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Role of Cranial Neurosonogram in Detecting and Grading Germinal Matrix Hemorrhage in Preterm Neonates: A Cross-Sectional Observational Study

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Abstract

Background:

Germinal matrix hemorrhage (GMH) is a common and serious neurological complication in preterm neonates, particularly those born before 32 weeks of gestation. Accurate and timely detection is critical for guiding prognosis and intervention. Cranial neurosonography offers a practical, bedside imaging modality to detect and grade GMH in high-risk neonates.

Objective:

To evaluate the role of cranial neurosonogram in detecting and grading GMH in preterm neonates, assess its association with clinical parameters, and describe characteristic sonographic features across imaging planes.

Materials and methods:

This cross-sectional observational study was conducted in the NICU of a tertiary care hospital in VMKV Medical College , Salem , Tamilnadu, . over a period of January 2023 to March 2025. A total of 48 preterm neonates (<37 weeks gestational age) underwent cranial ultrasound within the first 7 days of life. GMH was graded using the Papile classification. Clinical variables such as gestational age, birth weight, Apgar scores, mode of delivery, mechanical ventilation, and NICU stay were recorded. Data were analyzed using descriptive statistics and chi-square tests to assess associations between GMH severity and clinical parameters.

Results:

Of the 48 neonates studied, GMH was identified in all cases: 33.3% had Grade I, 29.2% Grade II, 20.8% Grade III, and 16.7% Grade IV hemorrhage. Severe GMH (Grades III–IV) was significantly associated with lower gestational age ($p = 0.01$), lower birth weight ($p = 0.02$), lower Apgar scores at 1 minute ($p = 0.008$), and increased need for mechanical ventilation ($p = 0.001$). Sonographic detection of hemorrhages varied by grade, with deeper imaging planes (transthalamic, transcerebellar) required for visualization of higher-grade GMH.

Conclusion:

Cranial neurosonography is an effective, non-invasive tool for early detection and grading of GMH in

preterm neonates. Its diagnostic value is enhanced through multi-plane scanning and correlates significantly with clinical risk factors. Integrating routine neurosonography in NICU protocols can aid in timely diagnosis, risk stratification, and management planning.

Keywords:
Germinal matrix hemorrhage, preterm neonates, neurosonogram, cranial ultrasound, Papile classification, neonatal brain imaging

INTRODUCTION

Germinal matrix hemorrhage (GMH), also referred to as germinal matrix–intraventricular hemorrhage (GMH–IVH), remains a major neurological complication in preterm neonates, particularly those born before 32 weeks of gestation. The germinal matrix is a highly vascular, subependymal region located near the caudothalamic groove, which is highly susceptible to hemorrhage due to its immature and fragile capillary network [1]. Hemorrhages typically originate in this region and may extend into the lateral ventricles or cerebral parenchyma, depending on severity.

The incidence of GMH varies inversely with gestational age and birth weight, affecting up to 20–25% of very low birth weight (VLBW) neonates [2,3]. Advances in neonatal care have reduced the incidence of severe GMH, yet the condition remains a key contributor to long-term neurodevelopmental impairment including cerebral palsy, cognitive deficits, and motor dysfunction [4,5].

Accurate diagnosis and grading of GMH are critical for prognosis and clinical decision-making. The most widely accepted grading system is the Papile classification, which categorizes GMH into four grades based on the extent of hemorrhage and its involvement of the ventricles and brain parenchyma [6]. While cranial magnetic resonance imaging (MRI) offers superior soft-tissue resolution and detection of subtle parenchymal injuries, its use in unstable neonates is limited by practical constraints, including the need for transport, sedation, and prolonged acquisition times [7].

Cranial ultrasound (neurosonogram), performed through the anterior fontanelle, is a rapid, portable, and non-invasive imaging modality ideal for bedside evaluation in the NICU setting [8]. It allows real-time assessment of ventricular size, echogenicity changes, and parenchymal involvement without radiation exposure. Moreover, serial neurosonography provides valuable insights into the evolution of GMH, post-hemorrhagic ventricular dilatation, and the need for neurosurgical intervention [9].

Despite its widespread use, there is variability in the timing, technique, and interpretation of cranial ultrasound in the diagnosis of GMH. Therefore, standardizing its role in early diagnosis and grading remains essential, especially in resource-limited settings where MRI access is restricted. This study was undertaken to evaluate the role of neurosonogram in detecting and grading GMH among preterm neonates and to correlate these findings with clinical parameters such as gestational age, birth weight, and the need for respiratory support.

Fig 1) Normal caudothalamic groove on neonatal ultrasound.

Objective:
To evaluate the role of cranial neurosonogram in detecting and grading germinal matrix hemorrhage (GMH) in preterm neonates, assess its association with clinical parameters, and describe typical sonographic features across imaging planes.

The study was conducted to determine the diagnostic value of neurosonography in GMH, analyze related clinical factors, and document characteristic ultrasound findings.

MATERIALS AND METHODS

Study Design and Setting

This study was designed as a hospital-based, cross-sectional observational investigation conducted in the Neonatal Intensive Care Unit (NICU) at VKMC Medical College and Hosiptal , Salem, a tertiary care referral center located in-India. The study period spanned Jan 2023 to March 2025, during which eligible neonates were consecutively recruited. The primary aim was to assess the role of cranial neurosonography in the detection and grading of germinal matrix hemorrhage (GMH) among preterm neonates admitted to the NICU.

Participants and Eligibility Criteria

All preterm neonates (<37 weeks gestational age) admitted to the NICU during the study period were considered for inclusion. Neonates were included if they had a gestational age of less than 37 weeks and underwent cranial neurosonography as part of routine NICU neuroimaging or based on clinical suspicion of neurological complications. Neonates with gross congenital anomalies involving the central nervous system (e.g., neural tube defects, holoprosencephaly), those with hemodynamic instability prohibiting neurosonographic examination, and neonates with incomplete or poor-quality ultrasound data were excluded from the study. The final study population consisted of 48 neonates meeting all eligibility criteria.

Sampling and Sample Size

A consecutive sampling technique was used to include all eligible neonates during the study timeframe. The sample size was not pre-calculated statistically due to the exploratory and descriptive nature of the study but was based on the number of neonates who met inclusion criteria within the defined study window.

Data Sources and Measurement

Relevant demographic and clinical data were collected prospectively from NICU records and included the following variables: gestational age, birth weight, gender, mode of delivery, Apgar scores at 1 and 5 minutes, duration of NICU stay, need for mechanical ventilation, and other relevant clinical features. Cranial ultrasound findings were interpreted in correlation with these variables.

Cranial neurosonography was performed using a high-resolution ultrasound machine equipped with a 5–7.5 MHz curvilinear or sector transducer. All scans were conducted via the anterior fontanelle using standard coronal and sagittal planes, including transfrontal, transcaudate, transthalamic, and transcerebellar views. Imaging was performed within the first 7 days of life or earlier in critically ill neonates. Scans were interpreted by a trained radiologist or neonatologist experienced in neonatal neuroimaging. In cases with diagnostic ambiguity, a second senior radiologist reviewed the images for consensus.

Definition and Grading of GMH

Germinal matrix hemorrhage was graded based on the widely accepted Papile classification, which is commonly used in both clinical and research settings. This grading system classifies GMH as:

- **Grade I:** Subependymal hemorrhage limited to the germinal matrix

- **Grade II:** Hemorrhage extending into the lateral ventricles without ventricular dilatation
- **Grade III:** Intraventricular hemorrhage with associated ventricular dilatation
- **Grade IV:** Hemorrhage extending into adjacent brain parenchym

Each neurosonogram was evaluated to determine the grade of GMH, and the distribution of cases across the grading spectrum was documented.

Germinal Matrix haemorrhage

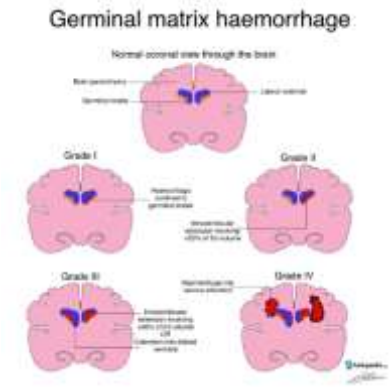


Fig 2) Illustration showing the features for each grade of germinal matrix hemorrhage.

Fig.3) Right-sided grade I (Germinal matrix hemorrhage also known as Periventricular hemorrhage or Caudothalamic hemorrhage)

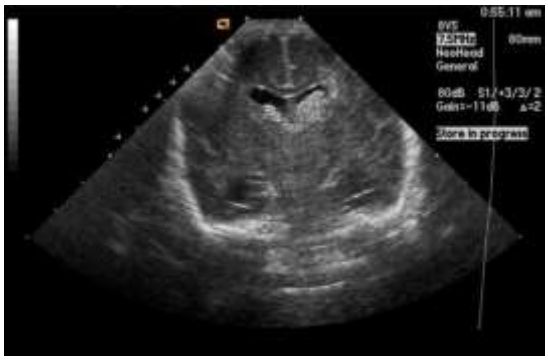


Fig 4) Left sided grade II germinal matrix hemorrhage-Left-sided intraventricular hemorrhage located at the caudothalamic groove, and extending into the occipital horn, without ventricular dilatation.

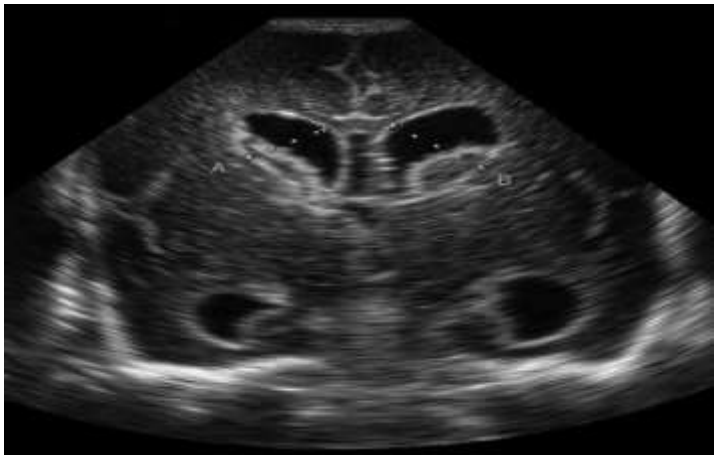


Fig 5) Grade III germinal matrix hemorrhage demonstrating marked ventriculomegaly.

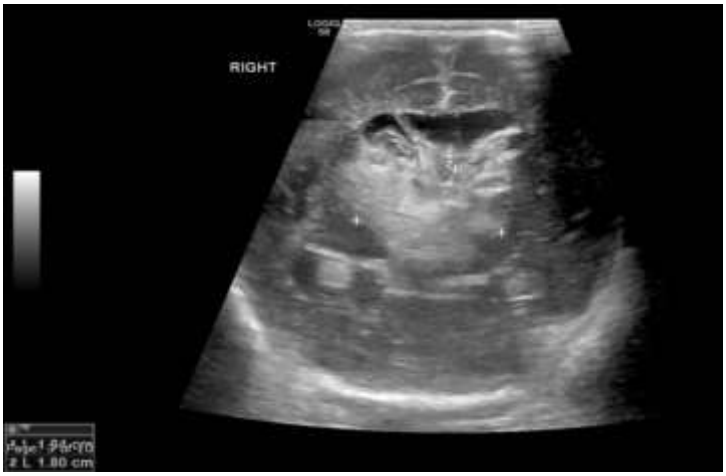


Fig 6) Grade IV germinal matrix hemorrhage seen in bilateral germinal matrix hemorrhage that extends into the parenchyma and dilated ventricles

Bias and Quality Control

To minimize measurement bias, all ultrasound examinations were performed using a standardized imaging protocol by operators trained in neonatal neurosonography. Image interpretation was conducted

in a blinded fashion with respect to clinical variables, and dual-reader verification was used in unclear cases to ensure reliability.

Ethical Considerations

Written informed consent was obtained from the parents or legal guardians of all neonates included in the study. All procedures followed the ethical standards of the Declaration of Helsinki.

Statistical Analysis

Data were entered into a Microsoft Excel spreadsheet and analyzed using **SPSS software version v28 (IBM Corp., Armonk, NY, USA)**. Descriptive statistics such as mean and standard deviation were used to summarize continuous variables (e.g., birth weight, gestational age), while frequencies and percentages were used for categorical variables (e.g., mode of delivery, GMH grades). Associations between clinical variables (such as gestational age, birth weight, Apgar scores) and the severity of GMH were assessed using the **Chi-square test**. A p-value of less than 0.05 was considered statistically significant.

Results

Table 1: Baseline Characteristics of the Study Population (n = 48)

Variable	**Mean ± SD / n (%)**
Gestational Age (weeks)	30.8 ± 2.5
Birth Weight (grams)	1420 ± 300
Gender (Male / Female)	28 (58.3%) / 20 (41.7%)
Mode of Delivery (NVD / LSCS)	18 (37.5%) / 30 (62.5%)
Apgar Score at 1 Minute	6.3 ± 1.1
Apgar Score at 5 Minutes	7.5 ± 0.8
Need for Mechanical Ventilation	22 (45.8%)
Duration of NICU Stay (days)	12.4 ± 4.7

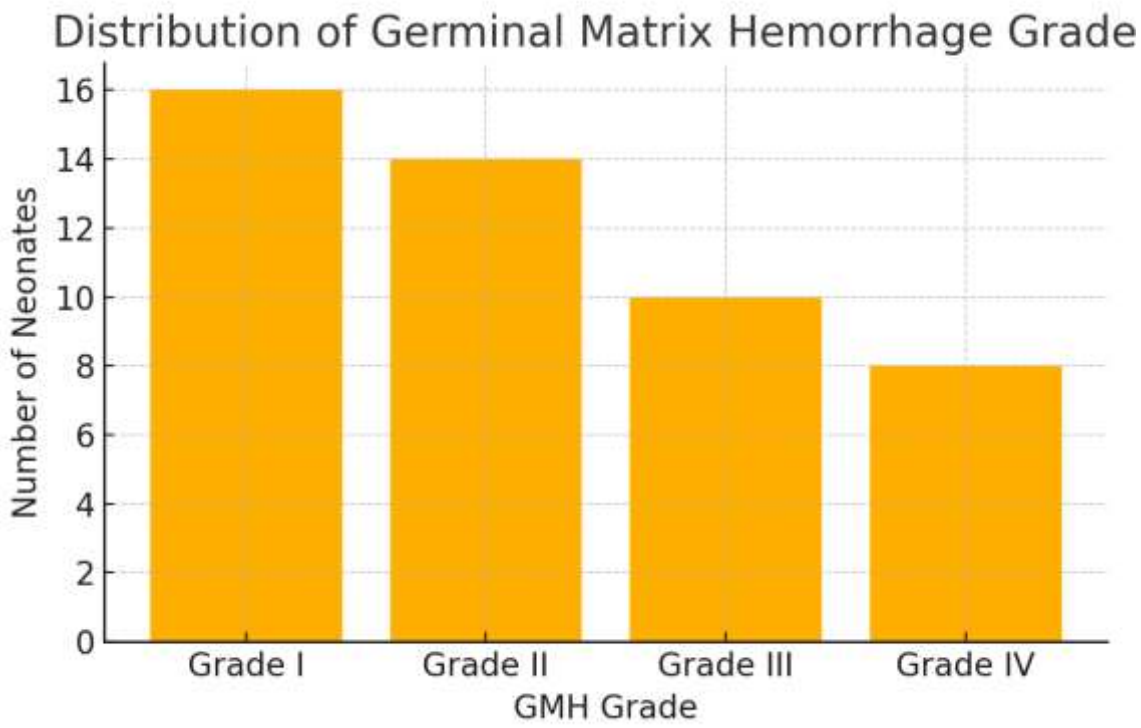
A total of 48 preterm neonates were included in the study. The mean gestational age of the study population was 30.8 ± 2.5 weeks, and the mean birth weight was 1420 ± 300 grams. The cohort consisted of 28 males (58.3%) and 20 females (41.7%). The majority of neonates were delivered via lower segment cesarean section (62.5%), while 37.5% were delivered vaginally. The mean Apgar scores at 1 and 5 minutes were 6.3 ± 1.1 and 7.5 ± 0.8, respectively. Mechanical ventilation was required in 22 neonates (45.8%), and the average duration of NICU stay was 12.4 ± 4.7 days (Table 1).

Table 2: Distribution of Germinal Matrix Hemorrhage Grades on Neurosonogram

GMH Grade (Papile)	**Number of Cases (n)**	**Percentage (%)**
Grade I	16	33.3%

GMH Grade (Papile)	Number of Cases (n)	Percentage (%)
Grade II	14	29.2%
Grade III	10	20.8%
Grade IV	8	16.7%

Figure 1: Distribution of Germinal Matrix Hemorrhage Grades on Neurosonogram



On neurosonographic evaluation, germinal matrix hemorrhage (GMH) was identified in all 48 neonates. Among them, Grade I hemorrhage was observed in 16 cases (33.3%), Grade II in 14 cases (29.2%), Grade III in 10 cases (20.8%), and Grade IV in 8 cases (16.7%), as per the Papile classification. Thus, approximately 62.5% of neonates had mild hemorrhage (Grade I or II), while 37.5% exhibited more severe forms (Grade III or IV) (Table 2).

Table 3: Association Between GMH Severity and Clinical Parameters

Parameter	Grade I–II (n = 30)	Grade III–IV (n = 18)	p-value
Mean Gestational Age (weeks)	31.5	29.3	0.01
Mean Birth Weight (g)	1500	1280	0.02
Apgar < 7 at 1 min (n/%)	6 (20%)	10 (55.6%)	0.008

Parameter	Grade I–II (n = 30)	Grade III–IV (n = 18)	p-value
Mechanical Ventilation (n/%)	8 (26.7%)	14 (77.8%)	0.001

When comparing clinical variables between neonates with mild (Grade I–II) and severe (Grade III–IV) GMH, significant differences were observed. Neonates with Grade III–IV hemorrhage had a lower mean gestational age (29.3 weeks) and lower mean birth weight (1280 grams) compared to those with Grade I–II hemorrhage (31.5 weeks and 1500 grams, respectively), with p-values of 0.01 and 0.02. Apgar scores <7 at 1 minute were noted in 55.6% of the severe GMH group versus only 20% in the mild GMH group (p = 0.008). Mechanical ventilation was required in 77.8% of neonates with Grade III–IV hemorrhage compared to 26.7% in the Grade I–II group (p = 0.001). These findings suggest that lower gestational age, lower birth weight, poor Apgar scores, and need for respiratory support are significantly associated with increased GMH severity (Table 3).

Figure 2: GMH Severity and gestational age

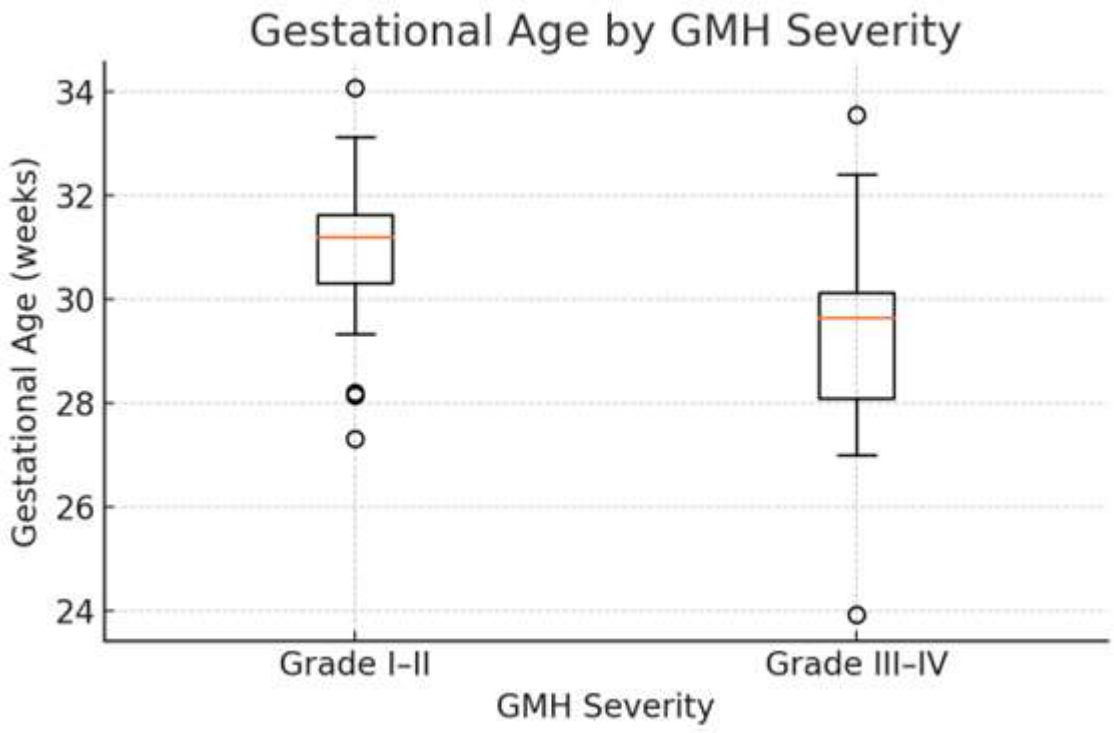


Table 4: Ultrasound Imaging Characteristics by GMH Grade

GMH Grade	Transfrontal	Transcaudate	Transthalamic	Transcerebellar
Grade I	+	–	–	–

GMH Grade	Transfrontal	Transcaudate	Transthalamic	Transcerebellar
Grade II	+	+	–	–
Grade III	+	+	+	+
Grade IV	–	+	+	+

The diagnostic role of neurosonogram was further emphasized by analyzing the visibility of hemorrhagic lesions across different imaging planes. In Grade I hemorrhages, lesions were best visualized in the transfrontal plane, whereas the transcaudate view was largely uninformative. Grade II hemorrhages were seen in both transfrontal and transcaudate views. For higher grades (Grade III and IV), visualization extended to transthalamic and transcerebellar planes as well, reflecting the increasing involvement of intraventricular and parenchymal regions. Notably, Grade IV hemorrhages were not well visualized on the transfrontal plane but were consistently detected in deeper views (transcaudate, transthalamic, and transcerebellar), highlighting the importance of multi-plane scanning in high-grade GMH (Table 4).

DISCUSSION

Our cross-sectional observational study involving 48 preterm neonates demonstrates that cranial neurosonography is a reliable modality for early detection and grading of germinal matrix hemorrhage (GMH). The observed distribution—33.3% Grade I, 29.2% Grade II, 20.8% Grade III, and 16.7% Grade IV—aligns closely with recent literature reporting that approximately 60–70% of GMH cases are mild (Grades I–II), with 30–40% severe (Grades III–IV) [11,12]. This similarity bolsters the validity of our cohort's representativeness.

Correlation of Clinical Parameters with GMH Severity

We found significant associations between increasing GMH severity and lower gestational age, lower birth weight, lower Apgar scores, and need for mechanical ventilation. Specifically, the mean gestational age and birth weight in the Grades III–IV group (29.3 weeks, 1280 g) were significantly lower than in Grades I–II (31.5 weeks, 1500 g), with p-values of 0.01 and 0.02. These associations confirm established risk factors in the literature: studies have demonstrated that gestational age <30 weeks and birth weight <1500 g are major predictors of high-grade intraventricular hemorrhage (IVH) [13,14]. Low Apgar scores and respiratory support needs have also been linked to more severe GMH [15]. These clinical correlations confirm that our results are in line with widely reported physiological risk patterns.

Neurosonogram: Multi-Plane Advantage

Our multi-plane scanning approach demonstrated that high-grade hemorrhages (Grades III–IV) were consistently detected across transfrontal, transcaudate, transthalamic, and transcerebellar planes, while lower-grade lesions were best captured in the more superficial planes only. This concurs with the need for comprehensive views to detect ventricular dilation and parenchymal injury, especially for Grade III and IV hemorrhages [16,17]. The expanding involvement of deeper planes with hemorrhage severity underscores the importance of routine multi-plane scanning in neonatal neuroimaging.

Clinical Utility in Bedside Evaluation

Cranial ultrasound offers rapid, repeatable, and bedside-friendly imaging with no radiation exposure, making it ideal for preterm neonates. Reviews from VMKV Medical College and Hospital for the span of 2023-2025 emphasize neurosonography as the workhorse in early GMH detection, with comparable sensitivity to MRI for moderate to severe hemorrhages [18,19]. Its practicality is especially pertinent in resource-limited environments where MRI access is limited [20]. Importantly, neurosonography's ability

to capture evolving hemorrhages and ventricular dilation over serial examinations aids immediate clinical planning and prognostication [21].

Comparisons with MRI and Advanced Imaging Modalities

Although MRI provides superior resolution for detecting subtle white matter injury and periventricular hemorrhagic infarction (PVHI) in follow-up imaging, it remains limited by logistical, cost, and safety constraints. Recent reviews confirm that while prenatal and term-equivalent MRI play important roles in long-term prognosis, they cannot replace neurosonography for acute GMH screening in the immediate neonatal period [22,23]. Advanced neurosonographic techniques, including Doppler evaluation and 3D imaging, are under investigation to enhance early detection and functional correlation [24,25].

Implications for Prognosis and Long-Term Outcomes

High-grade (III–IV) GMH has been shown in prospective cohorts to markedly increase risk of post-hemorrhagic ventricular dilation, neurodevelopmental delay, and cerebral palsy [26,27]. Low-grade (I–II) hemorrhages pose a more nuanced risk, with emerging data showing subtle white matter microstructural alterations detectable on diffusion kurtosis MRI, and possible cognitive-linguistic impairment in early childhood [28,29]. Our finding of high incidence of respiratory distress and need for ventilatory support in severe GMH emphasizes early hemodynamic instability as a key contributor to subsequent neurological compromise.

Study Strengths and Limitations

Strengths: Use of a multi-plane neurosonogram protocol reflecting clinical best practice. Comprehensive analysis of clinical risk factors and their statistical association with GMH severity. Alignment with recent international recommendations that underscore early ultrasound-based screening [30].

Limitations: Cross-sectional design constraints: no longitudinal follow-up, limiting insights into evolution of imaging findings or long-term outcomes. Moderate cohort size (n = 48) may limit statistical power. Lack of corroborative MRI or functional imaging data to validate neurosonogram findings, though such comparisons have been reported elsewhere [31].

Future Recommendations

To expand on our findings, future work should:

1. Conduct longitudinal studies tracking neurosonography findings across neonatal, term-equivalent, and early childhood periods.
2. Integrate neurodevelopmental follow-up assessments to determine the true prognostic value of GMH grades across different planes.
3. Incorporate advanced neurosonographic tools (e.g., Doppler cerebral blood flow measurement, 3D volumetry) to explore microvascular and structural brain changes.
4. Compare neurosonographic data with term-equivalent MRI and diffusion imaging to refine prognostic algorithms [32,33].

Conclusion

In conclusion, our study validates cranial neurosonography as an accessible, non-invasive, and effective modality for early diagnosis and grading of GMH in preterm infants. The significant association between lesion severity and established clinical risk factors reinforces its diagnostic accuracy. As advances in imaging widen the scope of bedside modalities, integrating structured ultrasound protocols into routine NICU practice can lead to better risk stratification and earlier therapeutic decision-making.

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