

Role of Neurosonography in Newborns

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Abstract: Background: Neurosonography is a rapid, non-invasive and radiation-free imaging modality for evaluating the neonatal brain, particularly in preterm and critically ill neonates. Serial examinations facilitate early detection and assessment of the evolution of cerebral abnormalities. Methods: This prospective observational study included 36 neonates undergoing neurosonographic evaluation for suspected brain abnormalities. Cranial ultrasonography was performed through the anterior fontanelle in coronal, sagittal and parasagittal planes. Initial examination was performed within the first 7 days of life, with follow-up at 10–14 days. Clinical and perinatal characteristics and neurosonographic abnormalities were evaluated. Results: Of 36 neonates, 27 (75.0%) were preterm and 24 (66.7%) were male. Germinal matrix/intraventricular hemorrhage (GMH/IVH) was the most frequent abnormality [11 (30.6%)], followed by periventricular leukomalacia (PVL) [10 (27.8%)]. On follow-up, 20 (55.6%) neonates showed normal/resolved findings, whereas 16 (44.4%) had persistent abnormalities. Persistent abnormal neurosonography was significantly associated with prematurity ($p=0.031$) and birth weight <1.5 kg ($p=0.008$), but not with sex. Grade I constituted 54.5% of GMH/IVH cases, and 77.8% of neonates had a favourable short-term clinical outcome. Conclusion: Neurosonography is a useful bedside modality for early detection and serial monitoring of neonatal brain abnormalities. GMH/IVH and PVL were the predominant findings, with persistent abnormalities significantly associated with prematurity and very low birth weight.

Keywords: Neurosonography; Cranial ultrasonography; Neonates; Germinal matrix hemorrhage; Periventricular leukomalacia; Prematurity.

1. Introduction

The neonatal period represents a critical phase of brain development, during which the immature central nervous system is particularly susceptible to hypoxic, ischemic, hemorrhagic, infectious, and metabolic insults. Premature neonates are especially vulnerable because cerebral vascular autoregulation and structural maturation are incomplete, increasing the risk of neurological injury and subsequent neurodevelopmental impairment [1]. Advances in neonatal intensive care have improved survival among very preterm and very-low-birth-weight infants; however, neurological morbidity remains an important concern [2].

Neurosonography plays a central role in the early detection, characterization, and follow-up of neonatal brain injury. Cranial ultrasonography or neurosonography is a simple, non-invasive and readily available imaging technique that permits bedside assessment of the neonatal brain through the open fontanelles [3]. It is particularly suitable for critically ill neonates because it is portable, relatively inexpensive, rapid, free of ionizing radiation, and generally does not require sedation [4]. The anterior fontanelle provides the principal acoustic window, while posterior and mastoid fontanelles can improve visualization of the posterior fossa and other intracranial structures [5].

The major cerebral abnormalities encountered in premature neonates include germinal matrix hemorrhage-intraventricular hemorrhage (GMH-IVH), periventricular leukomalacia (PVL), ventriculomegaly, and other forms of white-matter injury [6]. GMH-IVH originates from the fragile vascular network of the germinal matrix and occurs predominantly in very premature and very-low-birth-weight infants [7]. Its incidence and severity increase with decreasing gestational age [8]. Severe hemorrhage and associated post-

hemorrhagic ventricular dilatation are important predictors of adverse neurological outcomes [9].

PVL represents an important ischemic white-matter injury of prematurity and may initially appear as increased periventricular echogenicity before evolving into cystic changes [10]. Serial examinations are therefore important, as a single early scan may fail to demonstrate the complete extent or subsequent evolution of cerebral injury [11]. Cranial ultrasound is also useful for identifying hydrocephalus, cerebral edema, congenital abnormalities and complications of neonatal infection [12].

Although magnetic resonance imaging provides superior characterization of subtle white-matter and posterior fossa abnormalities [13], cranial ultrasonography remains the preferred initial modality for screening and serial monitoring because of its accessibility and feasibility [14]. Current recommendations support cranial ultrasonographic screening in very preterm infants and repeat imaging when abnormalities are identified [15]. Previous studies have demonstrated a considerable spectrum of neurosonographic abnormalities among high-risk neonates, with GMH-IVH and PVL among the most frequently encountered lesions [16–18]. The supplied reference article similarly identified GMH and PVL as its predominant abnormalities.

Therefore, the present study was undertaken to evaluate the spectrum of brain abnormalities detected by neurosonography in neonates and to assess their relationship with relevant clinical and perinatal characteristics.

2. Materials and Methods

A prospective observational study was conducted among 36 neonates undergoing neurosonographic evaluation for suspected brain abnormalities. Both preterm and term

neonates presenting with neurological manifestations such as seizures, lethargy, apnea, poor/absent suck, altered muscle tone, sudden-onset pallor, or bulging anterior fontanelle were included. Neonates older than one month and those with suspected traumatic brain injury or failed resuscitation were excluded, in accordance with the methodology of the reference study.

Neurosonography was performed using curvilinear and high-frequency linear-array transducers without sedation. The anterior fontanelle served as the principal acoustic window, with systematic examination in coronal, sagittal, and parasagittal planes. Posterior and mastoid fontanelles were used when required for assessment of the posterior fossa. An initial scan was performed within the first 7 days of life, followed by repeat neurosonography at 10–14 days. Findings including germinal matrix/intraventricular hemorrhage (GMH/IVH), periventricular leukomalacia (PVL), periventricular flaring, cystic lesions, cerebral edema, ventriculomegaly, congenital abnormalities, and infection were documented.

Categorical variables were expressed as frequency and percentage and continuous variables, where applicable, as mean $\pm$ standard deviation. Associations between categorical variables were assessed using the Chi-square test or Fisher's exact test, as appropriate. A p-value <0.05 was considered statistically significant. Ethical approval was obtained from the institutional ethics committee, and informed consent was obtained from the parent or legal guardian.

3. Results

A total of **36 neonates** undergoing neurosonographic evaluation for suspected brain abnormalities were included in the study. The results were analyzed with respect to demographic and perinatal characteristics, clinical presentation, spectrum and severity of neurosonographic

abnormalities, differences between preterm and term neonates, evolution of findings on follow-up neurosonography, and short-term clinical outcomes. Associations of persistent neurosonographic abnormalities with prematurity, birth weight, and sex were also assessed.

Table 1: Baseline demographic and perinatal characteristics of the study population (n=36)

Characteristic	n	%
Sex		
Male	24	66.7
Female	12	33.3
Gestational status		
Preterm (<37 weeks)	27	75.0
Term (≥ 37 weeks)	9	25.0
Gestational age		
<30 weeks	8	22.2
30–33+6 weeks	10	27.8
34–36+6 weeks	9	25.0
≥ 37 weeks	9	25.0
Birth weight		
<1.5 kg	12	33.3
1.5–1.99 kg	7	19.4
2.0–2.49 kg	10	27.8
≥ 2.5 kg	7	19.4

Table 1 summarizes the baseline demographic and perinatal characteristics of the 36 neonates included in the study. There was a male predominance, with 24 (66.7%) males and 12 (33.3%) females. Preterm neonates constituted 27 (75.0%) of the study population, while 9 (25.0%) were term. The largest proportion of neonates belonged to the gestational-age group of 30–33+6 weeks [10 (27.8%)], followed by 34–36+6 weeks [9 (25.0%)]. With respect to birth weight, 12 (33.3%) neonates weighed <1.5 kg, representing the largest birth-weight category. Thus, the study population was predominantly composed of preterm and low-birth-weight neonates.

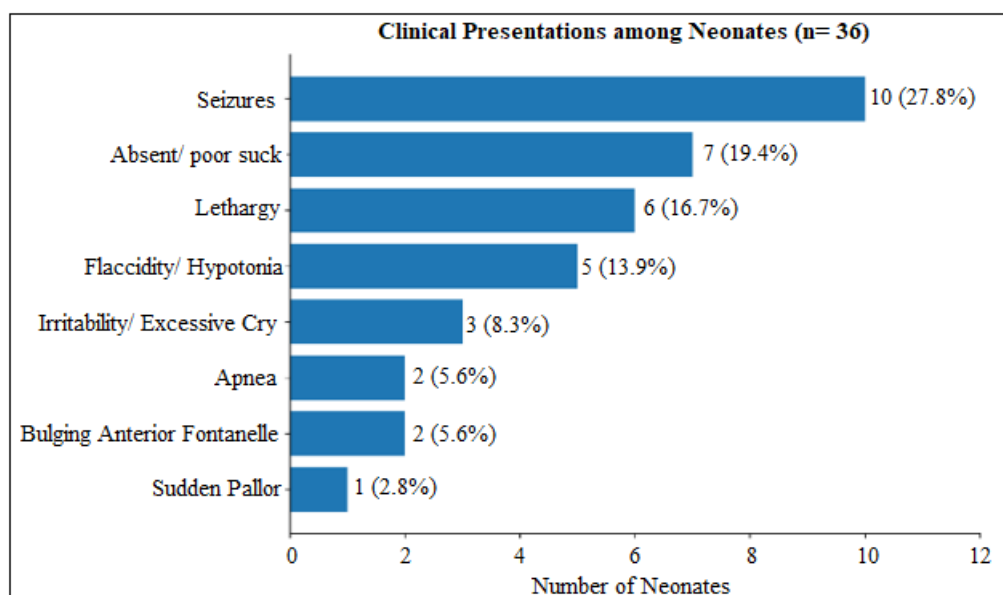


Figure 1: Distribution of clinical presentations among neonates undergoing neurosonographic evaluation (n=36)

The clinical presentations of the study population are illustrated in **Figure 1**. Seizures were the most frequent presentation, occurring in 10 (27.8%) neonates, followed by

absent or poor suck in 7 (19.4%) and lethargy in 6 (16.7%). Flaccidity/hypotonia was observed in 5 (13.9%), while irritability or excessive cry occurred in 3 (8.3%). Apnea and

bulging anterior fontanelle were each observed in 2 (5.6%) neonates, and sudden-onset pallor was the least frequent presentation [1 (2.8%)]. Thus, seizures, feeding difficulty and altered activity constituted the predominant clinical manifestations.

Table 2: Distribution of neurosonographic abnormalities on initial examination (n=36)

Neurosonographic finding	n	%
Germinal matrix/intraventricular hemorrhage (GMH/IVH)	11	30.6
Periventricular leukomalacia (PVL)	10	27.8
Periventricular flaring	4	11.1
Cystic lesion	4	11.1
Cerebral edema	3	8.3
Congenital CNS anomaly	2	5.6
Ventriculomegaly	1	2.8
CNS infection	1	2.8
Total	36	100.0

The distribution of abnormalities detected on initial neurosonography is presented in **Table 2**. Germinal matrix/intraventricular hemorrhage (GMH/IVH) was the most frequent finding, observed in 11 (30.6%) neonates, followed by periventricular leukomalacia (PVL) in 10 (27.8%). Periventricular flaring and cystic lesions were each identified in 4 (11.1%) neonates, while cerebral edema was observed in 3 (8.3%). Congenital CNS abnormalities were detected in 2 (5.6%), whereas ventriculomegaly and CNS infection were each observed in 1 (2.8%) neonate. Overall, GMH/IVH and PVL constituted the predominant neurosonographic abnormalities in the study population.

Table 3: Association between gestational maturity and major neurosonographic abnormalities (n=36)

NSG finding	Preterm (n=27)	Term (n=9)	p-value*
GMH/IVH	10 (37.0%)	1 (11.1%)	0.224
PVL	9 (33.3%)	1 (11.1%)	0.405
Periventricular flaring	4 (14.8%)	0	0.555
Cystic lesion	2 (7.4%)	2 (22.2%)	0.249
Cerebral edema	1 (3.7%)	2 (22.2%)	0.146
Congenital anomaly	1 (3.7%)	1 (11.1%)	0.444
Ventriculomegaly	0	1 (11.1%)	0.250
Infection	0	1 (11.1%)	0.250

*Fisher's exact test

Table 3 compares the distribution of neurosonographic abnormalities between preterm and term neonates. GMH/IVH was observed in 10/27 (37.0%) preterm neonates compared with 1/9 (11.1%) term neonates, while PVL was detected in 9/27 (33.3%) and 1/9 (11.1%), respectively. Periventricular flaring was confined to the preterm group [4/27 (14.8%)]. In contrast, cerebral edema was proportionately more frequent among term neonates [2/9 (22.2%)] than among preterm neonates [1/27 (3.7%)]. However, none of the individual lesion-wise differences between preterm and term neonates reached statistical significance (all $p > 0.05$). These findings indicate a predominance of hemorrhagic and white-matter abnormalities among preterm neonates, although the relatively small subgroup size limited statistical significance.

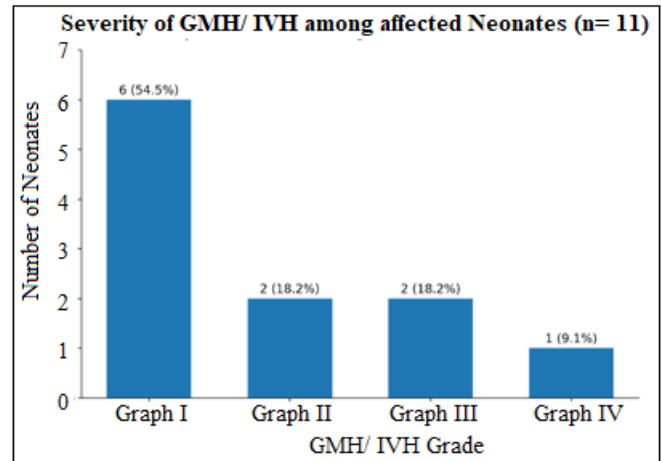


Figure 2: Distribution of germinal matrix/intraventricular hemorrhage according to severity grade among affected neonates (n=11)

The severity distribution of GMH/IVH among the 11 affected neonates is depicted in **Figure 2**. Grade I hemorrhage was the most frequent, occurring in 6 (54.5%) neonates. Grade II and Grade III hemorrhage were each identified in 2 (18.2%), while Grade IV hemorrhage was observed in 1 (9.1%) neonate. Thus, lower-grade hemorrhage predominated, with Grade I accounting for more than half of all GMH/IVH cases.

Table 4: Evolution of neurosonographic abnormalities on follow-up examination at 10–14 days (n=36)

Follow-up NSG finding	n	%
Normal/resolved	20	55.6
Persistent GMH/IVH	7	19.4
PVL	5	13.9
Cystic PVL/cystic lesion	2	5.6
Cerebral edema	1	2.8
Congenital anomaly	1	2.8
Periventricular flaring	0	0
Total	36	100.0

Serial changes in neurosonographic findings are shown in **Table 4**. At the follow-up examination performed at 10–14 days, 20 (55.6%) neonates demonstrated normal or resolved neurosonographic findings, whereas 16 (44.4%) continued to show abnormalities. Persistent GMH/IVH was the most frequent abnormal follow-up finding, occurring in 7 (19.4%) neonates, followed by PVL in 5 (13.9%). Cystic PVL/cystic lesions were identified in 2 (5.6%), while cerebral edema and congenital abnormalities were each present in 1 (2.8%) neonate. No persistent periventricular flaring was observed. These findings demonstrate the dynamic nature of neonatal cerebral abnormalities and the value of repeat neurosonography in documenting resolution, persistence, or evolution of lesions.

Table 5: Association of selected risk characteristics with persistent abnormal neurosonography at follow-up (n=36)

Characteristic	Persistent abnormal NSG n/N (%)	Normal/resolved n/N (%)	p-value*
Preterm (n=27)	15/27 (55.6)	12/27 (44.4)	0.031
Term (n=9)	1/9 (11.1)	8/9 (88.9)	
Birth weight <1.5 kg (n=12)	9/12 (75.0)	3/12 (25.0)	0.008

Birth weight ≥ 1.5 kg (n=24)	7/24 (29.2)	17/24 (70.8)	1.000
Male (n=24)	11/24 (45.8)	13/24 (54.2)	
Female (n=12)	5/12 (41.7)	7/12 (58.3)	

*Fisher's exact test

The association of selected neonatal characteristics with persistent abnormalities on follow-up neurosonography is presented in **Table 5**. Persistent abnormal NSG findings were observed in 15/27 (55.6%) preterm neonates compared with 1/9 (11.1%) term neonates, showing a statistically significant association with prematurity ($p=0.031$). Similarly, persistent abnormalities were present in 9/12 (75.0%) neonates with birth weight <1.5 kg compared with 7/24 (29.2%) neonates weighing ≥ 1.5 kg ($p=0.008$). No significant association was observed with sex ($p=1.000$). Thus, prematurity and very low birth weight were associated with persistence of abnormal neurosonographic findings on follow-up.

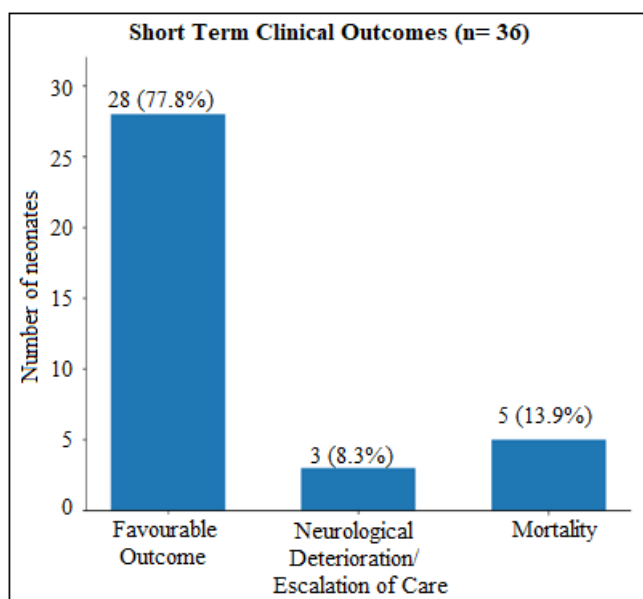


Figure 3: Short-term clinical outcomes among neonates undergoing neurosonographic evaluation (n=36)

Short-term clinical outcomes are presented in **Figure 3**. A favourable clinical outcome without major neurological deterioration was observed in 28 (77.8%) neonates. Three (8.3%) neonates demonstrated neurological deterioration or required escalation of care, while mortality occurred in 5 (13.9%). Overall, more than three-fourths of the study population had a favourable short-term clinical course.

Overall, GMH/IVH and PVL constituted the predominant neurosonographic abnormalities in the study population, with a greater burden of hemorrhagic and white-matter lesions among preterm neonates. Serial neurosonography demonstrated resolution of abnormalities in a substantial proportion of neonates by 10–14 days, while persistent abnormalities were significantly associated with prematurity and birth weight <1.5 kg. Lower-grade GMH/IVH predominated among hemorrhagic lesions, and the majority of neonates had a favourable short-term clinical outcome.

4. Discussion

The present study highlights the utility of neurosonography for detecting and monitoring cerebral abnormalities in neonates. Among the 36 neonates evaluated, GMH/IVH (30.6%) was the most frequent abnormality, followed by PVL (27.8%). These findings are consistent with the recognized vulnerability of the immature germinal matrix and periventricular white matter in premature infants. You et al. described GMH/IVH as an important neurological complication of prematurity, related to the fragile germinal-matrix vasculature [7]. Similarly, Parodi et al. emphasized the strong association of GMH with lower gestational age and its usefulness as a marker of neurological risk [8].

The predominance of GMH/IVH and PVL in the present study is comparable with previous neurosonographic studies. Nagaraj et al. reported intracranial hemorrhage, periventricular echogenicity, ventriculomegaly, and PVL among abnormalities detected by cranial ultrasonography in preterm neonates [16]. Prithviraj et al. also documented intracranial hemorrhage, cerebral edema and PVL among critically ill neonates undergoing neurosonography [17]. Furthermore, Reddy et al. reported GMH as the most frequent abnormality (31%), followed by PVL (28.6%), closely resembling the distribution observed in the present study [18]. Prematurity was an important determinant of persistent abnormalities in the current study. Abnormal follow-up neurosonography was observed in 55.6% of preterm compared with 11.1% of term neonates ($p=0.031$). Similarly, birth weight <1.5 kg was significantly associated with persistent abnormalities (75.0% vs. 29.2%; $p=0.008$). These findings support the observations of Back et al., who described the particular susceptibility of the immature cerebral white matter to injury [1]. Ballabh et al. similarly demonstrated that prematurity is a major determinant of GMH/IVH because of vascular fragility and impaired cerebral autoregulation [9].

Serial neurosonography demonstrated substantial evolution of abnormalities. At 10–14 days, 55.6% of neonates showed normal or resolved findings, whereas 44.4% had persistent abnormalities. This underscores the importance of sequential rather than single-point imaging. de Vries et al. demonstrated that early periventricular echogenicity may evolve into cystic leukomalacia, emphasizing the value of follow-up examinations [10]. Maalouf et al. also demonstrated the usefulness of serial cranial ultrasonography for assessing evolving brain abnormalities, although MRI provides greater sensitivity for subtle lesions [11]. Current recommendations by Hand et al. similarly support serial neuroimaging in high-risk premature infants [15].

Among neonates with GMH/IVH, Grade I hemorrhage predominated (54.5%), while severe Grade IV hemorrhage was uncommon. More than three-fourths (77.8%) of the study population had a favourable short-term outcome. Overall, the findings support neurosonography as a practical, non-invasive bedside technique for early identification and serial monitoring of neonatal cerebral injury, particularly among preterm and very-low-birth-weight neonates, as also emphasized by Maller and Cohen [14].

5. Conclusion

Cranial neurosonography is a valuable, non-invasive bedside imaging modality for the early detection and serial assessment of brain abnormalities in neonates. In the present study, **GMH/IVH and PVL were the predominant neurosonographic findings**, with hemorrhagic and white-matter abnormalities occurring mainly among preterm neonates. Follow-up imaging demonstrated resolution of abnormalities in more than half of the neonates, highlighting the importance of serial neurosonography in assessing the evolution of neonatal brain injury. Persistent abnormalities were significantly associated with **prematurity and birth weight <1.5 kg**, identifying these groups as particularly vulnerable. Thus, routine and timely neurosonographic assessment, particularly in preterm and very-low-birth-weight neonates, can facilitate early recognition, monitoring, and appropriate clinical management of neonatal cerebral abnormalities.

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