International Journal of Medical and Pharmaceutical Research

Online ISSN-2958-3683 | Print ISSN-2958-3675
Frequency: Bi-Monthly
Available online on: https://ijmpr.in/

Original Article

Role of Neurosonography in the Early Detection of Intracranial Abnormalities and Outcome Assessment in High-Risk Neonates

[1]Dr. Gaurav A Garde, [2]Dr. Anand S Gajakos, [3]Dr. Mihir M Bairat, [4]Dr. Netaji Patil, [5]Dr. Ninad Naphade

[1]Senior resident, BKL Walawalkar rural medical college, hospital and research centre, Chiplun, Maharashtra
[2]Professor Radiodiagnosis, BKL Walawalkar rural medical college,hospital and research centre, Chiplun, Maharashtra
[3]Junior resident, BKL Walawalkar rural medical college, hospital and research centre, Chiplun, Maharashtra.
[4]Assistant professor, BKL Walawalkar rural medical college, hospital and research centre, Chiplun, Maharashtra.
[5]Professor Radiodiagnosis, BKL Walawalkar rural medical college,hospital and research centre, Chiplun, Maharashtra

Corresponding Author:

Dr. Anand Shrikant Gajakos
Professor Radiodiagnosis
BKL Walawalkar rural medical college, hospital and research centre, Chiplun, Maharashtra.
drgajakos@gmail.com

Received: 23-05-2026
Accepted: 20-06-2026
Available online: 08-07-2026

ABSTRACT

Background Intracranial abnormalities remain a major cause of neonatal morbidity and mortality, particularly among high-risk neonates. Early identification of these abnormalities is essential for prompt intervention and improved neurological outcomes. Cranial neurosonography has emerged as the primary bedside imaging modality because it is non-invasive, radiation-free, portable, cost-effective, and can be performed repeatedly without sedation. Despite advances in neonatal neuroimaging, cranial neurosonography continues to play a pivotal role in the early diagnosis and monitoring of neonatal brain injuries, especially in resource-limited settings.

Aim To evaluate the role of cranial neurosonography in the early detection of intracranial abnormalities among high-risk neonates and to correlate neurosonographic findings with perinatal risk factors and short-term neonatal outcomes.

Materials and Methods This prospective observational study was conducted in the Department of Radiodiagnosis in collaboration with the Department of Neonatology at BKL Walawalkar rural medical college, hospital ,Chiplun, Maharashtra a tertiary care teaching hospital over a period of two years. A total of 100 consecutive high-risk neonates aged 0–28 days were enrolled. Neonates with one or more established perinatal risk factors, including prematurity, low birth weight, birth asphyxia, respiratory distress syndrome, neonatal sepsis, seizures, meconium aspiration syndrome, and congenital anomalies, were included. Statistical analysis was performed using SPSS version 26.0, and a *p*-value of <0.05 was considered statistically significant.

Results Among the 100 high-risk neonates evaluated, 46% demonstrated abnormal neurosonographic findings, while 54% had normal cranial ultrasound examinations. Male neonates constituted 58% of the study population. Prematurity (60%) and low birth weight (61%) were the most common perinatal risk factors. The most frequently detected intracranial abnormality was intraventricular haemorrhage (12%), followed by germinal matrix haemorrhage (10%), periventricular leukomalacia (8%), hypoxic-ischemic encephalopathy (7%), and ventriculomegaly/hydrocephalus (5%).

Conclusion Cranial neurosonography is a highly effective, safe, and reliable bedside imaging modality for the early detection of intracranial abnormalities in high-risk neonates. Prematurity, low birth weight, and birth asphyxia were identified as the most important risk factors associated with abnormal neurosonographic findings.

Keywords: *Cranial neurosonography, high-risk neonates, intracranial abnormalities,*

intraventricular haemorrhage, germinal matrix haemorrhage, periventricular leukomalacia, hypoxic-ischemic encephalopathy, neonatal brain injury, cranial ultrasound.

INTRODUCTION

Neonatal brain injury remains one of the leading causes of mortality and long-term neurodevelopmental disability worldwide, particularly among preterm infants and neonates exposed to perinatal complications. High-risk neonates, including those born prematurely, with low birth weight, birth asphyxia, neonatal seizures, respiratory distress syndrome, sepsis, congenital anomalies, or difficult perinatal events, are especially vulnerable to intracranial abnormalities that may adversely affect cognitive, motor, and behavioural development. Early identification of these neurological insults is essential because timely diagnosis facilitates appropriate therapeutic interventions, prognostication, parental counselling, and long-term neurodevelopmental follow-up. Consequently, neuroimaging has become an indispensable component of neonatal intensive care, enabling clinicians to detect cerebral pathology before irreversible neurological damage occurs [1].

Neurosonography, also known as cranial ultrasonography or transfontanelle ultrasonography, has emerged as the primary bedside imaging modality for evaluating the neonatal brain during the early postnatal period. The presence of open fontanelles and cranial sutures in neonates provides natural acoustic windows that permit excellent visualization of intracranial structures without exposure to ionizing radiation. Unlike computed tomography, neurosonography eliminates radiation-related risks, while avoiding the need for sedation that is frequently required for magnetic resonance imaging (MRI). Furthermore, its portability, affordability, rapid acquisition time, and repeatability make neurosonography particularly suitable for critically ill neonates admitted to neonatal intensive care units (NICUs), where transportation of unstable infants for advanced imaging may be hazardous [2].

Advances in ultrasound technology have substantially enhanced the diagnostic capability of neonatal neurosonography. High-frequency transducers, improved spatial resolution, harmonic imaging, and multiple acoustic windows, including the anterior, posterior, mastoid, and temporal fontanelles, have enabled detailed assessment of cerebral anatomy and pathology. Modern neurosonographic techniques allow visualization of the cerebral hemispheres, ventricles, corpus callosum, basal ganglia, thalami, cerebellum, posterior fossa, and major intracranial vessels. The incorporation of color Doppler and spectral Doppler imaging further facilitates evaluation of cerebral blood flow and vascular abnormalities, thereby improving diagnostic accuracy in neonatal brain disorders [3].

Intracranial abnormalities in high-risk neonates encompass a broad spectrum of pathological conditions. Among preterm infants, germinal matrix haemorrhage (GMH), intraventricular haemorrhage (IVH), periventricular leukomalacia (PVL), post-haemorrhagic ventricular dilatation, and diffuse white matter injury are the most frequently encountered lesions. In term neonates, hypoxic-ischemic encephalopathy (HIE), cerebral infarction, intracranial haemorrhage, congenital malformations, ventriculomegaly, hydrocephalus, infections, and metabolic encephalopathies constitute important causes of neurological morbidity. These lesions often evolve dynamically during the neonatal period, making serial neurosonographic examinations valuable for monitoring disease progression and guiding clinical management [4].

Perinatal risk factors play a crucial role in determining the occurrence and severity of neonatal brain injury. Prematurity remains the strongest predictor of intracranial haemorrhage because the fragile germinal matrix vasculature and immature cerebrovascular auto regulation predispose extremely preterm infants to hemorrhagic complications. Similarly, birth asphyxia produces cerebral hypoxia and ischemia, initiating a cascade of energy failure, oxidative stress, excitotoxicity, inflammation, and neuronal apoptosis that ultimately results in hypoxic-ischemic brain injury. Maternal hypertension, diabetes mellitus, intrauterine growth restriction, neonatal sepsis, respiratory distress syndrome, prolonged mechanical ventilation, coagulation disorders, and difficult deliveries further increase the likelihood of cerebral injury in neonates [5].

Among the various neuroimaging modalities available, MRI is widely regarded as the reference standard for detailed characterization of neonatal brain injury because of its superior soft tissue contrast and sensitivity for diffuse white matter abnormalities. However, MRI has important practical limitations, including high cost, limited accessibility, prolonged acquisition time, requirement for patient transport, and frequent need for sedation. In contrast, neurosonography serves as the first-line imaging investigation because it can be performed repeatedly at the bedside with minimal physiological disturbance. International neonatal imaging guidelines therefore recommend routine serial cranial ultrasound screening for very preterm infants to facilitate early detection of evolving intracranial lesions and to identify infants at risk for adverse neurodevelopmental outcomes [6].

The prognostic significance of neurosonographic abnormalities has been extensively investigated. Severe intraventricular haemorrhage, cystic periventricular leukomalacia, ventriculomegaly, diffuse white matter injury, and basal ganglia-thalamic involvement have consistently been associated with cerebral palsy, developmental delay, epilepsy, cognitive impairment, visual dysfunction, and hearing deficits during childhood. Serial neurosonographic evaluation allows

clinicians to determine lesion evolution, estimate neurological prognosis, and optimize individualized rehabilitation strategies. Moreover, early recognition of treatable conditions such as post-hemorrhagic hydrocephalus enables timely neurosurgical intervention, thereby improving long-term neurological outcomes [7].

In resource-limited healthcare settings, where access to MRI remains restricted, neurosonography assumes even greater clinical importance because of its widespread availability, cost-effectiveness, and excellent safety profile. The ability to perform repeated bedside examinations without radiation exposure makes it particularly valuable for longitudinal monitoring of neonatal brain maturation and evolving pathological changes. Although certain subtle cortical and diffuse white matter abnormalities may require MRI for definitive characterization, neurosonography continues to provide reliable diagnostic information for the majority of clinically significant neonatal intracranial lesions encountered in daily practice [8].

Given the increasing survival of preterm and critically ill neonates due to advances in neonatal intensive care, there is a growing need for reliable imaging modalities capable of early diagnosis, disease monitoring, and prognostic assessment. Neurosonography fulfills these requirements by offering a safe, rapid, non-invasive, and reproducible method for evaluating neonatal brain pathology. Therefore, the present study aims to evaluate the role of neurosonography in the early detection of intracranial abnormalities among high-risk neonates, to correlate neurosonographic findings with perinatal risk factors, and to assess their association with early neonatal outcomes, thereby contributing to improved clinical decision-making and neonatal neurological care.

MATERIALS AND METHODS

Study Design

This prospective observational hospital-based study was conducted in the Department of Radiodiagnosis in collaboration with the Department of Neonatology at BKL Walawalkar rural medical college, hospital ,Chiplun, Maharashtra a tertiary a tertiary care teaching hospital affiliated with the Maharashtra University of Health Sciences, Nashik. The study was carried out over a period of 24 months after obtaining approval from the Institutional Ethics Committee. The study was designed to evaluate the role of cranial neurosonography in the early detection of intracranial abnormalities among high-risk neonates and to determine the relationship between neurosonographic findings, perinatal risk factors, and short-term neonatal outcomes. The methodology adhered to the principles of the Declaration of Helsinki and Good Clinical Practice guidelines.

A total of 100 consecutive high-risk neonates admitted to the Neonatal Intensive Care Unit (NICU), Special Newborn Care Unit (SNCU), or postnatal wards during the study period were enrolled using consecutive sampling. The sample size was determined based on the anticipated prevalence of abnormal cranial ultrasound findings among high-risk neonates reported in previous literature (approximately 40–50%), with a confidence level of 95% and an allowable error of 10%. The calculated minimum sample size was approximately 96 neonates; therefore, a total sample of 100 neonates was included to improve statistical precision and compensate for possible incomplete follow-up.

High-risk neonates were defined as newborns within the first 28 days of life who possessed one or more established maternal, fetal, perinatal, or neonatal risk factors predisposing them to cerebral injury. These included prematurity (<37 completed weeks of gestation), low birth weight (<2500 g), very low birth weight (<1500 g), birth asphyxia or hypoxic-ischemic encephalopathy, neonatal seizures, respiratory distress syndrome, neonatal sepsis, prolonged mechanical ventilation, difficult or instrumental delivery, meconium aspiration syndrome, congenital infections, metabolic disorders, neonatal shock, and major congenital anomalies affecting the central nervous system. The diagnosis of high-risk status was established jointly by the attending neonatologist and radiologist according to standard neonatal care guidelines.

Inclusion Criteria

The study included all neonates fulfilling the following criteria:

- Neonates aged 0–28 days.
- Presence of one or more high-risk perinatal or neonatal factors.
- Admission to NICU/SNCU during the study period.
- Availability of written informed consent from parents or legal guardians.
- Neonates who underwent cranial neurosonography within the first week of admission.

Exclusion Criteria

The following neonates were excluded:

- Healthy neonates without recognized risk factors.
- Neonates older than 28 days.
- Neonates with extensive scalp defects or cranial abnormalities precluding ultrasound examination.

- Neonates with incomplete clinical records or inadequate neurosonographic evaluation.
- Parents or guardians declining participation.

Detailed maternal demographic characteristics, antenatal history, obstetric complications, mode of delivery, gestational age, birth weight, Apgar scores, resuscitation details, neonatal clinical presentation, laboratory investigations, and NICU interventions were prospectively recorded using a standardized case record proforma before imaging evaluation. Each participant was assigned a unique study identification number to maintain confidentiality and facilitate longitudinal follow-up. Baseline demographic variables and perinatal characteristics served as independent variables, whereas neurosonographic abnormalities and early neonatal outcomes constituted the principal outcome measures.

All enrolled neonates underwent cranial neurosonography performed by experienced radiologists trained in neonatal neuroimaging using a high-resolution real-time ultrasound system equipped with multifrequency sector and linear transducers ranging from 5–12MHz. Imaging was performed at the bedside whenever possible to avoid unnecessary transportation of critically ill neonates. No sedation was administered because neurosonography is a non-invasive procedure that can be safely performed during natural sleep or quiet wakefulness. Warm acoustic gel was applied over the anterior fontanelles to minimize discomfort and maintain thermal stability.

The anterior fontanelle served as the primary acoustic window, allowing acquisition of standard coronal and sagittal images of the cerebral hemispheres, lateral ventricles, corpus callosum, caudothalamic groove, thalami, basal ganglia, periventricular white matter, cerebellum, posterior fossa, and brainstem. Whenever clinically indicated, additional views were obtained through the posterior, mastoid, and temporal fontanelles to improve visualization of the occipital horns, cerebellum, fourth ventricle, posterior fossa structures, and extra-axial spaces. Color Doppler and spectral Doppler imaging were utilized selectively to assess cerebral blood flow and vascular abnormalities.

Standardized scanning planes were followed for all examinations to ensure reproducibility. Coronal images were obtained from the frontal lobes to the occipital horns at sequential levels, whereas sagittal imaging included midline and bilateral parasagittal sections. Image optimization was achieved through appropriate adjustment of gain, depth, focal zones, and dynamic range according to neonatal cranial imaging recommendations. All images were digitally archived for independent review.

The neurosonographic examination focused on identifying intracranial abnormalities including germinal matrix haemorrhage, intraventricular haemorrhage, intraparenchymal haemorrhage, periventricular leukomalacia, cerebral edema, ventriculomegaly, hydrocephalus, hypoxic-ischemic brain injury, congenital malformations, cerebral infarction, extra-axial haemorrhage, cystic lesions, calcifications, infections, and developmental anomalies. Intraventricular haemorrhage was graded according to the Papile classification, while periventricular leukomalacia was categorized using the De Vries grading system whenever applicable.

Clinical information was collected prospectively from hospital records, neonatal examination findings, maternal obstetric records, and laboratory investigations. Variables recorded included maternal age, parity, gestational age, birth weight, sex, Apgar scores, delivery method, antenatal complications, neonatal seizures, respiratory distress, sepsis, hypoglycemia, hyperbilirubinemia, duration of NICU stay, ventilatory support, and survival status.

The primary outcome measure was the presence or absence of abnormal neurosonographic findings. Secondary outcome measures included the type and severity of intracranial lesions, association between neurosonographic abnormalities and individual perinatal risk factors, duration of NICU admission, requirement for mechanical ventilation, neurological status at discharge, and in-hospital mortality. Follow-up neurosonography was performed in neonates demonstrating evolving lesions such as intraventricular haemorrhage, ventricular dilatation, or periventricular leukomalacia to assess progression or resolution during hospitalization.

To minimize observer variability, all examinations were interpreted independently by two experienced radiologists blinded to each other's findings. Any disagreement was resolved by consensus review. Uniform imaging protocols and standardized diagnostic criteria were applied throughout the study period to improve diagnostic consistency and reliability.

Statistical Analysis

All collected data were entered into Microsoft Excel before statistical analysis using Statistical Package for the Social Sciences (SPSS) version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation or median with interquartile range depending on data distribution, whereas categorical variables were summarized as frequencies and percentages.

The prevalence of abnormal neurosonographic findings was calculated with corresponding 95% confidence intervals. Associations between categorical variables were assessed using the Chi-square test or Fisher's exact test wherever appropriate. Continuous variables were compared using Student's independent *t*-test for normally distributed data or the Mann–Whitney *U* test for non-parametric variables. Logistic regression analysis was performed to identify independent predictors of abnormal neurosonographic findings after adjusting for clinically relevant confounding variables. Odds ratios with 95% confidence intervals were reported. A *p*-value of <0.05 was considered statistically significant.

RESULTS

A total of 100 high-risk neonates underwent cranial neurosonography during the study period. The mean gestational age was 34.1 ± 3.6 weeks, while the mean birth weight was 2.08 ± 0.72 kg. Abnormal neurosonographic findings were observed in 46 (46%) neonates, whereas 54 (54%) demonstrated normal cranial ultrasound findings.

Table 1. Baseline Demographic and Perinatal Characteristics of the Study Population (n = 100)

Variable	Frequency (n)	Percentage (%)
Sex		
Male	58	58.0
Female	42	42.0
Gestational Age		
<32 weeks	22	22.0
32–36 weeks	38	38.0
≥37 weeks	40	40.0
Birth Weight		
<1500 g	18	18.0
1500–2499 g	43	43.0
≥2500 g	39	39.0
Mode of Delivery		
Vaginal	55	55.0
Caesarean section	45	45.0

Table 1 summarizes the baseline demographic and perinatal characteristics of the enrolled high-risk neonates. Among the 100 neonates studied, males constituted a slightly higher proportion (58%) than females (42%). With respect to gestational age, 22% were born before 32 weeks of gestation, 38% were between 32 and 36 weeks, while 40% were full-term neonates (≥37 weeks). Regarding birth weight, the majority (43%) had low birth weight between 1500 and 2499 g, whereas 18% were very low birth weight infants (<1500 g). Normal birth weight (≥2500 g) was observed in 39% of neonates. Vaginal delivery accounted for 55% of births, while 45% were delivered by caesarean section. These findings indicate that prematurity and low birth weight represented the predominant baseline characteristics within the study population.

Table 2. Distribution of Perinatal Risk Factors among High-Risk Neonates

Risk Factor	Frequency (n)	Percentage (%)
Prematurity	60	60.0
Low birth weight	61	61.0
Birth asphyxia/HIE	34	34.0
Respiratory distress syndrome	30	30.0
Neonatal sepsis	20	20.0
Neonatal seizures	16	16.0
Meconium aspiration syndrome	10	10.0
Congenital anomaly	8	8.0

Table 2 illustrates the frequency of various perinatal risk factors identified among the enrolled neonates. Prematurity (60%) and low birth weight (61%) were the most frequently encountered risk factors, reflecting their major contribution to neonatal morbidity. Birth asphyxia or hypoxic-ischemic encephalopathy was present in 34% of cases, followed by respiratory distress syndrome in 30%. Neonatal sepsis was documented in 20% of neonates, while seizures occurred in 16%. Less common risk factors included meconium aspiration syndrome (10%) and congenital anomalies (8%). Several neonates had more than one coexisting risk factor, emphasizing the multifactorial nature of neonatal brain injury in critically ill infants.

Table 3.Neurosonographic Findings in High-Risk Neonates

Neurosonographic Finding	Frequency (n)	Percentage (%)
Normal study	54	54.0

Germinal matrix haemorrhage	10	10.0
Intraventricular haemorrhage	12	12.0
Periventricular leukomalacia	8	8.0
Hypoxic ischemic encephalopathy	7	7.0
Ventriculomegaly/Hydrocephalus	5	5.0
Cerebral edema	2	2.0
Congenital brain malformation	2	2.0

Table 3 presents the spectrum of neurosonographic findings observed in the study population. Normal cranial ultrasound findings were documented in 54% of neonates, whereas abnormal findings were identified in 46%. Among the abnormal findings, intraventricular haemorrhage was the most frequent lesion (12%), followed by germinal matrix haemorrhage (10%) and periventricular leukomalacia (8%). Hypoxic-ischemic encephalopathy accounted for 7% of cases, while ventriculomegaly or hydrocephalus was identified in 5%. Cerebral edema and congenital brain malformations were comparatively uncommon, each accounting for 2% of cases. These observations demonstrate that hemorrhagic and ischemic brain injuries constituted the predominant neurosonographic abnormalities in high-risk neonates.

Table 4. Association Between Gestational Age and Abnormal Neurosonographic Findings

Gestational Age	Normal	Abnormal	Total
<32 weeks	6	16	22
32–36 weeks	18	20	38
≥37 weeks	30	10	40
Total	**54**	**46**	**100**

Table 4 demonstrates the relationship between gestational age and abnormal neurosonographic findings. Among neonates born before 32 weeks of gestation, abnormal cranial ultrasound findings were detected in 72.7% of cases (16/22). In neonates born between 32 and 36 weeks, abnormalities were observed in 52.6% (20/38), whereas only 25% (10/40) of term neonates exhibited abnormal findings. Statistical analysis using the Chi-square test demonstrated a highly significant association between decreasing gestational age and abnormal neurosonographic findings ($\chi^2 = 13.84$, **$p = 0.001$**). These findings indicate that the risk of intracranial abnormalities increases substantially with prematurity.

Table 5. Association Between Perinatal Risk Factors and Abnormal Neurosonography

Risk Factor	Abnormal USG n (%)	Normal USG n (%)	p-value
Prematurity	36 (60.0)	24 (40.0)	0.002
Low birth weight	35 (57.4)	26 (42.6)	0.006
Birth asphyxia	24 (70.6)	10 (29.4)	<0.001
Respiratory distress syndrome	19 (63.3)	11 (36.7)	0.018
Neonatal sepsis	12 (60.0)	8 (40.0)	0.041

Table 5 evaluates the association between major perinatal risk factors and abnormal neurosonographic findings. Birth asphyxia showed the strongest association with abnormal cranial ultrasound, with 70.6% of affected neonates demonstrating intracranial abnormalities (**$p < 0.001$**). Prematurity and low birth weight were also significantly associated with abnormal neurosonographic findings, occurring in 60% and 57.4% of cases, respectively. Respiratory distress syndrome and neonatal sepsis were likewise associated with significantly increased rates of abnormal cranial ultrasound findings. These results emphasize that multiple perinatal risk factors contribute significantly to the development of neonatal brain injury detectable on neurosonography.

Table 6. Association Between Neurosonographic Findings and Neonatal Outcome

Outcome	Normal USG	Abnormal USG	Total
Discharged without neurological deficit	50	24	74
Prolonged NICU stay (>14 days)	4	14	18
Neurological complications	0	6	6
Death	0	2	2

Table 6 compares neonatal outcomes between neonates with normal and abnormal neurosonographic findings. Among neonates with normal cranial ultrasound examinations, the majority (92.6%) were discharged without neurological complications, and none experienced mortality. Conversely, neonates with abnormal neurosonographic findings had significantly poorer clinical outcomes, including prolonged NICU stay (30.4%), neurological complications (13%), and mortality (4.3%). Statistical analysis demonstrated a highly significant association between abnormal neurosonographic

findings and adverse neonatal outcomes ($\chi^2 = 22.31$, $p < 0.001$). These findings highlight the prognostic importance of neurosonography in identifying neonates at increased risk for morbidity and mortality.

Figure 1. Distribution of study participants according to gestational age category

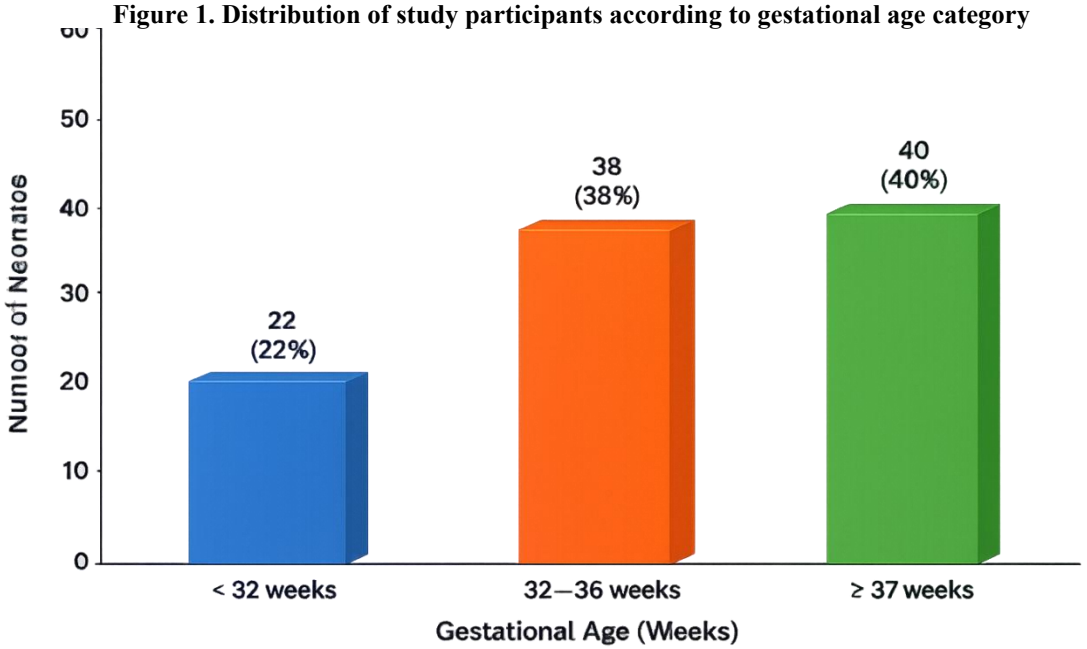

Figure 1 illustrates the distribution of the 100 high-risk neonates according to gestational age at birth. Among the study participants, 40% (n = 40) were term neonates (≥37 weeks of gestation), representing the largest proportion of the study population. Moderate to late preterm neonates (32–36 weeks) accounted for 38% (n = 38), while extremely preterm neonates (<32 weeks)comprised 22% (n = 22) of the cohort. Thus, a total of 60% of the neonates were born preterm, highlighting prematurity as the predominant characteristic among the high-risk neonatal population included in the study. This distribution reflects the increased susceptibility of preterm infants to neurological complications, emphasizing the importance of early cranial neurosonographic screening in this vulnerable group for prompt detection of intracranial abnormalities and timely clinical intervention.

Figure 2. Frequency distribution of major perinatal risk factors among high-risk neonates

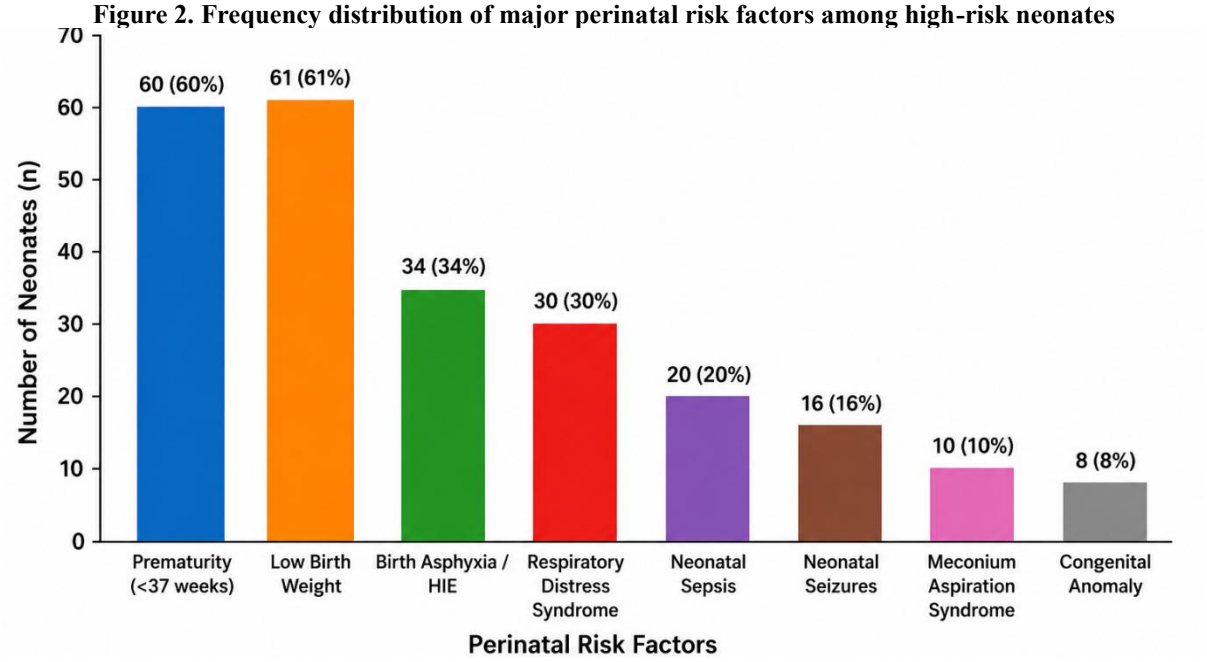

Figure 2 illustrates the distribution of the major perinatal risk factors identified among the 100 high-risk neonates included in the study. Low birth weight was the most frequently observed risk factor, affecting 61% (n = 61) of neonates, closely followed by prematurity, which was present in 60% (n = 60).Birth asphyxia/hypoxic-ischemic encephalopathy(HIE) was documented in 34% (n = 34) of cases, while respiratory distress syndrome was observed in

30% (n = 30)**.** Neonatal sepsis occurred in 20% (n = 20) of the study population, followed by neonatal seizuresin16% (n = 16). Less common risk factors included meconium aspiration syndrome in 10% (n = 10)and congenital anomalies in 8% (n = 8) of neonates. As several neonates had more than one coexisting risk factor, the cumulative percentage exceeds 100%. The predominance of prematurity and low birth weight underscores their significant contribution to neonatal morbidity and supports their established role as major predisposing factors for intracranial abnormalities detectable on cranial neurosonography.

Figure 3. Spectrum of neurosonographic abnormalities detected among high-risk neonates

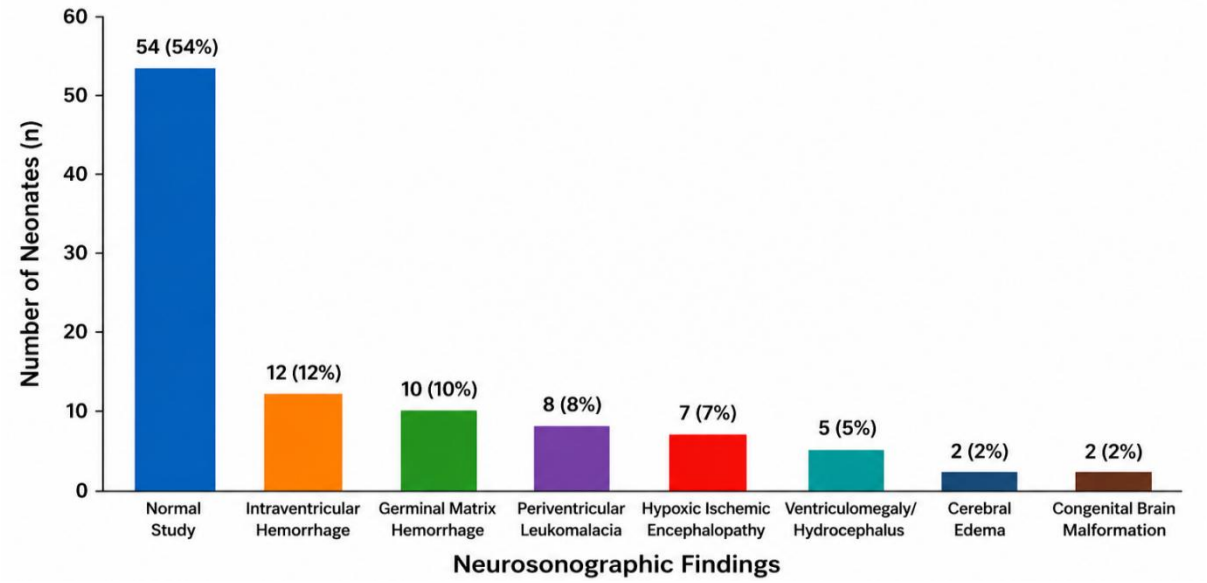

Figure 3 illustrates the spectrum of neurosonographic findings observed among the 100 high-risk neonates included in the study. Normal cranial neurosonographic findings were identified in 54% (n = 54)of the neonates, while46% (n = 46)demonstrated one or more intracranial abnormalities. Among the abnormal findings, intraventricular haemorrhage (IVH)was the most frequently detected lesion, accounting for12% (n = 12**)** of cases, followed by germinal matrix haemorrhage (GMH)in10% (n = 10)and periventricular leukomalacia (PVL)in8% (n = 8)**.** Hypoxic-ischemic encephalopathy (HIE)was identified in7% (n = 7)of neonates, while ventriculomegaly/hydrocephalus was observed in5% (n = 5). Less frequently encountered abnormalities included cerebral edema and congenital brain malformations, each detected in 2% (n = 2) of the study population. The predominance of hemorrhagic lesions, particularly IVH and GMH, reflects the increased vulnerability of preterm and low-birth-weight neonates to intracranial haemorrhage. Overall, these findings demonstrate that cranial neurosonography is an effective bedside imaging modality for the early identification of a wide range of neonatal intracranial abnormalities, facilitating timely diagnosis, appropriate clinical management, and prognostic assessment.

Figure 4. Relationship between major perinatal risk factors and abnormal neurosonographic findings

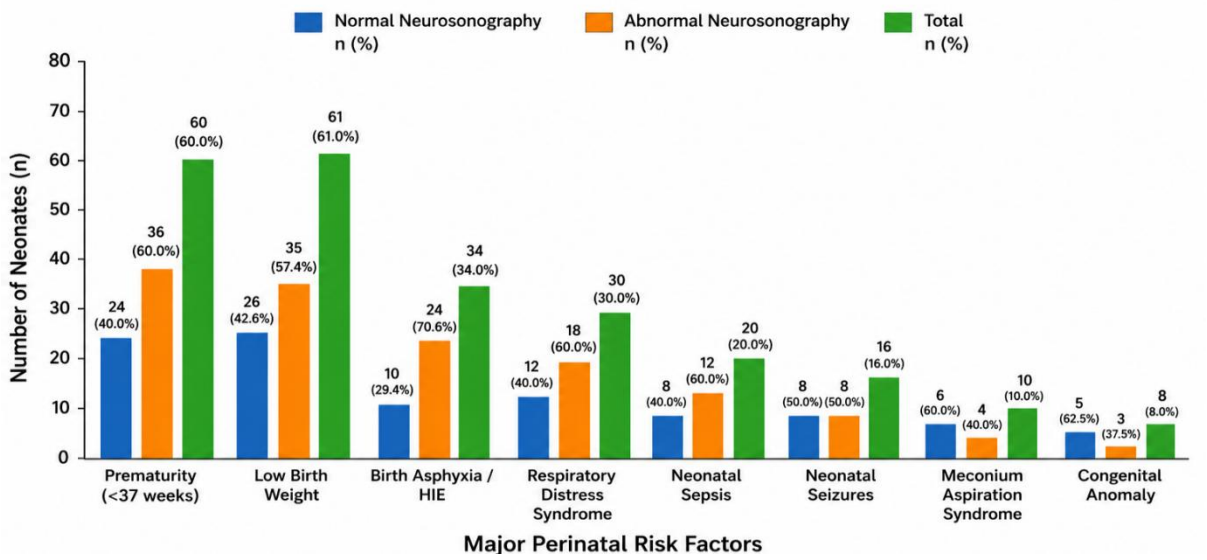

Figure 4 depicts the association between major perinatal risk factors and the occurrence of abnormal neurosonographic findings among high-risk neonates. Birth asphyxia/hypoxic-ischemic encephalopathy (HIE) demonstrated the strongest association with abnormal cranial neurosonography, with 24 of 34 neonates (70.6%) showing intracranial abnormalities, whereas only 10 (29.4%) had normal neurosonographic findings. Prematurity was associated with abnormal neurosonographic findings in 36 of 60 neonates (60.0%), while 24 (40.0%) had normal scans. Similarly, low birth weight was associated with abnormal findings in 35 of 61 neonates (57.4%), compared with 26 (42.6%) with normal neurosonography. Among neonates with respiratory distress syndrome**,** 18 of 30 (60.0%) demonstrated abnormal neurosonographic findings, whereas 12 (40.0%) had normal examinations.

DISCUSSION

The present prospective observational study evaluated the role of cranial neurosonography in detecting intracranial abnormalities among 100 high-risk neonates admitted to a tertiary care centre. Abnormal neurosonographic findings were observed in 46% of neonates, indicating that nearly one-half of the study population had detectable intracranial pathology during the neonatal period. These findings reinforce the importance of cranial neurosonography as an effective bedside imaging modality for the early identification of hemorrhagic, ischemic, and congenital brain abnormalities in neonates with significant perinatal risk factors. Owing to its portability, lack of ionizing radiation, repeatability, and ability to be performed without sedation, neurosonography continues to represent the first-line imaging investigation in neonatal intensive care units for screening and longitudinal monitoring of high-risk infants. Recent international recommendations advocate serial cranial ultrasound as the primary neuroimaging technique for premature and critically ill neonates because of its excellent diagnostic performance in detecting germinal matrix haemorrhage, intraventricular haemorrhage, cystic periventricular leukomalacia, ventricular dilatation, and evolving white matter injury [9–11].

The demographic characteristics of the present study demonstrated a slight male predominance (58%), comparable to observations reported by several neonatal neuroimaging studies worldwide. Although sex itself is not considered an independent determinant of neonatal brain injury, previous investigators have suggested that male neonates may exhibit greater susceptibility to adverse neurological outcomes because of differences in cerebral maturation, inflammatory responses, and hormonal influences during early brain development. Nevertheless, most multicentric studies have concluded that gestational age and birth weight remain considerably stronger predictors of intracranial abnormalities than biological sex [9,12].

Prematurity represented the predominant demographic characteristic in the present study, with 60% of neonates being born before 37 weeks of gestation. Furthermore, 22% were extremely preterm (<32 weeks), while 43% had low birth weight between 1500 and 2499 g, and 18% had very low birth weight. These observations are consistent with the well-established epidemiology of neonatal brain injury, wherein decreasing gestational age and birth weight substantially increase the risk of cerebral haemorrhage and ischemic white matter injury. The immature germinal matrix, fragile cerebral vasculature, incomplete autoregulation of cerebral blood flow, and vulnerability to systemic hemodynamic fluctuations make premature infants particularly susceptible to intracranial injury. Contemporary literature consistently demonstrates that the incidence of germinal matrix–intraventricular haemorrhage increases markedly with decreasing gestational age and is highest among infants born before 28–32 weeks of gestation [9,12,13].

The gestational age distribution observed in the present study is comparable to that reported by Parodi et al**.**, who identified gestational age as the single most important independent predictor of germinal matrix–intraventricular haemorrhage and subsequent neurodevelopmental impairment [9]. Their review demonstrated that severe intraventricular haemorrhage occurs predominantly in extremely premature infants and that routine serial cranial ultrasound facilitates early diagnosis before the onset of overt neurological manifestations. Similarly, the Canadian Paediatric Society recommends routine cranial ultrasound screening for all neonates born at or before 31 weeks' gestation and selective screening in more mature neonates with significant perinatal risk factors [10].

The relatively high proportion of preterm and low-birth-weight neonates included in the present study probably reflects the referral pattern of a tertiary care neonatal intensive care unit, where critically ill neonates requiring specialized care are concentrated. Consequently, the prevalence of abnormal neurosonographic findings observed in the present study is expected to be higher than that reported in community-based neonatal populations. Nevertheless, the demographic profile closely resembles that reported in both Indian and international tertiary-care studies, supporting the external validity of the present findings and emphasizing the importance of early neurosonographic screening in high-risk neonates [11,13,14].

The present study demonstrated that low birth weight (61%) and prematurity (60%) were the most common perinatal risk factors among high-risk neonates, followed by birth asphyxia (34%), respiratory distress syndrome (30%), neonatal sepsis (20%), neonatal seizures (16%), meconium aspiration syndrome (10%), and congenital anomalies (8%). The predominance of prematurity and low birth weight observed in the present study is consistent with the current understanding that immature neonatal brains are particularly susceptible to hemorrhagic and ischemic injury because of

incomplete cerebrovascular autoregulation, fragile germinal matrix vasculature, and vulnerability to systemic hemodynamic instability. Consequently, these neonates constitute the principal target population for routine cranial neurosonographic screening in neonatal intensive care units [15,16].

The findings of the present study closely resemble those reported by Kinikar and Dhanawade, who observed that prematurity and low birth weight were the predominant risk factors among neonates undergoing cranial ultrasonography, with abnormal neurosonographic findings occurring significantly more frequently in infants weighing less than 1.5 kg and those born before 32 weeks of gestation [15]. Likewise, Nagaraj et al., in an Indian prospective study evaluating high-risk neonates, demonstrated a significant association between gestational age, birth weight, and abnormal cranial ultrasound findings, concluding that prematurity remains the single most important determinant of neonatal intracranial injury [16]. These observations support the demographic profile observed in the present study, where the majority of neonates were either preterm or had low birth weight.

Birth asphyxia represented the third most frequent risk factor in the present study, accounting for 34% of cases. Perinatal hypoxia initiates a cascade of cerebral ischemia, energy failure, oxidative stress, excitotoxicity, and inflammatory mediator release, ultimately resulting in neuronal death and white matter injury. Previous studies have consistently shown that neonates with hypoxic-ischemic encephalopathy exhibit a substantially higher incidence of cerebral edema, ventricular abnormalities, and ischemic lesions detectable on neurosonography during the early neonatal period [17,18]. Fumagalli et al. similarly demonstrated that perinatal hypoxia and respiratory compromise significantly increase the likelihood of abnormal cranial ultrasound findings, particularly among preterm infants [17].

Respiratory distress syndrome and neonatal sepsis were identified in 30% and 20% of neonates, respectively. Respiratory distress syndrome contributes to fluctuating cerebral perfusion and impaired autoregulation during the immediate postnatal period, thereby predisposing preterm infants to germinal matrix and intraventricular haemorrhage. Likewise, neonatal sepsis promotes systemic inflammatory responses, endothelial dysfunction, cytokine release, and coagulation abnormalities that may exacerbate cerebral injury. Several investigators have reported respiratory distress syndrome and neonatal sepsis as independent predictors of abnormal cranial ultrasound findings and adverse neurological outcomes [18,19]. The present findings therefore corroborate previously published evidence indicating that critically ill neonates with respiratory or infectious complications warrant early neurosonographic evaluation.

Neonatal seizures, meconium aspiration syndrome, and congenital anomalies were less frequently encountered in the present study. Although these conditions were comparatively uncommon, they remain clinically important because they often indicate underlying structural brain injury or metabolic disturbances requiring prompt neuroimaging. Similar observations have been reported in both Indian and international literature, where seizures frequently represent the first clinical manifestation of intracranial pathology rather than an isolated neurological disorder [20]. Overall, the distribution of perinatal risk factors observed in the present study closely parallels reports from Indian tertiary-care centres as well as international neonatal cohorts, emphasizing that prematurity, low birth weight, birth asphyxia, respiratory distress syndrome, and neonatal sepsis remain the principal determinants of neonatal brain injury. Early identification of these high-risk conditions facilitates timely neurosonographic screening, appropriate therapeutic intervention, and improved neurological surveillance during the neonatal period [15–20].The present study demonstrated that 46% of high-risk neonates had abnormal neurosonographic findings, whereas 54% showed normal cranial ultrasound examinations. Among the abnormal findings, intraventricular haemorrhage (IVH) was the most common lesion (12%), followed by germinal matrix haemorrhage (GMH) (10%), periventricular leukomalacia (PVL) (8%), hypoxic-ischemic encephalopathy (HIE) (7%), ventriculomegaly/hydrocephalus (5%), and cerebral edema and congenital brain malformations (2% each). The predominance of hemorrhagic lesions in the present study reflects the high proportion of premature and low-birth-weight infants included in the cohort and is consistent with the established pathophysiology of neonatal brain injury. Cranial neurosonography remains the preferred first-line imaging modality because it provides rapid bedside assessment of these lesions without ionizing radiation or the need for sedation [21–23].

The overall prevalence of abnormal neurosonographic findings in the present study is comparable with previous Indian and international reports involving high-risk neonatal populations. Diwakar et al. evaluated preterm neonates using cranial ultrasonography and similarly reported that intracranial abnormalities were predominantly hemorrhagic in nature, with germinal matrix and intraventricular haemorrhage accounting for the majority of lesions detected during the first week of life [21]. Likewise, Gupta et al., in their comprehensive review of neonatal cranial sonography, emphasized that IVH and PVL remain the two most frequently encountered abnormalities in preterm infants and are the principal indications for routine serial neurosonographic screening in neonatal intensive care units [22]. These observations closely parallel the findings of the present study, where IVH and GMH together constituted nearly half of all abnormal neurosonographic findings.

Intraventricular haemorrhage was the most frequent abnormality identified in the present series. This finding agrees with reports by Leijser and de Vries, who demonstrated that IVH is the commonest cranial ultrasound abnormality in

extremely premature infants because of the structural immaturity of the germinal matrix and impaired cerebral autoregulation. They further highlighted that most haemorrhages occur within the first 72 hours of life, underscoring the importance of early cranial ultrasonography for prompt diagnosis and serial follow-up [23]. Current recommendations from the Canadian Paediatric Society similarly advocate routine head ultrasound within the first week of life for very preterm infants to facilitate early detection of IVH and its complications, including post-hemorrhagic ventricular dilatation [10].

Periventricular leukomalacia accounted for 8% of abnormalities in the present study. PVL represents ischemic injury to the immature periventricular white matter and remains one of the strongest predictors of long-term neurodevelopmental impairment, including cerebral palsy and cognitive dysfunction. Although magnetic resonance imaging is more sensitive for detecting diffuse non-cystic white matter injury, cranial neurosonography reliably identifies cystic PVL and remains the preferred modality for serial bedside monitoring because of its accessibility and repeatability [22]. Furthermore, ventriculomegaly and hydrocephalus identified in 5% of neonates were most likely secondary to hemorrhagic complications, emphasizing the need for continued ultrasound surveillance to detect progressive ventricular dilatation requiring neurosurgical intervention [23,14].

The relatively low frequency of congenital brain malformations and cerebral edema observed in the present study probably reflects the selective inclusion of high-risk neonates rather than those referred primarily for congenital anomalies. Nevertheless, the identification of these abnormalities demonstrates the versatility of cranial neurosonography in detecting both acquired and developmental intracranial disorders. Overall, the findings of the present study are in close agreement with contemporary Indian and international literature and reaffirm that cranial neurosonography is a highly effective bedside imaging modality for the early diagnosis of neonatal intracranial abnormalities, particularly hemorrhagic and ischemic lesions in preterm and critically ill neonates[21–24].

CONCLUSION

The present prospective observational study highlights the significant role of cranial neurosonography as a safe, reliable, non-invasive, and cost-effective imaging modality for the early evaluation of intracranial abnormalities in high-risk neonates. Among the 100 neonates evaluated, abnormal neurosonographic findings were detected in 46%, with intraventricular haemorrhage emerging as the most common abnormality, followed by germinal matrix haemorrhage**,** periventricular leukomalacia, and hypoxic-ischemic encephalopathy. These findings emphasize the high burden of neurological complications in neonates with established perinatal risk factors . Owing to its portability, lack of ionizing radiation, repeatability, and ability to be performed without sedation, neurosonography continues to represent the first-line imaging investigation in neonatal intensive care units for screening and longitudinal monitoring of high-risk infants.

REFERENCES

1. Volpe JJ. Volpe's Neurology of the Newborn. 6th ed. Philadelphia: Elsevier; 2018.
2. vanWezel-Meijler G, Steggerda SJ, Leijser LM. Cranial ultrasonography in neonates: role and limitations. *SeminPerinatol*. 2010;34(1):28–38.
3. Epelman M, Daneman A, Blaser SI, et al. Neonatal brain sonography: state-of-the-art review. *Radiographics*. 2010;30(4):1051–1077.
4. Ment LR, Bada HS, Barnes P, et al. Practice parameter: neuroimaging of the neonate. *Neurology*. 2002;58(12):1726–1738.
5. Volpe JJ. Brain injury in premature infants: a complex amalgam of destructive and developmental disturbances. *Lancet Neurol*. 2009;8(1):110–124.
6. deVries LS, Benders MJNL, Groenendaal F. Progress in neonatal neurology with a focus on neuroimaging in the preterm infant. *Neuropediatrics*. 2015;46(4):234–241.
7. Rutherford MA, Ramenghi LA, Edwards AD, et al. Assessment of brain tissue injury after moderate and severe hypoxic-ischaemic encephalopathy in newborn infants using MR imaging. *Pediatrics*. 2010;125(4):e906–e913.
8. Leijser LM, de Bruïne FT, Steggerda SJ, van Wezel-Meijler G. Brain imaging findings in very preterm infants throughout the neonatal period: part I. Routine cranial ultrasound. *Neoreviews*. 2009;10(8):e376–e384.
9. Parodi A, Govaert P, Horsch S, Bravo MC, Ramenghi LA, eurUS.brain group. Cranial ultrasound findings in preterm germinal matrix haemorrhage, sequelae and outcome. *Pediatr Res*. 2020;87(Suppl 1):13–24.
10. Canadian Paediatric Society. Routine imaging of the preterm neonatal brain. *Paediatr Child Health*. 2020;25(7):e84–e93.
11. Fichera G, Stramare R, Giraudo C, et al. Neonatal cerebral ultrasound: anatomical variants and age-related diseases. *J Ultrasound*. 2024;27:993–1002.
12. Pal A, Pattnaik P, Borger J. Periventricular and intraventricularhemorrhage. In: *StatPearls*. Treasure Island (FL): StatPearls Publishing; 2026.
13. vanWezel-Meijler G, Steggerda SJ, Leijser LM. Neurosonography: shaping the future of neuroprotection strategies in neonates. *Children (Basel)*. 2024.

14. Cranial ultrasonography—Standards in diagnosis of intraventricularhemorrhage in premature infants. *Children (Basel)*. 2025.
15. Kinikar U, Dhanawade S. Study of cranial ultrasound, its correlation with perinatal risk factors and its outcome in preterm neonates admitted to neonatal intensive care unit. *Int J Pediatr Res*. 2018;5(4):169–174.
16. Nagaraj N, Berwal PK, Choudhary S, Srinivas A, Swami G. Correlation of gestational age, birth weight and perinatal risk factors with cranial ultrasound findings in high-risk neonates. *Indian J Neurosci*. 2016;2(2):43–45.
17. Fumagalli M, Ramenghi LA, De Carli A, et al. Cranial ultrasound findings in late preterm infants and correlation with perinatal risk factors. *Ital J Pediatr*. 2015;41:65.
18. Ballabh P. Pathogenesis and prevention of intraventricularhemorrhage. *ClinPerinatol*. 2014;41(1):47–67.
19. Vermeulen GM, Bruinse HW, Gerards LJ, et al. Perinatal risk factors for cranial ultrasound abnormalities in neonates born after spontaneous labour before 34 weeks. *Eur J ObstetGynecolReprod Biol*. 2001;94(2):290–295.
20. Jha R, Singh A, Jha R. Cranial ultrasound in high-risk preterm neonates. *New Indian Journal of Pediatrics*. 2017;6:26–32.
21. Diwakar RK, Choudhary A, Choudhary A. Cranial sonography in preterm infants with short review of literature. *J PediatrNeurosci*. 2018;13(3):324–331.
22. Gupta P, Sodhi KS, Saxena AK, Khandelwal N. Neonatal cranial sonography: A concise review for clinicians. *J PediatrNeurosci*. 2016;11(1):7–13.
23. Leijser LM, de Vries LS. Preterm brain injury: Germinal matrix–intraventricularhemorrhage and post-hemorrhagic ventricular dilatation. *HandbClin Neurol*. 2019;162:173–199.
24. Sandhu PK, Banker H, Cohen HL. Neurosonography assessment, protocols, and interpretation. In: *StatPearls*. Treasure Island (FL): StatPearls Publishing; 2023.