MAK HILL Publications Research Journal of Medical Sciences

Research Article
doi: 10.36478/makrjms.2024.8.105.108

OPEN ACCESS

Key Words
Fetal brain imaging, magnetic resonance imaging, dedicated neurosonography, congenital brain anomalies, diagnostic accuracy

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Received: 20 May 2024
Accepted: 10 June 2024
Published: 11 July 2024

Citation: Sarita Jha and Irfan Ahmad, 2024. Fetal Brain Imaging: A Comparison between Magnetic Resonance Imaging and Dedicated Neurosonography. Res. J. Med. Sci., 18: 105-108, doi: 10.36478/makrjms.2024.8.105.108

Fetal Brain Imaging: A Comparison Between Magnetic Resonance Imaging and Dedicated Neurosonography

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Abstract
Fetal brain imaging is critical for the early detection and management of congenital brain anomalies. Magnetic Resonance Imaging (MRI) and dedicated neurosonography (NSG) are two prominent modalities used for this purpose. This study aims to compare the efficacy, accuracy and diagnostic value of MRI and dedicated NSG in fetal brain imaging. A prospective study was conducted from August 1, 2022, to July 31, 2023, in the Department of Radiology at Darbhanga Medical College and Hospital, Darbhanga. A total of 100 pregnant women with suspected fetal brain anomalies were included in the study. Each participant underwent both MRI and dedicated NSG. The imaging findings were independently reviewed by two radiologists. The parameters assessed included image clarity, diagnostic accuracy, detection of specific anomalies and overall diagnostic confidence. Statistical analysis was performed using SPSS software, with a $p<0.05$ considered statistically significant. Out of 100 cases, MRI identified brain anomalies in 65% of the fetuses, whereas dedicated NSG detected anomalies in 60% of the cases. MRI demonstrated superior image clarity and higher diagnostic confidence (90%) compared to NSG (85%). Specific anomalies such as ventriculomegaly, agenesis of the corpus callosum and intracranial hemorrhage were more accurately detected using MRI ($p<0.05$). The overall concordance rate between MRI and NSG was 85%. MRI proved to be more effective than dedicated NSG in detecting fetal brain anomalies, offering better image clarity and higher diagnostic confidence. While both modalities are valuable, MRI should be preferred in cases where detailed anatomical assessment is crucial. Further studies with larger sample sizes are recommended to validate these findings.

INTRODUCTION

Fetal brain imaging is a pivotal component of prenatal diagnostics, enabling early detection and management of congenital brain anomalies. These anomalies can significantly impact neonatal outcomes and long-term neuro developmental health. The two primary imaging modalities employed for fetal brain evaluation are Magnetic Resonance Imaging (MRI) and dedicated neurosonography (NSG). MRI offers high-resolution images and superior soft tissue contrast, which is particularly beneficial in evaluating complex brain structures and anomalies[1]. On the other hand, dedicated NSG, an advanced form of ultrasound, is widely used due to its real-time imaging capabilities and accessibility[2].

The comparative efficacy of MRI and NSG in diagnosing fetal brain anomalies has been a subject of considerable research. MRI is renowned for its ability to provide detailed anatomical visualization, crucial for diagnosing conditions such as ventriculomegaly, agenesis of the corpus callosum and intracranial hemorrhage[3]. In contrast, NSG, while less detailed, is highly effective for initial screening and is particularly advantageous in detecting structural anomalies during routine prenatal care[4]. Despite these strengths, there remains a need for comprehensive comparative studies to determine the optimal imaging modality for various clinical scenarios.

Recent studies suggest that while NSG is valuable for initial assessments, MRI's superior diagnostic accuracy and image clarity make it indispensable for detailed fetal brain evaluation, especially in high-risk cases[5,6]. However, these studies often emphasize different aspects of imaging quality and diagnostic confidence, leading to varied conclusions about the relative merits of MRI and NSG. Therefore, this study aims to provide a direct comparison between MRI and dedicated NSG in a clinical setting, focusing on diagnostic accuracy, image clarity and overall diagnostic confidence.

By conducting this study, we aim to enhance the understanding of the respective roles of MRI and NSG in fetal brain imaging, providing valuable insights for clinicians in selecting the most appropriate diagnostic tool based on specific clinical needs.

MATERIALS AND METHODS

Study Design: This was a prospective comparative study conducted in the Department of Radiology at Darbhanga Medical College and Hospital, Darbhanga, from August 1, 2022, to July 31, 2023. The study was approved by the Institutional Ethics Committee and informed consent was obtained from all participants.

Participants: A total of 100 pregnant women with suspected fetal brain anomalies, referred for detailed fetal brain imaging, were included in the study. Inclusion criteria were women with a singleton pregnancy and an indication for detailed fetal brain imaging based on initial screening ultrasounds. Exclusion criteria included multiple pregnancies, maternal contraindications to MRI and cases where the fetus was deemed non-viable.

Imaging Techniques:

Magnetic Resonance Imaging (MRI): MRI examinations were performed using a 1.5 Tesla MRI scanner (Philips Achieva). The protocol included T2-weighted single-shot fast spin-echo sequences in axial, coronal, and sagittal planes and T1-weighted gradient echo sequences in at least two planes. The total scan time was approximately 20-30 minutes. Fetal sedation was not administered, but maternal comfort measures, including adequate hydration and frequent breaks, were provided to minimize motion artifacts.

Dedicated Neurosonography (NSG): NSG was conducted using a high-frequency transabdominal ultrasound transducer (Voluson E10, GE Healthcare). The examination included multiplanar imaging of the fetal brain with a focus on the ventricles, midline structures, posterior fossa and cortical development. Each NSG scan lasted approximately 30 minutes. All NSG examinations were performed by a radiologist specialized in fetal imaging.

Data Collection: The MRI and NSG images were independently reviewed by two experienced radiologists blinded to the other modality's findings. The imaging parameters assessed included:

- **Image Clarity:** Graded on a scale from 1 (poor) to 5 (excellent) based on visibility of brain structures.
- **Diagnostic Accuracy:** Determined by comparing imaging findings with postnatal outcomes or postmortem examination (where applicable).
- **Detection of Specific Anomalies:** Including ventriculomegaly, agenesis of the corpus callosum, intracranial hemorrhage and other structural abnormalities.
- **Diagnostic Confidence:** Rated on a scale from 1 (low confidence) to 5 (high confidence).

Statistical Analysis: Data were analyzed using SPSS software (version 26.0). Descriptive statistics were used to summarize the findings. The diagnostic accuracy, image clarity and diagnostic confidence between MRI and NSG were compared using paired t-tests. The level of agreement between MRI and NSG in detecting specific anomalies was assessed using Cohen's kappa coefficient. A $p<0.05$ was considered statistically significant.

Table 1. MRI consistently showed higher clarity scores compared to NSG.

Parameter	MRI Mean Score (SD)	NSG Mean Score (SD)
Ventricles	4.8 (0.4)	4.2 (0.6)
Midline Structures	4.7 (0.5)	4.1 (0.7)
Posterior Fossa	4.6 (0.5)	4.0 (0.8)
Cortical Development	4.5 (0.6)	3.9 (0.9)
Overall Image Clarity	4.7 (0.5)	4.1 (0.7)

Table 2. MRI demonstrated higher accuracy rates across all anomalies compared to NSG.

Anomaly	MRI Detection Rate (%)	NSG Detection Rate (%)
Ventriculomegaly	95	90
Agenesis of Corpus Callosum	93	88
Intracranial Hemorrhage	92	85
Other Structural Anomalies	90	82

Table 3. MRI showed higher diagnostic confidence scores across all categories.

Parameter	MRI Mean Score (SD)	NSG Mean Score (SD)
Ventriculomegaly	4.9 (0.3)	4.4 (0.5)
Agenesis of Corpus Callosum	4.8 (0.4)	4.3 (0.6)
Intracranial Hemorrhage	4.7 (0.5)	4.2 (0.7)
Other Structural Anomalies	4.6 (0.5)	4.1 (0.7)
Overall Diagnostic Confidence	4.8 (0.4)	4.3 (0.6)

RESULTS AND DISCUSSIONS

Patient Demographics: A total of 100 pregnant women were included in the study. The mean maternal age was 28.5 years (range 20-38 years). The gestational age at the time of imaging ranged from 20 to 34 weeks, with a mean of 26 weeks.

Image Clarity: The image clarity scores for MRI and NSG are presented in Table 1. MRI consistently showed higher clarity scores compared to NSG.

Diagnostic Accuracy: The diagnostic accuracy for detecting specific anomalies using MRI and NSG is shown in Table 2. MRI demonstrated higher accuracy rates across all anomalies compared to NSG.

Diagnostic Confidence: Diagnostic confidence ratings for MRI and NSG are presented in Table 3. MRI showed higher diagnostic confidence scores across all categories.

Concordance Between MRI and NSG: The overall concordance rate between MRI and NSG in detecting fetal brain anomalies was 85%. The Cohen's kappa coefficient for agreement between the two modalities was 0.76, indicating substantial agreement.

- MRI identified fetal brain anomalies in 65% of the cases, while NSG detected anomalies in 60% of the cases.
- MRI showed superior image clarity (mean score: 4.7) compared to NSG (mean score: 4.1).
- MRI had higher diagnostic accuracy rates for ventriculomegaly (95%), agenesis of the corpus callosum (93%), intracranial hemorrhage (92%), and other structural anomalies (90%) compared to NSG.
- MRI demonstrated higher overall diagnostic confidence (mean score: 4.8) compared to NSG (mean score: 4.3).

These results suggest that MRI is more effective than dedicated NSG in detecting and diagnosing fetal brain anomalies, offering better image clarity, higher diagnostic accuracy and greater diagnostic confidence.

This study aimed to compare the efficacy of Magnetic Resonance Imaging (MRI) and dedicated neurosonography (NSG) in detecting fetal brain anomalies. The findings indicate that MRI outperforms NSG in terms of image clarity, diagnostic accuracy and diagnostic confidence.

Image Clarity: MRI demonstrated superior image clarity compared to NSG across all assessed parameters. The high-resolution imaging capability of MRI, coupled with its excellent soft tissue contrast, allows for detailed visualization of fetal brain structures[1]. This is consistent with previous studies that have highlighted MRI's advantages in providing clear and detailed images, which are crucial for accurate diagnosis[2].

Diagnostic Accuracy: Our study found that MRI had higher diagnostic accuracy rates for ventriculomegaly, agenesis of the corpus callosum, intracranial hemorrhage, and other structural anomalies compared to NSG. This aligns with existing literature that emphasizes MRI's superior diagnostic performance in detecting various fetal brain anomalies[3,4]. The ability of MRI to detect subtle anomalies that might be missed by NSG underscores its importance in comprehensive fetal brain assessment.

Diagnostic Confidence: The higher diagnostic confidence associated with MRI, as observed in this study, further reinforces its utility in clinical practice. Radiologists reported higher confidence in diagnosing anomalies using MRI, which can be attributed to the modality's detailed and clear imaging[5]. This is crucial for clinical decision-making and planning appropriate interventions.

Concordance Between MRI and NSG: The overall concordance rate between MRI and NSG was substantial, with a Cohen's kappa coefficient of 0.76. This suggests that while NSG remains a valuable initial screening tool, MRI provides additional diagnostic information that enhances the overall accuracy and confidence of the diagnosis[6]. Previous studies have also reported similar findings, highlighting the complementary roles of NSG and MRI in fetal brain imaging[7].

Clinical Implications: The findings of this study have important clinical implications. Given MRI's superior diagnostic capabilities, it should be considered the preferred modality for detailed fetal brain imaging, especially in high-risk cases or when initial NSG results are inconclusive. However, NSG remains a valuable tool for routine screening due to its accessibility, real-time imaging capabilities and lower cost[8].

Limitations: This study has several limitations. First, the sample size was relatively small, which may limit the generalizability of the findings. Second, the study was conducted at a single center and the results may not be applicable to other settings with different equipment and expertise levels. Future studies with larger, multi-center cohorts are needed to validate these findings.

CONCLUSION

In conclusion, MRI outperforms dedicated NSG in detecting fetal brain anomalies, offering better image clarity, higher diagnostic accuracy and greater diagnostic confidence. While NSG remains a valuable initial screening tool, MRI should be the modality of choice for detailed fetal brain evaluation. Further research is warranted to explore the cost-effectiveness and broader clinical applications of these imaging modalities.

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