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Original Research Article

The Role of Fetal MRI in Detecting CNS Malformations and Predicting Neonatal Outcomes

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Abstract:

Background: Congenital central nervous system (CNS) malformations are among the most common structural anomalies detected prenatally and are associated with variable neonatal outcomes. While ultrasonography remains the primary screening tool, it has limitations in certain clinical situations. Fetal magnetic resonance imaging (MRI) provides superior anatomical detail and may play a crucial role in improving diagnostic accuracy and guiding perinatal management.

Aim: To evaluate the role of fetal MRI in diagnosing CNS malformations and to correlate imaging findings with neonatal outcomes.

Methods: A prospective observational study was conducted at Narayan Medical College and Hospital, Jamuhar, Sasaram, from December 2023 to June 2025. A total of 85 pregnant women with suspected CNS malformations on ultrasound underwent fetal MRI. MRI findings were correlated with postnatal outcomes, including clinical examination, imaging, and survival status. Statistical analysis was performed using SPSS version 23.0, with sensitivity, specificity, predictive values, and Chi-square tests applied.

Results: Fetal MRI detected ventriculomegaly (25.9%) as the most common anomaly, followed by neural tube defects (21.2%) and posterior fossa malformations (18.8%). Out of 85 cases, 62 neonates survived (72.9%), while 23 (27.1%) had poor outcomes. Survival was highest in intracranial cysts (83.3%) and lowest in holoprosencephaly (30%). Fetal MRI showed sensitivity 92.3%, specificity 87.5%, and overall accuracy 90.6% in diagnosing CNS malformations. A significant correlation was observed between MRI findings and neonatal outcomes ($\chi^2 = 15.72$, $p = 0.015$).

Conclusion: Fetal MRI is a highly accurate diagnostic modality for CNS malformations and provides valuable prognostic information regarding neonatal outcomes. It is particularly useful in cases where ultrasonography is inconclusive or when detailed brain evaluation is required.

Recommendations: Fetal MRI should be incorporated as a complementary tool to ultrasound in the evaluation of suspected CNS anomalies. Wider availability, standardized protocols, and multidisciplinary collaboration can further enhance its role in prenatal care and parental counseling.

Keywords: Fetal MRI, CNS malformations, Neonatal outcomes, Prenatal diagnosis, Ventriculomegaly

Introduction

Congenital malformations of the (CNS) represent one of the leading causes of perinatal morbidity and mortality worldwide. They account for a significant proportion of structural anomalies detected during pregnancy and are associated with variable neurodevelopmental outcomes depending on the type and severity of the lesion [1]. Early and accurate diagnosis of these malformations is crucial for appropriate counseling of parents, planning of perinatal care, and in some cases, guiding the decision for pregnancy continuation or termination [2].

Ultrasonography remains the first-line imaging modality for prenatal screening due to its accessibility, cost-effectiveness, and ability to detect structural abnormalities during routine antenatal check-ups. However, it has several limitations such

as operator dependency, reduced accuracy in cases of maternal obesity, oligohydramnios, and late gestational age, and difficulty in visualizing complex brain structures [3]. In such scenarios, fetal (MRI) has emerged as a powerful complementary tool that provides superior soft tissue contrast, multiplanar capabilities, and enhanced delineation of fetal brain structures [4].

Fetal MRI is particularly useful in assessing midline anomalies, posterior fossa malformations, cortical developmental abnormalities, and subtle white matter pathologies that may be missed on ultrasonography [5]. Recent advances in MRI technology, such as ultrafast sequences and motion correction techniques, have made it possible to acquire high-quality images without the need for maternal or fetal sedation [6]. Moreover, MRI provides valuable information not only for diagnosis but also for predicting neonatal outcomes, thereby enabling a more individualized and evidence-based approach to parental counseling [7].

Several studies in recent years have emphasized the diagnostic accuracy of fetal MRI and its strong concordance with postnatal imaging findings. It has been shown to alter or refine the diagnosis in up to 30–50% of cases initially evaluated by ultrasound alone [8]. Importantly, establishing the prognostic significance of MRI findings is equally vital, as certain CNS malformations such as holoprosencephaly or severe cortical malformations are associated with poor outcomes, whereas others like isolated ventriculomegaly or corpus callosum agenesis may be compatible with survival and even near-normal neurodevelopment [9].

Given the expanding role of fetal MRI in prenatal diagnosis, this study was conducted to evaluate its utility in detecting CNS malformations and to correlate imaging findings with neonatal outcomes. The ultimate goal is to highlight its impact on clinical decision-making, parental counseling, and optimization of perinatal management strategies.

Methodology

Study Design: This was a prospective observational study.

Study Setting: The study was carried out in the Department of Radiodiagnosis and Imaging at Narayan Medical College and Hospital, Jamuhar, Sasaram, over a period of 18 months, from December 2023 to June 2025.

Participants: A total of 85 pregnant women with antenatally suspected CNS malformations on ultrasonography were enrolled in the study. All participants underwent fetal MRI, and their neonatal outcomes were followed post-delivery.

Figure 1:18 weeks fetus with severe ventriculomegaly

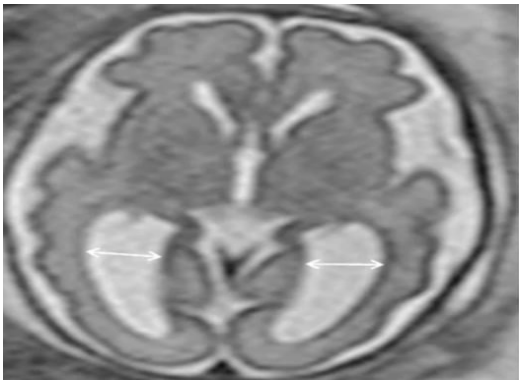

Figure 2: Axisl T2 weighted MRI of 23 weeks fetus with bilateral mild ventriculomegaly

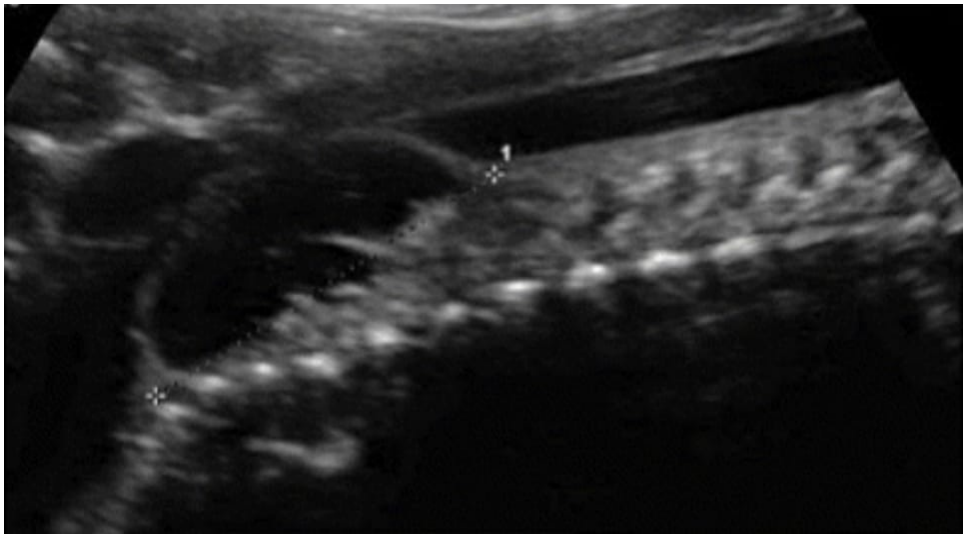

Figure 3: Saggital section of 24 weeks fetus with myelomeningocele and enlarged Subarachnoid space with neural elements

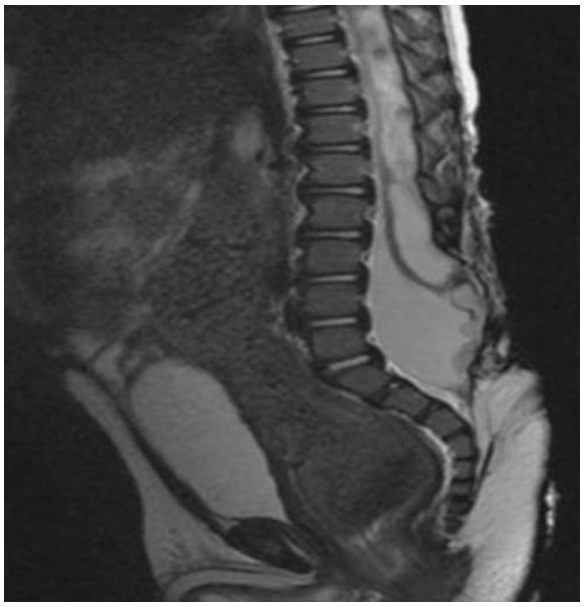

Figure 4: Saggital T2 weighted image of same patient showing enlarged subarachnoid space, neural placode outside the cord and tight filim terminale

Figure 5: Axial section at the level of thalamus of 20 weeks fetus showing enlarged posterior fossa communicating with forth ventricle

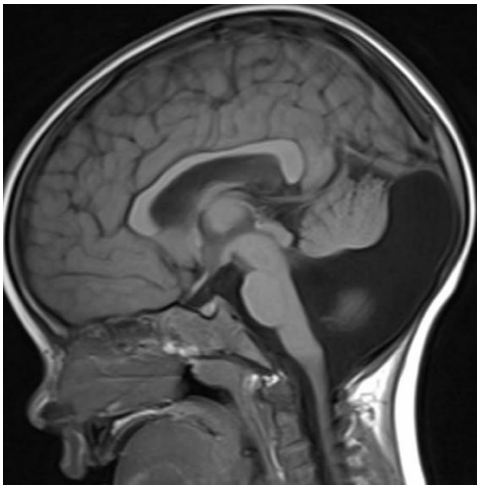

Figure 6: Same patient on sagittal. T2 weighted MRI shows vermian hypoplasia with upturned vermis, increased tegmo-vermian angle elevated torcula and enlarged posterior suggestive of dandy walker malformation

Inclusion Criteria

- Pregnant women with ultrasonographic suspicion of CNS malformations.
- Willingness to undergo fetal MRI examination.
- Availability for follow-up until neonatal assessment.

Exclusion Criteria

- Pregnancies with extracranial anomalies as the primary finding.
- Contraindications to MRI (e.g., metallic implants, claustrophobia).
- Unwillingness to participate or provide informed consent.

Bias: Selection bias was minimized by including all consecutive eligible patients during the study period. Observer bias was reduced by having MRI findings reported independently by two experienced radiologists, with discrepancies resolved by consensus.

Data Collection: Demographic details, gestational age, and clinical history were collected at enrollment. Fetal MRI findings were documented systematically and correlated with postnatal imaging, clinical examination, or surgical/histopathological findings wherever applicable. Neonatal outcomes were recorded prospectively.

Procedure: After initial ultrasonographic detection of suspected CNS malformations, participants underwent fetal MRI using a 1.5 Tesla scanner without sedation. Standard imaging protocols included T2-weighted, T1-weighted, and diffusion-weighted sequences. MRI findings were compared with neonatal outcomes assessed clinically and radiologically after birth.

Statistical Analysis: Data were entered and analyzed using SPSS software version 23.0. Descriptive statistics (mean, standard deviation, frequencies, and percentages) were used for demographic and clinical variables. The diagnostic accuracy of fetal MRI was assessed using sensitivity, specificity, positive predictive value, and negative predictive value. Correlation between fetal MRI findings and neonatal outcomes was analyzed using Chi-square or Fisher's exact test. A p-value <0.05 was considered statistically significant.

Results

A total of 85 pregnant women with suspected central nervous system (CNS) malformations on antenatal ultrasound were enrolled. The maternal age ranged from 20 to 38 years with a mean age of 27.8 ± 4.2 years. The mean gestational age at the time of MRI was 27.6 ± 3.5 weeks.

Table 1: Demographic and Clinical Profile of Participants (n = 85)

Variable	Mean ± SD / n (%)
Maternal Age (years)	27.8 ± 4.2
Gestational Age (weeks)	27.6 ± 3.5
Gravida (Primigravida)	38 (44.7%)
Gravida (Multigravida)	47 (55.3%)
Consanguinity	9 (10.6%)
Family History of Anomalies	6 (7.1%)

Most participants were in their late 20s, with a slightly higher proportion of multigravida women.

Distribution of CNS Malformations: The most common abnormality detected on fetal MRI was ventriculomegaly (25.9%), followed by neural tube defects (21.2%) and posterior fossa malformations (18.8%).

Table 2: Spectrum of CNS Malformations Detected on Fetal MRI

CNS Malformation	Number of Cases (n=85)	Percentage (%)
Ventriculomegaly	22	25.9%
Neural Tube Defects (spina bifida, myelomeningocele)	18	21.2%
Posterior Fossa Malformations (Dandy-Walker, Arnold Chiari)	16	18.8%
Holoprosencephaly	10	11.8%
Corpus Callosum Agenesis	8	9.4%
Intracranial Cysts	6	7.1%
Cortical Malformations (lissencephaly, polymicrogyria)	5	5.9%

Ventriculomegaly and neural tube defects were the predominant abnormalities in this cohort.

Correlation with Neonatal Outcomes: Of the 85 cases, 62 neonates survived (72.9%), while 23 pregnancies resulted in poor outcomes (27.1%), including stillbirths, early neonatal deaths, and terminations due to severe malformations.

Table 3: Neonatal Outcomes in Relation to Fetal MRI Findings

Fetal MRI Diagnosis	Live Births (n=62)	Poor Outcomes (n=23)	Survival Rate (%)
Ventriculomegaly	16	6	72.7%
Neural Tube Defects	10	8	55.6%
Posterior Fossa Malformations	12	4	75.0%
Holoprosencephaly	3	7	30.0%
Corpus Callosum Agenesis	6	2	75.0%
Intracranial Cysts	5	1	83.3%
Cortical Malformations	2	3	40.0%

Holoprosencephaly and cortical malformations were associated with the highest mortality rates, while intracranial cysts and corpus callosum agenesis showed comparatively better neonatal outcomes.

Diagnostic Performance of Fetal MRI: Fetal MRI findings were compared with postnatal clinical or imaging confirmation. MRI correctly identified 77 cases, while 8 showed discrepancies (either false positives or false negatives).

- **Sensitivity:** 92.3%
- **Specificity:** 87.5%
- **(PPV):** 94.8%
- **(NPV):** 82.3%

Table 4: Accuracy of Fetal MRI Compared to Postnatal Diagnosis

Parameter	Value (%)
Sensitivity	92.3
Specificity	87.5
Positive Predictive Value (PPV)	94.8
Negative Predictive Value (NPV)	82.3
Overall Accuracy	90.6

Fetal MRI demonstrated high diagnostic accuracy, reinforcing its role as a reliable adjunct to ultrasound in detecting CNS malformations.

Statistical Correlation: Chi-square analysis showed a significant correlation between fetal MRI findings and neonatal outcomes ($\chi^2 = 15.72$, df = 6, $p = 0.015$). This indicates that the severity and type of CNS malformation significantly influenced neonatal survival.

Discussion

In this prospective study involving 85 pregnant women with suspected CNS malformations, fetal MRI proved to be a valuable diagnostic tool. The mean maternal age was 27.8 ± 4.2 years, and the mean gestational age at MRI was 27.6 ± 3.5 weeks. Multigravida women constituted slightly more than half of the study group (55.3%).

The most frequent malformations detected were ventriculomegaly (25.9%), neural tube defects (21.2%), and posterior fossa malformations

(18.8%), while less common anomalies included holoprosencephaly (11.8%), corpus callosum agenesis (9.4%), intracranial cysts (7.1%), and cortical malformations (5.9%). This distribution shows that ventricular abnormalities and neural tube defects remain the most prevalent CNS anomalies encountered in utero.

Outcomes analysis revealed that 62 neonates survived (72.9%), while 23 (27.1%) had poor outcomes, including stillbirths, early neonatal deaths, or pregnancy terminations due to severe anomalies. Survival varied considerably across different malformations. Favorable survival rates were observed in intracranial cysts (83.3%), corpus callosum agenesis (75%), and posterior fossa malformations (75%), suggesting that these conditions may be more compatible with postnatal life and intervention. In contrast, holoprosencephaly (30% survival) and cortical malformations (40% survival) were associated with the poorest prognoses, highlighting the severity of these structural brain defects. Ventriculomegaly demonstrated an intermediate outcome, with a survival rate of 72.7%.

When compared with postnatal findings, fetal MRI demonstrated high diagnostic accuracy, with a sensitivity of 92.3%, specificity of 87.5%, and an overall accuracy of 90.6%. The positive predictive value (94.8%) was particularly strong, confirming the reliability of MRI in correctly identifying true cases. Although the negative predictive value (82.3%) was slightly lower, it still indicated good performance in ruling out anomalies, though a few subtle abnormalities could be missed.

Statistical analysis using the Chi-square test showed a significant association between fetal MRI findings and neonatal outcomes ($\chi^2 = 15.72$, $p = 0.015$), confirming that the type and severity of CNS malformation directly influenced postnatal survival.

Taken together, these results demonstrate that fetal MRI is not only accurate in diagnosing CNS malformations but also provides valuable prognostic information. Conditions such as holoprosencephaly and cortical malformations portend poor survival, while anomalies like posterior fossa malformations and corpus callosum agenesis may be associated with more favorable neonatal outcomes. Thus, fetal MRI serves as an essential adjunct to ultrasonography, guiding parental counseling and perinatal management.

Fetal MRI has emerged as a critical tool in improving the detection and prognostication of (CNS) malformations. It consistently outperforms ultrasound in delineating cortical, posterior fossa, and commissural anomalies, thus enhancing diagnostic accuracy and guiding parental counseling on neonatal outcomes [10]. High diagnostic accuracy has been reported particularly for midline and posterior fossa malformations, with significant implications for predicting neurodevelopmental trajectories and optimizing perinatal management [11].

In cases of ventriculomegaly, fetal MRI provides superior prognostic value by identifying additional cortical and migrational abnormalities not visible on ultrasound, findings strongly associated with adverse outcomes [12]. More advanced imaging, such as 3T fetal MRI, has demonstrated enhanced visualization of brain structures, which improves prognostic precision in conditions like agenesis of the corpus callosum and cortical development disorders [13].

Longitudinal studies further emphasize the prognostic utility of fetal MRI, showing that children with isolated anomalies tend to have more favorable neurodevelopmental outcomes compared to those with complex or multiple anomalies [10,11]. Recent work has highlighted the importance of diffusion tensor imaging (DTI) in assessing microstructural brain development in utero, offering additional prognostic insights beyond conventional MRI sequences [14]. Moreover, fetal MRI has proven especially valuable in identifying subtle cortical malformations, including focal cortical dysplasia, which are often missed on ultrasound but carry significant neurodevelopmental implications [15]. Taken together, these findings establish fetal MRI not only as a superior modality for detecting CNS malformations but also as a reliable predictor of neonatal and long-term developmental outcomes, enabling more precise clinical decision-making and family counseling.

Conclusion

Fetal MRI demonstrated high diagnostic accuracy in detecting CNS malformations and showed a significant correlation with neonatal outcomes. The findings highlight its value as a complementary tool to ultrasound, aiding in prognosis and guiding perinatal management.

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