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ORIGINAL ARTICLE

A Comparative Study of Fetal MRI and Antenatal Ultrasound in Prenatal Diagnosis with Histopathological Correlation

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Abstract The aim of this study was to assess the role of magnetic resonance imaging (MRI) in the diagnosis of fetal anomalies and its correlation with antenatal Ultrasound (US) and histopathology. The study was conducted in the Department of Radiodiagnosis, Basaveshwar Teaching and General Hospital attached to Mahadevappa Rampure Medical College, Kalaburagi. It was conducted over 6 months and included pregnant women with suspected fetal anomalies on US. MR images were read independently by two radiologists and findings were confirmed with histopathology and post natal follow up. 15 patients underwent MRI for different indications all of who were referred after US. In 8/15 cases (53.34%), the US findings and MRI findings were concordant. MRI imaging provided additional information in 7/15 cases (46.66%). With advances in MRI technology and cumulative experience, MRI can be used as a valuable complementary tool to ultrasound in detecting and better evaluating fetal anomalies. The major role of fetal MRI is confirmation of abnormal sonological findings, evaluation of sonological occult fetal CNS pathologies and reassurance in equivocal US findings.

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Introduction

Ultrasonography (US) is the most widely used modality for fetal imaging because of its relative low cost, realtime imaging and no harmful effects on the fetus or mother. However, there are a few limitations which includes small field of view (FOV), poor image quality in oligohydramnios, limited soft-tissue contrast and beam attenuation by the adipose tissue and limited visualization of the posterior fossa structures [1–3].

Fetal MRI is largely a useful complementary tool in the assessment of fetal anomalies, especially those involving the central nervous system (CNS) [4–6]. MRI is a vital complement to US when additional information is required to confirm fetal pathology during pregnancy. Recently, MRI with fast sequences has made it possible for images to be obtained without maternal or fetal sedation. It provides better soft tissue contrast resolution resulting in distinguishing individual fetal structures such as lung, liver, kidney, and bowel [7]. Fetal MRI also allows multiplanar imaging as well as a large field of view, enabling examination of fetuses with complex anomalies, and visualization of the lesions within the context of the entire fetal body [8]. It facilitates better fetal imaging in conditions such as oligohydramnios and maternal obesity where it may be challenging to obtain clear images by US because of technical limitations. MRI has also proved to be effective for a wide spectrum of anomalies, mainly those involving the central nervous system, especially in late gestation when calvarial ossification limits visualization of the encephalic structures. However, the fetal MRI study may give minimal diagnostic information in early

gestational age because of small size of the fetus and fetal motion [9]. MRI is non-invasive, does not include ionizing radiation and has no known associated adverse effects or reported delayed complications. No known detrimental effects to the developing human fetus have been documented at 1.5 Tesla or less. In utero MRI does not manifest any adverse effect on fetal growth [10].

Materials and Methods

The study was conducted in the Department of Radiodiagnosis, Basaveshwar Teaching and General hospital attached to Mahadevappa Rampure Medical college, Kalaburagi, over a span of 6 months from December 2020 to June 2021. A total of 15 pregnant women with suspected fetal anomaly on US and above 18 years of age were included in the study after obtaining an informed consent. Pregnant women who had a history of claustrophobia, metallic implants insertion, cardiac pacemakers and metallic foreign body were excluded from study. MRI was also avoided in pregnant women who require sedation. A dedicated neurosonogram was performed after the screening ultrasound in all foetuses with suspicion of CNS anomalies, as recommended by ISUOG guidelines for performance of Fetal MRI, following which patients underwent fetal MRI examination in our hospital during the study period. A PHILIPS 1.5 Tesla ACHIEVA MRI machine (Fig. 1) was used. Non–imaging data was collected in a prescribed format. An 8 channel Body coil was used with as small a 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 three orthogonal planes. The mother was kept nil orally for 4 h prior to the MRI exam

Fig. 1 PHILIPS 1.5 Tesla ACHIEVA MRI machine

in order to reduce fetal motion. Written informed consents were obtained prior to the study in all cases. The mother was supine during the course of the exam in as comfortable a position as possible during the MRI exam in order to minimize fetal motion. Most fetal MRI is primarily performed using an initial localizer obtained in three orthogonal planes with respect to the mother, using 6–8 mm thick slices with a 1–2 mm interslice 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 centred over the region of interest. Typically, 3 to 4 mm thick continuous ultrafast T2-W images of the fetal brain were acquired. Images were acquired in the axial, sagittal, and coronal planes. Fetal abdomen and genitourinary tract in desired cases were acquired with 3–5 mm thick continuous ultrafast T2-W sequences in all three orthogonal planes with FOV adjusted to fetal size and maternal body habitus.

All patients were followed up clinically and patients with significant fetal anomalies were offered the option to undergo termination of pregnancy and the fetuses were subjected to autopsy after obtaining informed consent from both the parents. Radiological and pathological findings were compared. The data was collected in a pre-designed study proforma. All the data were entered in Microsoft Excel Program and checked for any inconsistencies. Data was presented in terms of proportions and percentages.

Results and Observations

15 patients underwent MRI in our department for different indications, all of whom were referred after US. The age of the patients included in this study ranged between 19 and 32 years with an average age of 25 years. The gestational age of the fetus was calculated by using fetal biometry and it was found to be corresponding with the first trimester dating scan and menstrual age. All MRI examinations were done in the second trimester on the same day as the US examination, therefore, the possibility of disparity due to gestational age was nullified. All pregnant women included in this study were at 18–28 weeks of gestation with an average gestational age of 24 weeks. History of consanguineous marriage was found in 5/15(33.33%) and previous pregnancy with congenital anomalies was seen in 4/15(26.66%) patients. In all 15/15 cases comparison between US and MRI reports was made. In 8/15 cases (53.34%), the US findings and MRI findings were concordant and MRI provided additional information/ruled out US suspicious pathologies in 7/15 cases (46.66%).

There were 13 CNS anomalies, 1 genitourinary and 1 miscellaneous anomaly with multisystem involvement (Fig. 2).

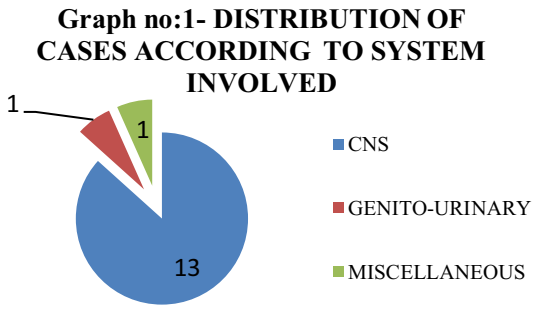

Fig. 2 Distribution of cases according to system involved

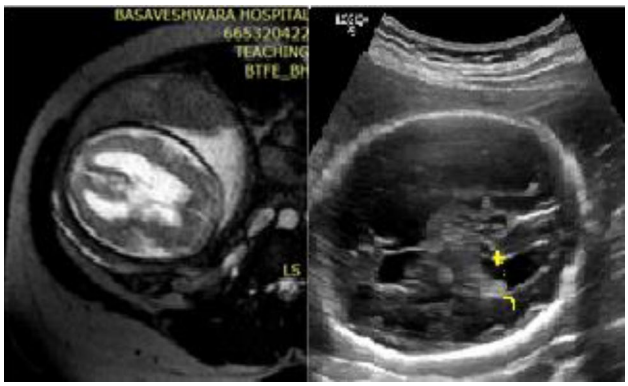

Fig. 3 MRI & US depicting ventriculomegaly

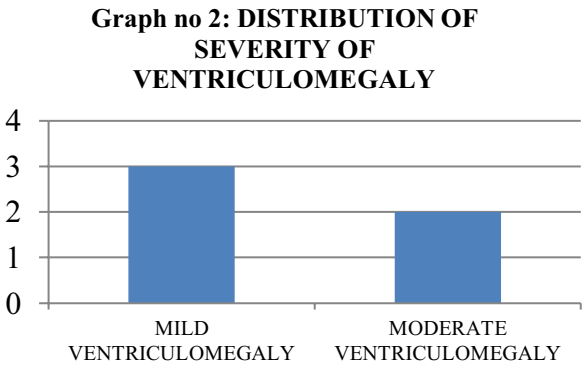

Fig. 4 Distribution of severity of ventriculomegaly

In 13 cases with ultrasound-detected CNS anomalies in our study we found ventriculomegaly in 5/15 (33.33%) cases (Fig. 3). 4/5 cases (80%) were bilateral, and 1/5 (20%) was unilateral. 2/5(40%) were of moderate category while 3/5(60%) cases had mild ventriculomegaly (Fig. 4).

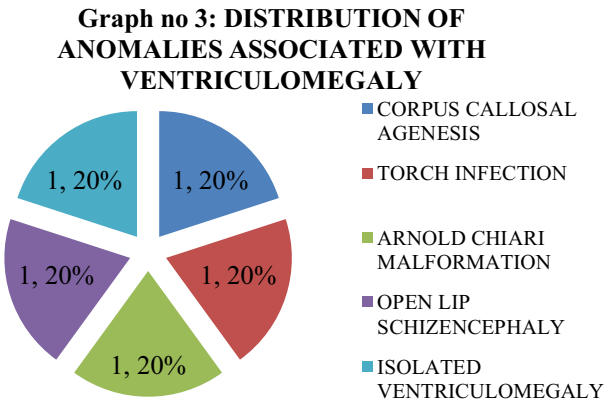

Fig. 5 Distribution of anomalies associated with ventriculomegaly

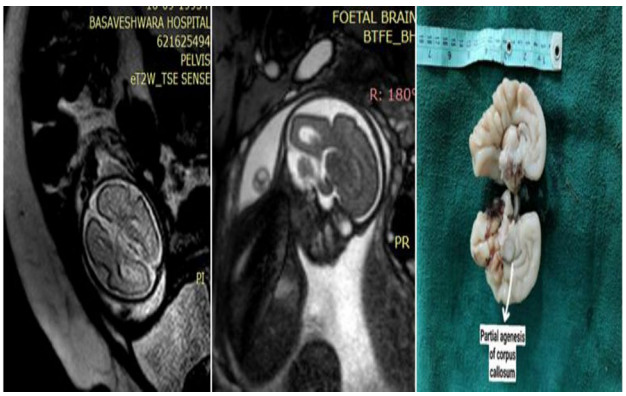

Fig. 6 MRI & AUTOPSY depicting partial agenesis of corpus callosum

The criteria used in our study to measure ventricles was considered mild when it measured 10–12 mm; moderate when 12–15 mm & Severe ventriculomegaly when > 15 mm.

In 4/5 cases (80%) we found various associated central nervous system anomalies which included agenesis of corpus callosum, Arnold-Chiari-malformation, open-lip schizencephaly and TORCH infection. 1/5 cases of mild ventriculomegaly had no associated anomaly and continued pregnancy, which had normal delivery with normal postnatal neurosonogram (Fig. 5).

In 4/13(30%) cases corpus callosum was not well visualized on US or had suspicious of corpus callosal abnormality. In 3/4 cases (75%) MRI could confidently diagnose corpus callosal agenesis/dysgenesis, all 3 underwent termination and foetuses were subjected to autopsy. MRI findings were consistent on histopathology. In 1/4 cases MRI disproved US

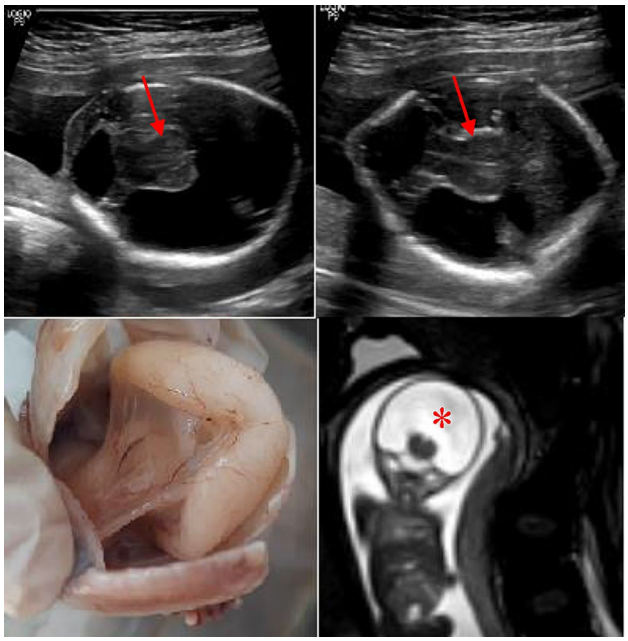

Fig. 7 US, MRI & AUTOPSY depicting alobar holoprosencephaly

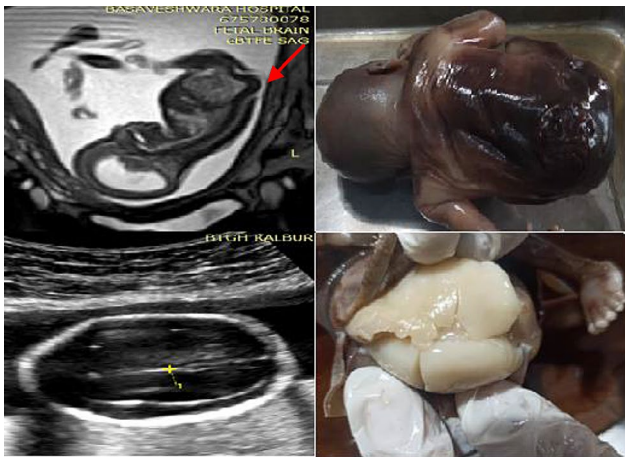

Fig. 8 US, MRI & AUTOPSY depicting Arnold-chiari malformation

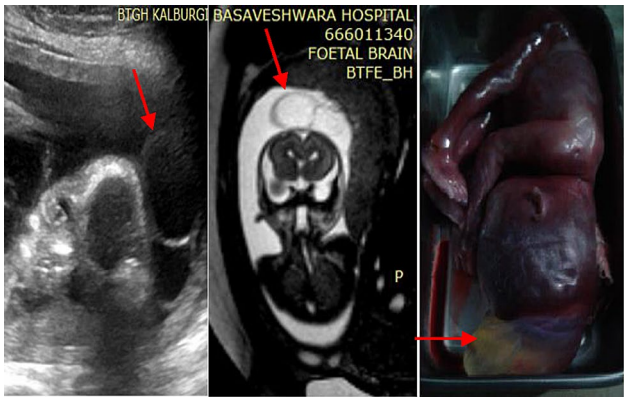

Fig. 9 US, MRI & AUTOPSY depicting parietal encephalocele

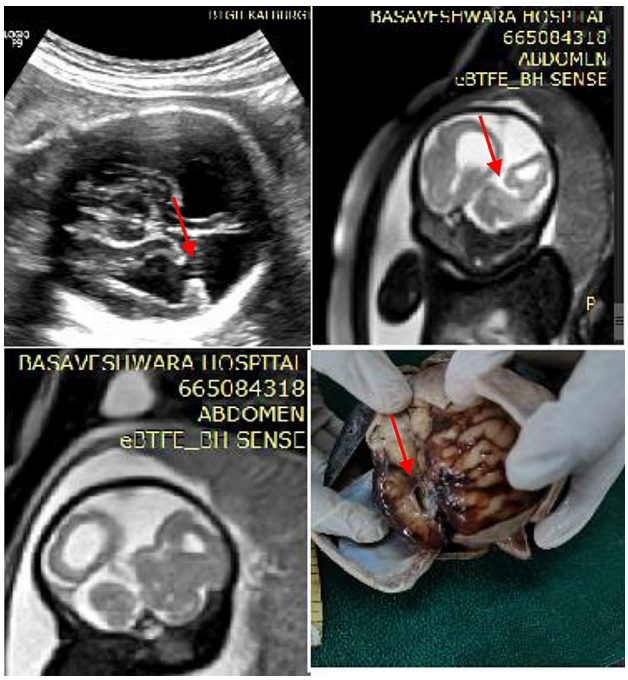

Fig. 10 US, MRI & AUTOPSY depicting open lip schizencephaly

diagnosis of agenesis of corpus callosum and no significant abnormality was noted and the pregnancy was continued (Fig. 6).

1/13 (7.7%) had alobar holoprosencephaly, US findings included fused thalami (arrows) and a monoventricle. Fetal MRI was able to demonstrate the monoventricle (*) with absence of interhemispheric falx. Autopsy confirmed the findings (Fig. 7).

1/13 (7.7%) had Arnold-chiari malformation, US findings included a lemon shaped fetal skull, ventriculomegaly, shallow posterior fossa and a lumbar myelomeningocele. MRI was able to demonstrate a lumbar myelomeningocele (arrow) and kyphotic deformity of spine. Autopsy confirmed the findings (Fig. 8).

1/13(7.7%) had parietal encephalocele US finding included an exophytic cystic swelling in the parietal region, MRI revealed an extracranial cystic lesion (arrows) with thin intracranial communication in the high parietal region through a cranial vault defect. Autopsy confirmed the findings (Fig. 9).

1/13 cases had open-lip Schizencephaly. US finding included ventriculomegaly and suspicious of intracranial cystic lesion. MRI demonstrated grey matter lined cleft extending from cortex to ventricle (arrows) and a diagnosis

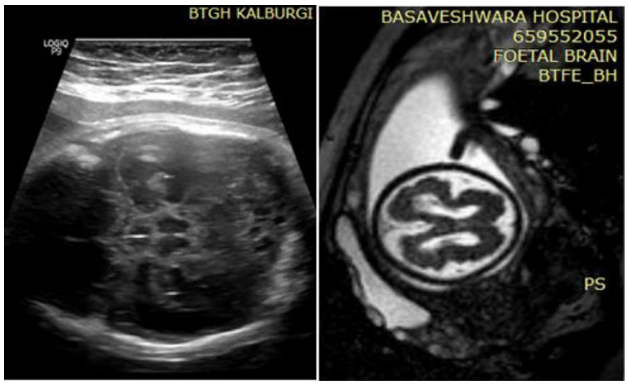

Fig. 11 US & MRI depicting polymicrogyria

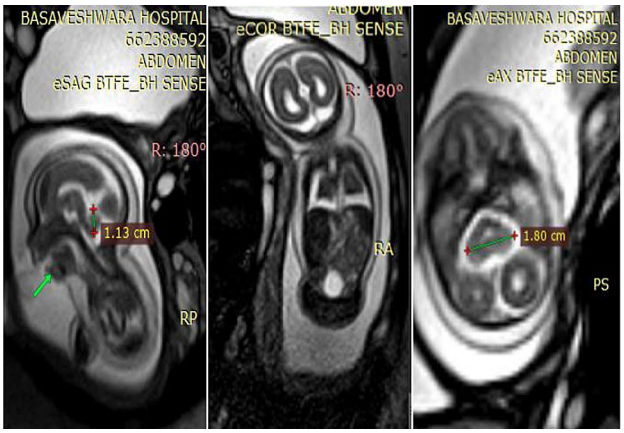

Fig. 12 MRI depicting cerebellar hypoplasia, fetal hydrops, retrognathia

of open lip schizencephaly was made. The same was confirmed on autopsy (Fig. 10)

Sulcation pattern was normal for age in 12/13 cases. In one fetus there was polymicrogyria. US findings included an absent cavum septum pellucidum and cerebellar hypoplasia. MRI revealed polymicrogyria with associated callosal agenesis and cerebellar hypoplasia. The patient continued pregnancy even after counseling. The baby expired on post natal day 2 (Fig. 11).

In one case, US findings included cerebellar hypoplasia, fetal hydrops, retrognathia (arrow) and a suspicion of Walker Warburg syndrome. Fetal MRI agreed with all the findings except that the brainstem appeared normal and Walker Warburg was ruled out. The pregnancy was terminated elsewhere and the patient did not opt for a fetal autopsy (Fig. 12).

In one case US findings suggested microcephaly with suspicious of lissencephaly. On MRI, the sulcation pattern appeared normal for age but there was reduction in transcerebellar diameter and vermian height for gestational age

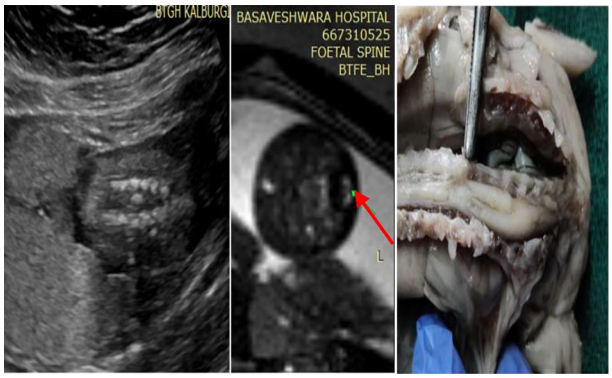

Fig. 13 US, MRI & autopsy depicting Type 1 Diastomatomyelia

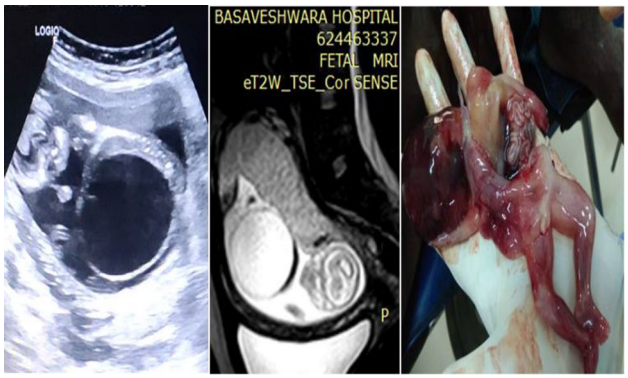

Fig. 14 US, MRI & autopsy depicting Megacystis

and a diagnosis of microcephaly with vermian hypoplasia was made.

In one case, on US there was a suspicion of splitting of the spinal cord at the dorsolumbar level. On MRI there was evidence of intraspinal midline spur (arrow) at the L1 vertebral body level with splitting of the cord proximal to the spur and distal reunion associated with a separate dural sac and a diagnosis of Type 1 Diastomatomyelia was made. The same was confirmed on autopsy (Fig. 13).

In one case involving the genitourinary system, US revealed a large urinary bladder with no evidence of a keyhole appearance. MRI clearly demonstrated the same and autopsy confirmed the radiological findings (Fig. 14).

1/15 cases included in the miscellaneous category involved multiple systems. US findings suggested herniation of abdominal contents i.e. heart, liver (green arrow), spleen, kidney (red arrow) and bowel through a thoracoabdomonal wall defect with hypoplastic lungs and kyphoscoliotic deformity of the spine. MRI revealed similar findings and helped in distinguishing each organ separately and

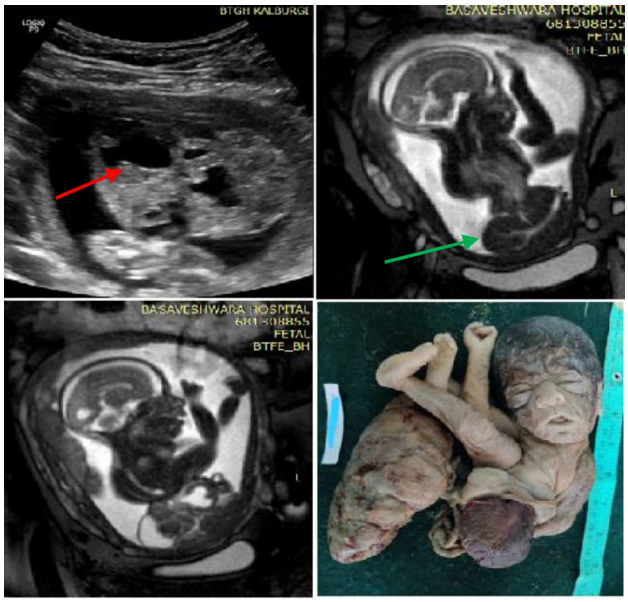

Fig. 15 US, MRI & autopsy depicting OEIS complex

a diagnosis of OEIS complex was made. The same was correlated with histopathology on autopsy (Fig. 15).

Discussion

Major indications for fetal MRI were confirmation of abnormal sonological findings and the evaluation of sonologically occult fetal pathologies.

Frates MC et al., Radiology. 2004 did a prospective study of 27 pregnant women of 19–36 weeks of gestation whose fetuses were thought to have a central nervous system abnormality on the basis of antenatal US. They found MRI provided information additional to the US in 37% of cases & US and MRI results were concordant in 25% cases [7]. In our study 8/15 cases (53.34%), the diagnoses established by US were confirmed by MRI. MRI imaging provided additional information than did US in 7/15 cases (46.66%). In 46.66% cases MRI gave additional information in our study which was 37% in the study done by Frates MC et al. Superior soft-tissue contrast resolution and development of fast T2W sequences like steady state free precession sequence (SSFSE) has made MRI faster with excellent soft tissue details.

Raafat et al. (2020), did a prospective observational study of 78 pregnant women at 19–36 weeks of gestation whose fetuses had suspected central nervous system abnormality on the basis of antenatal US. They found that MRI provided information additional to the US in 43.2% of cases & US and MRI results were concordant in 56.76 cases [11]. Compared to this study where US and MRI was in agreement in up to 56.76% case, in our study it was found it to be 53.34% (Table 1).

For evaluation of the corpus callosum, sulcation abnormalities and morphological abnormalities are much better seen with MRI where the corpus callosum is directly visualized unlike US which depends a lot on indirect signs. In our study where corpus callosum was not optimally evaluated on US or had sonological suspicion of callosal abnormality, MRI was superior in establishing/ruling out US diagnosis. In our study, findings of posterior fossa abnormalities on ultrasound and MRI are in agreement. Detection rate for ventriculomegaly were same for both ultrasound and MRI, however MRI was superior in diagnosing the associated anomalies which were occult on ultrasound.

Conclusion

MRI proved to be a valuable complementary technique to US in the investigation of fetal anomalies especially CNS malformations. However US is the main primary survey and MRI can be used as an adjunct to add additional information, especially for corpus callosal abnormalities and posterior fossa anomalies. Recent advances and developments in MR based sequences and ultrasound applications, have helped in making tremendous progress in the field of prenatal imaging. Both imaging modalities are complimentary to each other and play an important role in diagnosis, parental counselling and management in prenatal care.

Master Chart

Table 1 Comparison with other studies

Study	Frates MC et al. Radiology [7] (%)	Raafat et al. Egyptian Journal of Radiology [11] (%)	Our study (%)
MRI provided additional information/ruled out US diagnosis	37	43.2	46.66
MRI & US findings concordant	25	56.76	53.34

Sl.No	Maternal Age (Yrs)	GA (weeks) Calculated by US & MRI	Consanguinity	Previous pregnancy with congenital anomalies	USG findings	Fetal MRI	MRI providing additional information/ concordant with USG	F/U & autopsy
1	22	26	−	No	Suspected corpus callosal agenesis (CCA)	Partial agenesis of corpus callosum	Additional information was obtained on MRI	Confirmed on HPR
2	20	28	−	No	Ventriculomegaly	Ventriculomegaly	Concordant with USG	Torch screening +
3	30	18	−	No	Holoprosencephaly	Alobar holoprosencephaly	Concordant with USG	confirmed on HPR
4	22	26	−	No	Suspected corpus callosal agenesis	Normal	MRI ruled out USG suspected CCA	pregnancy continued
5	23	26	+	Yes	Suspected corpus callosal agenesis	Corpus callosal agenesis, polymicrogyria and cerebellar hypoplasia	Additional information was obtained on MRI	Baby expired PND1
6	22	28	−	No	Unilateral ventriculomegaly	Unilateral ventriculomegaly	Concordant with USG	Pregnancy continued
7	26	24	+	Yes	Colpocephaly with? CCA	Corpus callosal agenesis	Additional information was obtained on MRI	confirmed on HPR
8	32	24	−	No	? OEIS complex	OEIS complex	Concordant with USG	Confirmed on HPR
9	19	24	−	No	Suspected walker warburg	Cerebellar hypoplasia, micrognathia, fetal hydrops	MRI ruled out USG suspected Walker Warburg	MTP outside
10	31	22	−	No	?SPLIT CORD	Type 1 diastematomyelia	Concordant with USG	Confirmed ON HPR
11	20	24	−	No	?Microlissencephaly	Microcephaly	MRI ruled out USG suspected microlissencephaly	MTP outside
12	24	28	+	Yes	Ventriculomegaly with ?Cystic lesion	Open LIP schizencephaly with corpus callosal dysgenesis, pachygyria	Additional information was obtained on MRI	Confirmed on HPR
13	30	18	−	No	Megacystis	Megacystis	Concordant with USG	Confirmed on HPR
14	29	24	+	No	Encephalocele	Encephalocele	Concordant with USG	confirmed on HPR
15	30	20	+	Yes	Chiari II malformation	Chiari II malformation	Concordant with USG	Confirmed on HPR

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Consent to participate Informed consent was obtained from all individual participants included in the study.

Consent to publish Patients signed informed consent regarding publishing their data and photographs.

Ethics approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Institutional Ethics Committee of Mahadevappa Rampure Medical College, Kalaburagi.

References

1. Sonigo PC, Rypens FF, Carteret M, Delezoide AL, Brunelle FO. MR imaging of fetal cerebral anomalies. PediatrRadiol. 1998;28(4):212–22.
2. Garel C, Brisse H, Sebag G, Elmaleh M, Oury JF, Hassan M. Magnetic resonance imaging of the fetus. PediatrRadiol. 1998;28(4):201–11.
3. Angtuaco TL, Shah HR, Mattison DR, Quirk JG Jr. MR imaging in high-risk obstetric patients: a valuable complement to US. Radiographics. 1992;12(1):91–109 (**discussion 110**).
4. Rossi AC, Prefumo F. Additional value of fetal magnetic resonance imaging in the prenatal diagnosis of central nervous system anomalies: a systematic review of the literature. Ultrasound Obstet Gynecol. 2016;47(6):690–7. https://doi.org/10.1002/uog.14900.
5. Rajeswaran R, Chandrasekharan A, Joseph S, et al. Ultrasound versus MRI in the diagnosis of fetal head and trunk anomalies. J Matern Fetal Neonatal Med. 2009;22(2):115–23. https://doi.org/10.1080/14767050802488238.
6. Glenn OA, Barkovich AJ. Magnetic resonance imaging of the fetal brain and spine: an increasingly important tool in prenatal diagnosis, part 1. AJNR Am J Neuroradiol. 2006;27(8):1604–11.
7. Frates M, Kumar A, Benson C, Ward V, Tempany C. Fetal anomalies: comparison of MR imaging and US for diagnosis. Radiology. 2004;232:398–404.
8. Miller E, Ben-Sira L, Constantini S, Beni-Adani L. Impact of prenatal magnetic resonance imaging on postnatal neurosurgical treatment. J Neurosurg. 2006;105(3 Suppl):203–9.
9. American College of Radiology (ACR), Society for Pediatric Radiology (SPR). ACR-SPR practice guideline for the safe and optimal performance of fetal magnetic resonance imaging (MRI). (ACR); 2010. 10 p.
10. Stecco A, Saponaro A, Carriero A. Patient safety issues in magnetic resonance imaging: state of the art. Radiol Med. 2007;112:491–508.
11. Raafat, et al. Beyond fetal magnetic resonance diagnosis of corpus callosum agenesis. Egypt J Radiol Nucl Med. 2020;51:31. https://doi.org/10.1186/s43055-020-0146-0.