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TRANSCRANIAL SONOGRAPHIC EVALUATION OF PRETERM NEONATES PRESENTING WITH SEIZURES AND ITS ASSOCIATION WITH INTRACRANIAL ABNORMALITIES

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Abstract

Background:
Seizures in preterm neonates are critical indicators of neurological dysfunction, often linked to underlying intracranial abnormalities. Due to immature cerebral autoregulation, preterm infants are at increased risk of ischemic and hemorrhagic injuries. Transcranial sonography (TCS) offers a non-invasive, bedside imaging modality for early detection of these pathologies.

Objective:
To evaluate the association of intracranial abnormalities in preterm neonates presenting with seizures through transcranial sonography.

Methodology:
This cross-sectional analytical study was conducted at Shalamar Hospital, Lahore. A total of 122 preterm neonates (63 males, 59 females) presenting with seizures were recruited between March and November 2021. Participants were categorized into three gestational age-based preterm classes. All underwent cranial ultrasound via anterior fontanelle using high-frequency probes. Data were analyzed for sonographic findings and their correlation with preterm classifications.

Results:
Abnormal cranial findings were observed in 42 (34.4%) neonates. The most prevalent abnormalities included ventriculomegaly (15.6%) and intracranial hemorrhage (14.8%). Other findings were periventricular echogenicity (7.4%), echogenic sulci (4.9%), cerebral edema (2.5%), congenital anomalies (2.5%), choroidal cysts (1.6%), and corpus callosum agenesis (0.8%). Class I preterm neonates showed higher frequency of hemorrhage (19.7%), while ventriculomegaly was more frequent in Classes II and III.

Keywords:
Preterm neonates, transcranial ultrasound, intracranial hemorrhage, ventriculomegaly, neonatal seizures.

Introduction

Preterm birth, defined as delivery before 37 completed weeks of gestation, is a leading cause of neonatal morbidity and mortality worldwide (1). According to the World Health Organization, more than 15 million babies are born prematurely each year (2). In Pakistan, the preterm birth rate is estimated at 18.89%, significantly higher than the global average (3, 4). Preterm neonates are especially susceptible to neurological complications due to immature brain structures, limited cerebral autoregulation, and physiological instability (5).

One of the most alarming neurological manifestations in this population is neonatal seizures, which occur in approximately 22.2% of preterm infants substantially higher than the 0.5% observed in term neonates (6). Seizures are often indicative of underlying intracranial abnormalities, such as intraventricular hemorrhage (IVH), periventricular leukomalacia (PVL), and ventriculomegaly (VM). These conditions, if not detected and managed promptly, may lead to long-term complications including cerebral palsy, epilepsy, and developmental delays (7).

Cranial ultrasound (CUS) through the anterior fontanelle is a valuable bedside tool for assessing preterm brain abnormalities (8). It is non-invasive, radiation-free, and provides real-time visualization of the brain parenchyma and ventricular system. CUS is especially effective for early detection of IVH, VM, and other structural or ischemic brain lesions (9, 10).

Despite its diagnostic value, there remains a lack of local data correlating CUS findings with clinical seizure presentation in preterm neonates (10-12). This study aims to evaluate the association of intracranial abnormalities detected by transcranial ultrasound in preterm neonates presenting with seizures and to analyze these abnormalities across different gestational age categories. Early identification of such abnormalities can significantly improve prognosis through timely intervention and appropriate management.

Methodology

This cross-sectional analytical study was conducted at the Radiology Department of Shalamar Hospital, Lahore, from March 2021 to November 2021. A total of 122 preterm neonates presenting with clinically diagnosed seizures were enrolled using a non-probability purposive sampling technique. The inclusion criteria comprised neonates born before 37 weeks of gestation who exhibited seizure activity during the neonatal period and were admitted to the neonatal intensive care unit (NICU). Neonates with major congenital malformations unrelated to the central nervous system (CNS) or those born at term were excluded from the study.

Each participant underwent a detailed cranial ultrasound examination performed within the first few days of life. Ultrasound imaging was carried out using a high-frequency (5–7.5 MHz) transducer through the anterior fontanelle, providing optimal acoustic access to intracranial structures. The scans were interpreted by experienced radiologists, and findings were documented regarding the presence or absence of intracranial abnormalities, including intraventricular hemorrhage (IVH), ventriculomegaly (VM), periventricular echogenicity, cerebral edema, echogenic sulci, congenital anomalies, and other relevant findings.

Neonates were further categorized into three preterm classes based on gestational age: Class I (extremely preterm, <28 weeks), Class II (very preterm, 28–32 weeks), and Class III (late preterm, 32–37 weeks). This classification allowed for analysis of the distribution of sonographic abnormalities in relation to prematurity severity.

Data were analyzed using SPSS version 25. Frequencies and percentages were calculated for categorical variables, and chi-square tests were employed to determine statistical associations between cranial ultrasound findings and preterm classification. A p-value of less than 0.05 was considered statistically significant. Ethical approval was obtained from the institutional review board, and informed consent was taken from the parents or guardians of all participating neonates.

Results

This cross-sectional analytical study included a total of 122 preterm neonates who presented with seizures. Of these, 63 (51.6%) were male and 59 (48.4%) were female. The majority of cranial ultrasounds (CUS) were performed within the first three days of life in 63 neonates (51.6%), followed by 21 neonates (20.4%) scanned between days 4–7, and 19 neonates (18.4%) scanned between days 7–28.

Neonates were categorized into three gestational age classes: Class I (<28 weeks) included 10 neonates (8.2%), Class II (28–32 weeks) had 35 neonates (28.7%), and Class III (32–37 weeks) accounted for 77 neonates (63.1%). In terms of birth weight, 4 neonates (3.9%) were classified as having extremely low birth weight (ELBW), 9 (8.7%) had very low birth weight (VLBW), 47 (45.6%) had low birth weight (LBW), and 43 (41.7%) had normal birth weight. These characteristics are summarized in Table 1.

Table 1. Baseline Characteristics of Preterm Neonates with Seizures (n = 122)

Characteristic	Category	Frequency (n)	Percentage (%)
Gender	Male	63	51.6%
	Female	59	48.4%
Age at CUS	1st–3rd Day	63	51.6%
	4th–7th Day	21	20.4%
	7th–28th Day	19	18.4%
Preterm Class	Class I (<28 weeks)	10	8.2%
	Class II (28–32 weeks)	35	28.7%
	Class III (32–37 weeks)	77	63.1%
Birth Weight	ELBW (700–999g)	4	3.9%
	VLBW (1000–1499g)	9	8.7%
	LBW (1500–2499g)	47	45.6%
	Normal (>2500g)	43	41.7%

Out of 122 neonates, 80 (65.6%) had normal cranial ultrasound findings, while 42 (34.4%) showed abnormalities. The most frequent abnormal finding was ventriculomegaly (VM) observed in 19 neonates (15.6%), followed by intraventricular hemorrhage (IVH) in 18 cases (14.8%). Other findings included increased periventricular echogenicity (7.4%), echogenic sulci (4.9%), cerebral edema (2.5%), congenital abnormalities (2.5%), choroidal cysts (1.6%), and corpus callosum agenesis (0.8%) (Table 2).

Table 2. Cranial Ultrasound Findings of Preterm Neonates with Seizures (n = 122)

Cranial Abnormality	Frequency (n)	Percentage (%)
Intraventricular Hemorrhage (ICH)	18	14.8%
Ventriculomegaly (VM)	19	15.6%
Periventricular Echogenicity	9	7.4%
Echogenic Sulci	6	4.9%
Cerebral Edema	3	2.5%
Congenital Abnormalities	3	2.5%
Choroidal Cysts	2	1.6%
Corpus Callosum Agenesis	1	0.8%
Normal CUS	80	65.6%
Abnormal CUS	42	34.4%

A breakdown of IVH and VM by gestational age category revealed that IVH was most common in Class I (19.7%), while VM was more prevalent in Class III (23.9%), suggesting a possible correlation between the degree of prematurity and the type of cranial pathology. However, the chi-square test revealed no statistically significant association between overall cranial abnormalities and preterm categories ($p = 0.734$) (Table 3 and Table 4).

Table 3. Distribution of ICH and VM by Preterm Class (n = 122)

Preterm Class	ICH (n, %)	VM (n, %)
Class I (<28 weeks)	6 (19.7%)	0 (0.0%)
Class II (28–32 weeks)	6 (13.1%)	6 (13.1%)
Class III (32–37 weeks)	6 (13.1%)	11 (23.9%)
Total	18 (14.8%)	19 (15.6%)

Table 4. Crosstabulation Between Preterm Class and Cranial Ultrasound Results

Preterm Class	Normal CUS (n)	Abnormal CUS (n)	Total (n)
Class I (<28 weeks)	7	3	10
Class II (28–32 weeks)	21	14	35
Class III (32–37 weeks)	33	25	58
Total	61	42	122

Among the 42 neonates with abnormal cranial ultrasound (CUS) findings, further analysis revealed distinct patterns of pathology distribution across gestational age groups. Intraventricular hemorrhage (ICH) was most frequently observed in Class I neonates (20%), reflecting the high vulnerability of extremely preterm infants to hemorrhagic insults. The incidence of ICH was slightly lower but comparable in Class II and Class III neonates, where it was identified in 17% of cases in each group.

In contrast, the occurrence of ventriculomegaly (VM) showed a different trend. VM was absent in Class I neonates, while it was identified in 14% of Class II and 24% of Class III neonates, suggesting that moderate to late preterm infants are more susceptible to ventricular dilatation, which may be post-

hemorrhagic or congenital in origin. These findings are supported by the data presented in Tables 5 and 6.

Table 5. Cross Tabulation Between CUS and Intraventricular Hemorrhage (ICH) in Preterm Classes

Preterm Class	CUS Result	ICH Absent (n)	ICH Present (n)	Total (n)
Class I (<28 weeks)	Normal	7 (70%)	0 (0%)	7 (70%)
	Abnormal	1 (10%)	2 (20%)	3 (30%)
	Total	8 (80%)	2 (20%)	10 (100%)
Class II (28–32 wks)	Normal	21 (60%)	0 (0%)	21 (60%)
	Abnormal	8 (22%)	6 (17%)	14 (40%)
	Total	29 (82%)	6 (17%)	35 (100%)
Class III (32–37 wks)	Normal	33 (56%)	0 (0%)	33 (56%)
	Abnormal	15 (25%)	10 (17%)	25 (43%)
	Total	48 (82%)	10 (17%)	58 (100%)

Table 6. Cross Tabulation Between CUS and Ventriculomegaly (VM) in Preterm Classes

Preterm Class	CUS Result	VM Absent (n)	VM Present (n)	Total (n)
Class I (<28 weeks)	Normal	7 (70%)	0 (0%)	7 (70%)
	Abnormal	3 (30%)	0 (0%)	3 (30%)
	Total	10 (100%)	0 (0%)	10 (100%)
Class II (28–32 wks)	Normal	21 (60%)	0 (0%)	21 (60%)
	Abnormal	9 (25%)	5 (14%)	14 (40%)
	Total	30 (85%)	5 (14%)	35 (100%)
Class III (32–37 wks)	Normal	33 (56%)	0 (0%)	33 (56%)
	Abnormal	11 (18%)	14 (24%)	25 (43%)
	Total	44 (75%)	14 (24%)	58 (100%)

Additionally, several neonates exhibited overlapping cranial abnormalities, with some cases showing combinations of IVH, VM, periventricular echogenicity, echogenic sulci, and congenital anomalies. These coexisting findings were more prevalent in the later gestational age groups, particularly in Class III. A comprehensive overview of both solitary and combined cranial abnormalities across all three preterm classes is provided in Table 7, illustrating the complexity and variability of intracranial pathology in this high-risk population.

Table 7. Distribution of Solitary and Combined Cranial Abnormalities by Preterm Class

Findings	Class I	Class II	Class III	Total (n)
No findings (Normal CUS)	7	21	33	61
Cerebral Edema	0	1	1	2
Choroidal Cyst	0	1	1	2
Echogenic Sulci	0	2	0	2

Congenital Abnormalities	0	0	1	1
Ventriculomegaly	0	4	7	11
Intraventricular Hemorrhage (ICH)	2	4	3	9
Periventricular Echogenicity (PVE)	1	0	1	2
ICH + VM	0	0	2	2
ICH + PVE + Echogenic Sulci	0	0	1	1
VM + ICH + Cerebral Edema	0	0	1	1
VM + ICH + Congenital Abnormality	0	0	1	1
VM + PVE + Congenital Abnormality	0	0	1	1
PVE + Echogenic Sulci	0	0	1	1
ICH + Echogenic Sulci	0	0	1	1
VM + Echogenic Sulci	0	0	1	1
VM + Corpus Callosum Agenesis	0	0	1	1
ICH + PVE	0	1	1	2
VM + ICH + PVE	0	1	0	1
Total Abnormal Cases	3	14	25	42

These results highlight that while the prevalence of intracranial pathologies was relatively high across all preterm categories, extremely preterm neonates (Class I) had a greater risk for hemorrhagic lesions, and moderate to late preterms (Class III) were more affected by ventricular dilatation.

Discussion

This study aimed to evaluate intracranial abnormalities detected via transcranial cranial ultrasound in preterm neonates presenting with seizures. Out of the 122 preterm neonates assessed, 34.4% were found to have abnormal cranial ultrasound findings. These included ventriculomegaly (15.6%), intraventricular hemorrhage (14.8%), periventricular echogenicity (7.4%), and less common abnormalities such as echogenic sulci, cerebral edema, congenital anomalies, and corpus callosum agenesis.

The high rate of abnormal neurosonographic findings in this study is consistent with previously published literature indicating a strong association between prematurity and neurological injury. In particular, intraventricular hemorrhage (IVH) was more prevalent in Class I neonates (extremely preterm)—which aligns with known vulnerabilities of this population due to immature germinal matrix vasculature and impaired autoregulatory mechanisms. This finding is supported by studies such as Volpe (2008), which emphasize the predisposition of extremely preterm infants to IVH within the first few days of life (13).

On the other hand, ventriculomegaly (VM) was more frequently observed in moderate to late preterm infants (Class III), possibly reflecting sequelae of post-hemorrhagic hydrocephalus, congenital anomalies, or maturational factors. This is consistent with findings from studies by Brouwer et al. (2021), who observed increasing ventricular size in late preterm neonates with or without preceding hemorrhage (14).

The presence of overlapping abnormalities in several cases—such as combined IVH, VM, and echogenic sulci—suggests the complexity and multifactorial nature of neurological injury in this population. These combinations were especially common in Class III neonates, which may reflect cumulative brain insults

over time or delayed diagnosis of earlier evolving pathologies. These findings reinforce the importance of early and serial neurosonography, particularly in neonates with clinical seizures.

Interestingly, while a greater proportion of Class I neonates demonstrated ICH, statistical analysis showed no significant association between preterm class and overall abnormal cranial ultrasound findings ($p = 0.734$). This may be due to sample size limitations within individual subgroups or overlapping risk factors such as birth asphyxia and sepsis that influence neurological outcomes across all gestational ages.

Our findings underscore the diagnostic utility of cranial ultrasound as a first-line imaging tool in the evaluation of preterm neonates with seizures. It is non-invasive, cost-effective, and feasible at the bedside, making it particularly useful in resource-limited settings like Pakistan. Moreover, the early identification of critical abnormalities such as IVH and VM through ultrasound enables timely clinical interventions, potentially improving neurodevelopmental outcomes.

However, this study has several limitations. The sample size for extremely preterm neonates (Class I) was relatively small, which may affect the generalizability of results. In addition, cranial ultrasound may have lower sensitivity compared to MRI in detecting subtle white matter injuries or cortical abnormalities. Future studies employing longitudinal follow-up and advanced imaging techniques may provide deeper insights into the prognostic implications of these sonographic findings.

Conclusion

This study highlights that a considerable number of preterm neonates presenting with seizures exhibit abnormal cranial ultrasound findings, with ventriculomegaly and intraventricular hemorrhage being the most common. While intraventricular hemorrhage was more prevalent among extremely preterm neonates (Class I), ventriculomegaly was more frequently observed in moderate to late preterms (Class III), indicating varying patterns of intracranial pathology based on gestational age. Although no statistically significant association was found between preterm class and overall abnormal findings, the presence of overlapping abnormalities further emphasizes the complexity of brain injury in this vulnerable population. Cranial ultrasound proves to be a vital, non-invasive, and accessible imaging modality for early detection of neurological complications in preterm infants with seizures. Its routine use can aid in timely diagnosis and intervention, potentially improving neonatal outcomes. Further studies with larger cohorts and long-term follow-up are recommended to better understand the clinical implications of these findings.

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