to ensure that the coil is centered over the region of interest. Typically, 3 mm thick ultrafast T2 weighted (T2W) images of the fetal brain were then prescribed from the localizer with no skip. Images were acquired in the axial, sagittal, and coronal planes.

Diffusion-weighted imaging was also used to identify focal areas of injury as well as to assess brain development using A B value of 0 s/mm<sup>2</sup> and 600 s/mm<sup>2</sup>. The data were collected on pre-designed study performa. All the data were entered in Microsoft Excel Program and checked for any inconsistencies. Data were presented in terms of percentages and proportions.

## RESULTS

About 29 patients underwent MRI in our department for different indications all of who were referred after the US. In 26/29 cases, MRI was done within 15 days of US. Age of the patients included in this study ranged between 19 and 34 years with an average age of 28 years. All MRI examinations were done in the second and third trimester. MRI examination was avoided in the first trimester in accordance to ACR guidelines to avoid potential risk to the developing fetus. All pregnant women included in this study were of 19-36 weeks of gestation with average gestational age of 26 weeks.

History of previous pregnancy with congenital anomalies was elicited in 5 patients. In our study, we have studied fetal anomalies involving CNS. In 4/5 patients CNS abnormality was found in present pregnancy.

In 4/29 patients, detailed US report was not available. In 2/29 cases were twin pregnancies. In one twin pregnancy, laser ablation of umbilical artery of one fetus was done for twin-twin transfusion syndrome. Thus, in 26/31 fetuses comparison between US and MRI reports was made.

As shown in Figure 1 in 12/26 fetuses (46%), the diagnoses established by the US were confirmed by MRI. MRI imaging provided more information than did the US in 9/26 fetuses (35%). There were 6/26 fetuses in which US provided additional information to that provided with

MRI in terms of intrauterine growth restriction (IUGR), Rhabdomyomas in the case of tuberous sclerosis, cleft lip, cleft palate, and limb anomalies. Discrepancies occurred in 5/26 fetuses (19%) details of which are given in Table 1.

The criterion used in our study to measure ventricles was same as for ultrasound. It was considered mild when it measured 10-15 mm, moderate when >15 mm with >3 mm of adjacent cortical thickness and severe when ventriculomegaly with <2 mm of adjacent cortical thickness. In our study, we found ventriculomegaly in 12/30 (40%) fetuses. 8/12 cases (66%) were bilateral, and rests were unilateral. 2/12 cases (17%) of ventriculomegaly were of severe category. 3/12 (25%) were of moderate category while 7/12 (58%) cases had mild ventriculomegaly (Figure 2). In 6/12 cases (50%), we have found various associated CNS anomalies which included sulcation abnormality, agenesis of corpus callosum, and germinal matrix bleed.

In 3/7 (43%) cases of mild ventriculomegaly, associated anomalies were detected. In 3/7 (43%) patients pregnancy was terminated, 2 of which did not have associated

anomaly. 1/7 case was lost follow-up, which had associated partial agenesis of corpus callosum. 2/4 cases of mild ventriculomegaly and no associated anomaly continued pregnancy, one of which had normal delivery with normal postnatal neurosonogram while another pregnancy was ongoing. 2/4 cases of mild ventriculomegaly and no associated anomaly underwent termination of pregnancy despite isolated nature of ventriculomegaly. 2/7 cases (29%) delivered with normal early milestones.

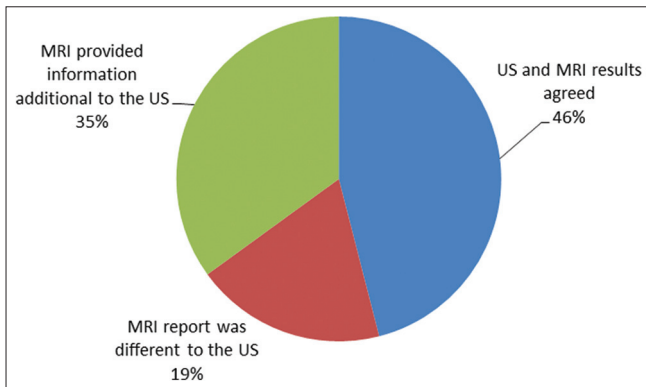
In 6/29 (21%) corpus callosum was not visualized on the US or had suspected corpus callosal abnormality. In 5/6 cases (83%) MRI confirmed US findings. In 1/6 cases MRI disproved US diagnosis of agenesis of corpus callosum. 1/6 cases were lost follow-up. In 1/6 cases pregnancy was terminated. In 4/6 cases child had normal early milestone although postnatal imaging was not available.

Sulcation pattern was normal for age in 29/30 fetuses. In single fetus, it showed time lag of 2-3 weeks.

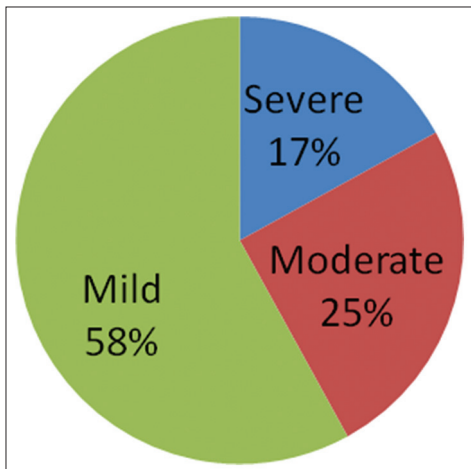
5/30 had posterior fossa malformations. 2/5 were of Dandy-Walker continuum, one case was of isolated inferior vermian hypoplasia, one of unproven partial rhombencephalosynopsis, and one of arachnoid cyst.

1/30 fetuses had schizencephaly which appears as grey matter lined cleft extending from ependyma to pia matter; (Figure 3). 1/30 fetuses had tuberous sclerosis. In 1/30 case unilateral deep asymmetric calcarine sulcus (CS) was found.

2/29 cases lost follow-up. Follow-up was available in 27/29 patients. 2/29 cases were twin pregnancies. In 1/2 twin pregnancy fetoreduction by laser ablation of umbilical artery was done, emergency lower section caesarean section was done, and surviving fetus was normal. Another twin pregnancy was terminated. In 14/25 cases pregnancy was continued. In 11/25 cases patient underwent termination or pregnancy terminated spontaneously or pregnancy had terminated due to the maternal indication.



**Figure 1: Comparison between ultrasonography and magnetic resonance imaging findings**

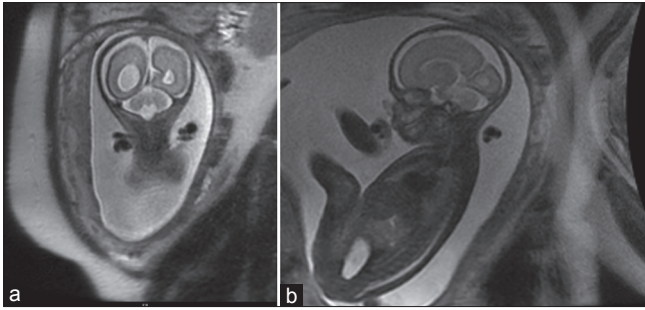


**Figure 2: Ventriculomegaly**

## DISCUSSION

Due to increased social awareness and improved antenatal care facilities, there is active participation from the community in the field of antenatal care. Thus, the number of antenatal US scans has increased significantly in recent time, which is partly responsible for increased anomaly detection rate; thus, making the development possible in the field of US and MR technology.

Major indications for fetal MRI were confirmation of inconclusive sonographic findings and the evaluation of sonographically occult diagnoses.



**Figure 3: (a and b) T2 weighted sagittal, and coronal images of 27W fetus showing Fluid filled tract on the medial aspect of the right parieto-occipital lobe (arrow) with no connection to the ventricles suggestive of right deep calcarine sulcus**



**Figure 4: T2 weighted images of 23W fetus with gray matter lined tract (arrow) in the left parietotemporal region communicating with left lateral ventricle with associated dimpling of the left lateral ventricle suggestive of schizencephaly**

History of previous pregnancy with congenital anomalies is a risk factor for congenital anomaly. In pregnancies with a history of congenital abnormalities, anomalies were found in present pregnancy in 4/5 (80%) (Table 2).

Whitby *et al.*, 2003,<sup>15</sup> did a prospective, observational study of 21 pregnant women of 19-36 weeks of gestation whose fetuses were thought to have a CNS abnormality on the basis of antenatal US. They found that MRI report was different to the US in 10/21 (47.6%); MRI provided information additional to the US in 5/21 (23.8%) and US and MRI results agreed in 6/21 (28.6%).

In study conducted in our institute, MRI report was different to the US in 19%, MRI provided information additional to the US in 35%, US and MRI results agreed in 46%. There were 23% fetuses in which US provided additional information to that provided with MRI in terms of IUGR, rhabdomyomas in the case of tuberous sclerosis, cleft lip, cleft palate, limb anomalies, vertebral anomalies (Table 2).

In our study 46% cases, diagnoses established by the US were confirmed by MRI compared to their study in which it was 28.6%. Indicating that diagnosis of congenital anomalies with the US has been improved reaching up to 46% in our study. This can be explained by the advances in US technology like 3D, 4D, software like Omni view, tomographic ultrasound imaging, and the radiologist's operative and interpretation skills particularly in last decade.

The conventional ultrasound is still the standard in diagnostic ultrasound studies. In the new 3D fetal scanning technology, sound waves are sent at different angles and returning echoes are processed by sophisticated software resulting in a reconstructed three-dimensional (3D) volume image of fetus's surface or internal organs. 3D ultrasounds allow one to see width, height and depth of images but no movement is shown. The latest 4D fetal ultrasounds are similar to 3D scans, with the difference associated with time. 4D allows a 3D picture in real time, rather than delayed, due to the lag associated with the computer constructed image, as in classic 3D ultrasound. The volume data acquisition also allows us to interpret images in various sectional planes where we can manipulate slice thickness. This is useful in objective assessment of the brain surface, to detect the cranial bone abnormality as well as in migration disorders and cortical development.

Fetal echocardiography has experienced vast development along with high resolution, and real-time scanning. Doppler flow examinations have improved detection rate of the fetal cardiac anomalies. Hence, even detection of intraventricular rhabdomyomas of heart was possible as in our case US had limitations in cases of maternal obesity, improper fetal position, Oligohydramnios, improper visualization of the fetal structures in cases of post acoustic shadowing due to bony structures, where MRI plays a significant role in decision making.

In 35% cases, MRI gave additional information in our study which was 23.8% in study done by Whitby *et al.* indicating improved MRI diagnosis also.

Excellent tissue contrast, large field of view, superior soft-tissue contrast resolution, and the ability to distinguish individual structures are the advantages of MRI. Development of fast T2W sequences like steady state free precession sequence (SSFSE) has made available the assessment of the intracranial structure. The examination time is reduced significantly reaching to minimum of 10-15 min in our institute. Overall, the benefits of fetal MRI are much more in CNS anomalies than in non-CNS anomalies.

Diffusion MRI is very helpful for early detection of fetal hypoxia. MR Spectroscopy is potential new advances in MRI whose role needs to be explored.

**Table 1: Findings in present pregnancy in patients having history of previous pregnancy with congenital anomalies**

History of pregnancy with congenital abnormalities	Present pregnancy
Joubert's syndrome	Normal
CDH, ventriculomegaly, micrognathia, microcephaly	Bilateral mild ventriculomegaly. Multiple foci of T2 hypointensity around lateral ventricles. DD-old hemorrhage or small tubers. Poorly visualized posterior corpus callosum
ACC; unilateral ventriculomegaly	Bilateral mild ventriculomegaly. Partial ACC
Microcephaly ACC	Good visualization of corpus callosum anteriorly, poorly visualized posteriorly-probably just forming. Suggested follow-up
Ventricular septal defect	Left choroid plexus cyst

ACC: Agenesis of corpus callosum, CDH: Congenital diaphragmatic hernia

**Table 2: Details of cases where discrepancies between US and MRI was observed**

US findings	MRI findings
Asymmetric IUGR. Bilateral mild ventriculomegaly? Dueto lissencephaly. Corpus callosum is normal	Bilateral mild ventriculomegaly. No other abnormality
Lateral ventricle appeared pinched out and lifted up, measurement could not be taken	Schizencephaly in the left parietotemporal region. No other abnormality
Three cysts in the right cerebral hemisphere (arachnoid cysts) displacing falx to left and not communicating with the meningeal spaces. Bilateral ventriculomegaly (right - 16.4 mm; left-11 mm)	Interhemispheric cyst with few thin septae. Bilateral moderate ventriculomegaly
CSP was not visualized. Pericallosal artery not seen suggestive of ACC.	Bilateral Mild to moderate ventriculomegaly. NoACC
Bilateral Mild to moderate ventriculomegaly	
Bilateral ventriculomegaly	Unilateral moderate ventriculomegaly

ACC: Agenesis of corpus callosum, CSP: Cavum septum pellucidum, US: Ultrasonography, MRI: Magnetic resonance imaging, IUGR: Intrauterine growth restriction

Discrepancies occurred in 5/26 (19%) cases which were 47.6% in their study, significantly reducing incorrect interpretation rates. This again can be explained by improvements in ultrasound equipment and skills along with advances in MRI and their interpretation.

The impact of fetal MRI on treatment can be particularly difficult to assess because a contemporaneous standard of reference was lacking in our setting. Furthermore, studies in which fetal MRI performed at academic centers is compared with sonography performed at other hospitals or diagnostic centers, rather than sonography performed at equivalent academic centers, which tend to exaggerate the apparent advantages of MRI.

In a study done by Frates *et al.*, 2004<sup>4</sup> images of 27 fetuses (28 diagnostic cases) with anomalies diagnosed at US were evaluated. Prenatal US and MRI imaging findings were compared with postnatal diagnoses which were an added advantage, compared to our study. In 7/28 (25%) diagnostic cases, US and MRI imaging findings were in complete agreement with postnatal diagnoses. MRI imaging correctly provided additional information to the US determined diagnosis in another 7/28 (25%) and correctly changed the US diagnosis in 3/28 (11%). The MRI imaging-determined diagnosis was incorrect, and the US diagnosis was correct in 4/28 (14%). In 7/28 (25%) cases, the diagnoses at both US and MRI imaging were incorrect when correlated with the postnatal outcome.

In comparison to our study where in US and MRI results agreed in 46%, they found it to be 25%. MRI imaging correctly provided additional information to the US-determined diagnosis in another 25% in their study which was found to be 35% in our study. This discrepancy can be explained by the fact that they have not included the cases where US and MRI imaging were incorrect when correlated with the postnatal outcome. In our study, postnatal diagnosis like autopsy or imaging was unavailable as most patients were not willing for the same after termination.

Hosny *et al.*, in 2010<sup>16</sup> examined 25 pregnant women with MRI in whom US detected fetal congenital anomalies. MRI findings altered the diagnosis of 2/25 (8%) cases. MRI added additional findings two out of 4 cases. In the remaining 18/25 (72%) cases MRI confirmed the diagnosis of US. Compared to this study where US and MRI were in agreement in up to 72% case, in our study it was found to be 46%. As in our study, they also did not include postnatal follow-up like autopsy or imaging.

In one interesting case, unilateral deep asymmetric CS was found which is normal developmental variant as shown in Fig.4. It is most commonly found on the right side as in our case. This can be mistaken as schizencephaly, thus careful evaluation should be made to differentiate both entities (Figure 3).

Evaluation of corpus callosum is much better with MRI where it is directly visualized unlike US which relies on indirect signs. In 21% corpus callosum was not visualized on US or had suspected corpus callosal abnormality. In 83% MRI confirmed US findings. In 1/6 cases MRI disproved US diagnosis of agenesis of corpus callosum. 1/6 cases was lost follow-up. In 1/6 cases pregnancy was terminated. In 4/6 cases child had normal early milestone although postnatal imaging was not available. This proves deductions made by Glenn *et al.*, 2005<sup>17</sup> in their study about the upper hand of MRI in evaluation of corpus callosum.

In 3/7 (43%) cases of mild ventriculomegaly, associated anomalies were detected. In 3/7 (43%) patients pregnancy was terminated, 2 of which did not have associated anomaly. 1/7 case was lost follow-up, which had associated partial agenesis of corpus callosum. 2/4 cases of mild ventriculomegaly without associated anomaly continued pregnancy, one of which had normal delivery with normal postnatal neurosonogram while another pregnancy was ongoing. 2/7 cases (29%) delivered with normal early milestones. 2/4 cases of mild ventriculomegaly and no associated anomaly underwent termination of pregnancy despite isolated nature of ventriculomegaly.<sup>13,14</sup>

Reported fetal anomaly on ultrasound can add to mother's mental stress in Indian scenario. Having pregnancy with fetal anomaly adds social burden to parents forcing them to think in favor of termination of pregnancy. Thus, apart from the general need for psychological support to women undergoing prenatal examinations, there may be a need for additional support. Prenatal counseling helps the family to decide between prenatal or postnatal therapies or the termination of the pregnancy. Prenatal MRI can help in management decisions in such cases.

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