

Ventricular Morphometric Parameters in Preterm Neonates Assessed by Transcranial Ultrasound: A Prospective Cohort Study in a Nigerian Population

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DOI: <https://doi.org/10.51244/IJRSI.2026.1309000008>

Received: 12 September 2026; Accepted: 18 September 2026; Published: 29 September 2026

ABSTRACT

Background: Ventricular morphometry provides objective measures of ventricular size and configuration and complements qualitative cranial ultrasound assessment in preterm neonates. This study characterised ventricular morphometric parameters in a Nigerian preterm population and examined their distribution in relation to neonatal characteristics and ultrasound-detected brain pathology.

Methods: This prospective cohort study included 105 preterm neonates admitted to neonatal intensive care units at Meridian Hospitals, Rivers State, and Lily Hospitals, Delta State, Nigeria, between November 2025 and May 2026. Eligible neonates were born before 37 completed weeks, weighed $\leq 2,500$ g at birth, and underwent cranial ultrasound. Ventricular index (VI), anterior horn width (AHW), and thalamo-occipital distance (TOD) were measured through the anterior fontanelle. Descriptive statistics, independent-samples *t* tests, and one-way analysis of variance were performed.

Results: Mean gestational age was 32.12 ± 1.93 weeks and mean birth weight was $1,706.67 \pm 447.92$ g. Mean AHW was 3.62 ± 1.16 mm, TOD 25.14 ± 14.26 mm, right VI 13.07 ± 2.14 mm, and left VI 13.39 ± 2.41 mm. Abnormal VI and AHW were identified in 63 (60.0%) and 50 (47.6%) neonates, respectively. Structural brain injury was detected in 61 (58.1%). Lower birth weight was significantly associated with brain injury ($t(103) = 7.08, p < .001$), while birth weight differed significantly across pathology categories ($F(4,100) = 14.60, p < .001$).

Conclusion: Ventricular morphometry demonstrated substantial variation among Nigerian preterm neonates and may enhance quantitative cranial ultrasound assessment. Larger multicentre studies with age-stratified reference data are warranted.

Keywords: Ventricular Morphometry; Ventricular Index; Anterior Horn Width; Transcranial ultrasound; Preterm neonates.

INTRODUCTION AND LITERATURE REVIEW

Preterm birth remains an important global public health problem and is associated with increased risks of neonatal morbidity, mortality, and long-term neurological impairment. The burden is particularly important because birth before term interrupts a period of rapid cerebral growth, neuronal organisation, myelination, synaptic development, and white-matter maturation. Gui et al. (2019) described longitudinal changes in neonatal brain tissue volumes among preterm infants, illustrating the dynamic nature of cerebral development during the period immediately surrounding birth. Volpe (2019) similarly examined the biological basis of dysmaturation in the premature brain and noted that the immature brain is vulnerable to multiple forms of developmental disruption. More recent global evidence also demonstrates the continuing magnitude of preterm birth as a worldwide health problem (Liang et al., 2024; Ohuma et al., 2023; Walani, 2020).

One important neuroimaging consequence of prematurity is alteration of the cerebral ventricular system. Ventricular dimensions may be affected by intraventricular haemorrhage (IVH), post-haemorrhagic ventricular dilatation, altered cerebrospinal fluid dynamics, white-matter injury, and changes in cerebral tissue growth. Ozek and Kersin (2020) described IVH as a major neurological complication of prematurity, while Parodi et al. (2020) examined the sonographic appearance, evolution, and sequelae of germinal matrix haemorrhage in preterm infants. Afifi et al. (2022) further investigated the epidemiology of post-haemorrhagic ventricular dilatation in very preterm infants. These conditions make objective assessment of ventricular size clinically relevant, particularly in infants requiring repeated monitoring.

Cranial or transcranial ultrasound is well suited to neonatal ventricular assessment because the open anterior fontanelle provides an acoustic window to the brain. The examination is portable, can be performed at the bedside, does not use ionising radiation, and can be repeated when clinical circumstances require serial assessment. Guillot et al. (2020) described routine imaging of the preterm neonatal brain and highlighted the continuing role of cranial ultrasound in neonatal care. Ní Leidhin et al. (2025) similarly examined contemporary paediatric cranial ultrasound practice and its application to assessment of the preterm brain. These advantages are especially relevant in settings where access to MRI may be constrained by cost, availability, transport requirements, or the clinical instability of very sick neonates.

Although qualitative ultrasound remains important, visual descriptions alone may not adequately characterise subtle or progressive ventricular enlargement. Quantitative ventricular morphometry provides objective measurements that can be recorded, compared, and followed over time. Three commonly used parameters are ventricular index (VI), anterior horn width (AHW), and thalamo-occipital distance (TOD). VI provides an estimate of lateral ventricular width in the coronal plane and is widely used in the assessment and monitoring of ventricular enlargement. In the present study protocol, a VI range of 10.0–12.0 mm was considered normative. AHW assesses the anterior portion of the lateral ventricle and is obtained in the coronal plane at the level of the foramen of Monro. The study protocol identified values below 3 mm as a reference for infants born before 33 weeks' gestation, while values greater than 4 mm are suggestive of ventricular enlargement in neonatal assessment (Parodi et al., 2020).

TOD complements anterior ventricular measurements by assessing the posterior component of the lateral ventricle. It is measured in the parasagittal plane between the lateral border of the thalamus and the posterior tip of the occipital horn. The source study adopted a reference range of 8.7–24.7 mm based on the protocol cited in the manuscript. The use of more than one parameter is important because ventricular enlargement is not necessarily uniform. An anterior measurement may appear relatively stable while posterior ventricular configuration changes, or vice versa. Brouwer et al. (2012) examined neonatal cerebral ventricular dimensions and provided reference values that demonstrate the importance of systematic measurement rather than reliance on qualitative impressions alone.

Evidence from previous research supports the clinical relevance of quantitative ventricular measurements. Beijst et al. (2020) examined the relationship between cranial ultrasound measurements and MRI-derived ventricular volume in preterm infants with germinal matrix IVH and found significant relationships involving VI, AHW, and TOD. Their findings support the practical use of ultrasound-derived measurements as indicators of ventricular size when MRI is unavailable. Gontard et al. (2021) also investigated automated ventricular-volume segmentation using three-dimensional ultrasonography in post-haemorrhagic ventricular dilatation, illustrating the increasing emphasis on objective quantification. Hou et al. (2020) examined cranial ultrasound measures in relation to neurodevelopmental outcomes among preterm infants, further demonstrating the potential value of quantitative imaging information.

Notwithstanding these advances, ventricular measurement should not be equated automatically with a clinical diagnosis of hydrocephalus or post-haemorrhagic ventricular dilatation. Interpretation depends on gestational age, postmenstrual age, clinical context, associated brain injury, serial change, and the specific measurement technique used. Leijser et al. (2021) examined inter-observer reliability of ventricular size measurements in extremely preterm infants and demonstrated the importance of measurement consistency. Afifi et al. (2022) also described post-haemorrhagic ventricular dilatation as a clinically important condition requiring careful

surveillance. Thus, a quantitative value is most useful when interpreted within a standardised imaging and clinical framework.

The Nigerian context provides an important reason for documenting local ventricular measurements. Differences in gestational-age distribution, birth weight, neonatal morbidity, antenatal care, referral pathways, and neonatal management may influence the characteristics of preterm populations undergoing imaging. Nigerian studies have documented the continuing burden of preterm birth and associated neonatal challenges (Obetta et al., 2021). However, locally generated quantitative information describing ventricular morphometry among preterm neonates remains limited. Establishing descriptive measurements from Nigerian clinical populations is therefore a useful step toward improving the interpretation of cranial ultrasound and identifying areas for future reference-range research.

The present study consequently examined ventricular morphometric parameters in preterm neonates using transcranial ultrasound. Specifically, it characterised AHW, TOD, and bilateral VI measurements and examined their distribution in relation to selected neonatal characteristics and structural brain findings. The study was descriptive and analytical within the available cohort; it was not designed to establish definitive Nigerian normative standards or causal relationships between birth weight and brain injury. This distinction is important because the cohort included neonates with structural abnormalities and was recruited from only two hospitals. The findings should therefore be understood as locally generated descriptive evidence that can support further multicentre investigation.

METHODOLOGY

Study design and setting. A prospective cohort study was conducted between November 2025 and May 2026 among preterm neonates receiving care in the neonatal intensive care units of Meridian Hospitals, Rivers State, and Lily Hospitals, Delta State, Nigeria. The source study incorporated neonatal imaging and subsequent developmental follow-up; the present manuscript was restricted to ventricular morphometry and its relationship with selected neonatal and structural imaging characteristics.

Study population and eligibility. The study population comprised preterm neonates admitted to the participating neonatal intensive care units. Eligibility criteria were birth before 37 completed weeks of gestation, birth weight of $\leq 2,500$ g, admission to a participating NICU, at least one cranial ultrasound examination, accessible clinical and imaging records, and parental or guardian consent. Neonates with major congenital malformations, chromosomal or genetic abnormalities, antenatally diagnosed intracranial abnormalities, severe birth asphyxia or hypoxic-ischaemic encephalopathy, significant birth trauma, established neurological or metabolic disorders, incomplete records, or loss to follow-up were excluded.

Sample size and sampling. A total of 105 neonates were recruited. Sample size was derived using Cochran's formula, assuming a population proportion of 0.5, a 95% confidence level, and a 10% margin of error. A 10% allowance for anticipated attrition resulted in a target of approximately 105 neonates. Consecutive sampling was used, with eligible neonates encountered during the study period enrolled until the required sample size was achieved.

Transcranial ultrasound protocol. Cranial ultrasound was performed through the anterior fontanelle using standard neonatal scanning techniques. The principal equipment specified in the study protocol was a Toshiba Aplio 300 ultrasound system with a 7.5-MHz variable-frequency transducer. A fixed 7.5-MHz frequency and 90° scanning angle were used. Standard coronal and sagittal planes were obtained to assess the cerebral hemispheres, ventricular system, periventricular regions, and other relevant intracranial structures.

Ventricular morphometric measurements. Three principal measurements were evaluated. VI was measured in the coronal plane as an index of lateral ventricular width, with 10.0–12.0 mm specified as the normative range in the study protocol. AHW was measured in the coronal plane at the level of the foramen of Monro at the widest portion of the anterior horn; the protocol used the <3 mm reference for infants born before 33 weeks' gestation and a >4 mm threshold suggestive of enlargement. TOD was measured in the parasagittal plane from

the lateral border of the thalamus to the posterior tip of the occipital horn, using 8.7–24.7 mm as the reference range specified in the study.

Statistical analysis. Data were analysed using SPSS version 30. Continuous variables were summarised using means and standard deviations and, where appropriate, minimum and maximum values. Categorical variables were presented as frequencies and percentages. Independent-samples t tests were used to compare continuous variables between selected groups, while one-way analysis of variance was used to compare birth weight across categories of structural brain pathology. Statistical significance was set at $p < .05$. The analysis remained within the variables and statistical comparisons available in the source dataset; no additional effect estimates or subgroup analyses were introduced.

RESULTS AND DISCUSSION

Results

Clinical characteristics of the cohort. The analysis included 105 preterm neonates. The mean gestational age was 32.12 ± 1.93 weeks (range, 29–36 weeks). Mean birth weight was $1,706.67 \pm 447.92$ g, ranging from 1,000 to 2,500 g. Mean Apgar score was 5.53 ± 0.93 at one minute and 7.74 ± 1.09 at five minutes. The cohort therefore represented a clinically relevant group of preterm neonates with variation in gestational maturity and birth weight.

Distribution of ventricular morphometric measurements. The mean AHW was 3.62 ± 1.16 mm, with measurements ranging from 1.7 to 6.3 mm. Mean TOD was 25.14 ± 14.26 mm, ranging from 1.8 to 56.0 mm. Mean right VI was 13.07 ± 2.14 mm and mean left VI was 13.39 ± 2.41 mm. The right and left VI measurements were relatively similar at the group level. TOD demonstrated the widest dispersion among the reported measurements.

Table 1. Ventricular morphometric parameters among preterm neonates

Parameter	N	Minimum (mm)	Maximum (mm)	Mean $\pm$ SD (mm)
Anterior horn width	105	1.7	6.3	3.62 ± 1.16
Thalamo-occipital distance	105	1.8	56.0	25.14 ± 14.26
Right ventricular index	105	9.2	18.0	13.07 ± 2.14
Left ventricular index	105	8.6	19.0	13.39 ± 2.41

Categorical interpretation of ventricular index. Using the predefined study interpretation, 63 neonates (60.0%) had an abnormal VI, whereas 42 (40.0%) had a normal VI. Thus, abnormal VI was identified in approximately three-fifths of the cohort. This proportion describes classification according to the study protocol and should not be interpreted as a population prevalence of hydrocephalus or post-haemorrhagic ventricular dilatation.

Table 2. Categorical interpretation of ventricular index

Ventricular index interpretation	Frequency (n)	Percentage (%)
Normal	42	40.0
Abnormal	63	60.0
Total	105	100.0

Categorical interpretation of anterior horn width. AHW was interpreted as normal in 55 neonates (52.4%) and abnormal in 50 neonates (47.6%). Thus, nearly half of the cohort had an AHW measurement classified as abnormal according to the criteria specified in the study protocol.

Table 3. Categorical interpretation of anterior horn width

AHW interpretation	Frequency (n)	Percentage (%)
Normal	55	52.4
Abnormal	50	47.6
Total	105	100.0

Right-left ventricular index symmetry. The mean right VI was 13.07 ± 2.14 mm compared with 13.39 ± 2.41 mm on the left. The small difference between the group means indicates relative bilateral symmetry at cohort level. However, similar group means do not exclude clinically relevant individual-level asymmetry, and the available analysis does not establish the absence of unilateral ventricular enlargement in individual neonates. Ventricular morphometry and structural brain pathology. Structural brain injury was detected in 61 (58.1%) neonates. The major abnormalities were IVH, cystic lesions, periventricular leukomalacia (PVL), and periventricular flaring.

IVH occurred in 33 (31.4%) neonates and was the most common reported abnormality. Neonates with detectable brain injury had a mean birth weight of $1,490.16 \pm 353.41$ g compared with $2,006.82 \pm 390.23$ g among those without detectable injury. This difference was statistically significant, $t(103) = 7.08$, $p < .001$. Mean birth weight also differed significantly across the specific categories of structural brain pathology, $F(4,100) = 14.60$, $p < .001$.

Table 4. Birth weight according to structural brain pathology

Ultrasound category	n	Mean birth weight (g)	SD (g)
No injury	44	2,006.82	390.23
Periventricular flaring	7	1,771.43	434.79
Cysts	14	1,507.14	387.23
IVH	33	1,466.67	285.77
PVL	7	1,285.71	157.36
Total	105	1,706.67	447.92

DISCUSSION

This prospective cohort study characterised ventricular morphometric parameters among 105 preterm neonates undergoing transcranial ultrasound in southern Nigeria. The principal measurements were AHW, TOD, and bilateral VI. The findings demonstrate considerable variation in ventricular dimensions and a substantial proportion of measurements classified as abnormal according to the predefined reference criteria used in the study. The results are clinically relevant because quantitative measurements can complement qualitative cranial ultrasound and provide a reproducible way of documenting ventricular calibre in neonates who may require repeated imaging.

The mean AHW was 3.62 mm. This value is higher than the <3 mm reference cited in the protocol for infants born before 33 weeks' gestation. However, interpretation of the cohort mean requires caution because the study included neonates with gestational ages from 29 to 36 weeks. Ventricular dimensions change with maturation, and a single threshold applied across a heterogeneous preterm population may influence the proportion classified as abnormal. Parodi et al. (2020) described the value of cranial ultrasound measurements in preterm germinal matrix haemorrhage and its sequelae, supporting the use of quantitative parameters alongside the broader clinical and imaging context.

The mean TOD was 25.14 mm, with a standard deviation of 14.26 mm, indicating substantial inter-individual variation. The mean was slightly above the upper reference value of 24.7 mm adopted in the study. The wide range, from 1.8 to 56.0 mm, is particularly important because it demonstrates that posterior ventricular morphology varied considerably within the cohort. TOD therefore provides potentially useful complementary information, but the present data do not establish a Nigerian reference range. Brouwer et al. (2012) demonstrated the importance of reference values when interpreting neonatal cerebral ventricular dimensions, while the findings of Beijst et al. (2020) support the relationship between ultrasound-derived ventricular measurements and ventricular volume assessed by MRI.

VI demonstrated the largest proportion of abnormal classifications, with 60.0% of neonates falling outside the study's predefined normative range. Mean right and left VI values were 13.07 mm and 13.39 mm, respectively, both above the 10–12 mm range specified in the protocol. The relatively high proportion of abnormal VI measurements may reflect the clinical characteristics of the recruited preterm population, including the presence of structural brain injury. Ventricular enlargement can occur in association with IVH and post-haemorrhagic ventricular dilatation, but altered cerebral growth and white-matter injury may also contribute to ventricular configuration (Inder et al., 2021; Parodi et al., 2020). Accordingly, the abnormal VI proportion should not be interpreted as a direct estimate of disease prevalence.

The similarity between right and left VI measurements is also noteworthy. The small difference between the group means suggests no pronounced lateral difference at cohort level. This observation is consistent with a generally bilateral pattern in the overall measurements, although it does not exclude individual asymmetry. In clinical practice, assessment of each ventricle should remain individualised, particularly where haemorrhage, focal injury, or cerebrospinal fluid obstruction may produce asymmetric changes. The present study did not report a dedicated individual-level asymmetry analysis, so no stronger inference should be drawn from the similarity of the means.

Almost half of the neonates had AHW classified as abnormal. AHW is useful because it assesses the anterior horns and may identify changes that are not fully represented by VI. The combined use of VI and AHW can therefore provide a broader description of ventricular configuration. The value of multiple quantitative measures is supported by Beijst et al. (2020), who investigated the relationship between ultrasound measurements and MRI-derived ventricular volume. Similarly, Gontard et al. (2021) demonstrated the feasibility of quantitative ventricular-volume assessment using three-dimensional ultrasonography in post-haemorrhagic ventricular dilatation. These studies indicate a wider movement toward objective quantification in neonatal neuroimaging.

The relationship between structural brain injury and birth weight provides additional context for the ventricular findings. Brain injury was detected in 61 neonates, with IVH occurring in 33 and representing the most frequently reported abnormality. Neonates with detectable injury had a mean birth weight approximately 517 g lower than those without detectable injury. The difference was statistically significant, and birth weight also varied significantly across the specific pathology categories. The lowest mean birth weight occurred among neonates with PVL, followed by those with IVH, whereas the highest mean birth weight occurred among neonates without detectable injury. This pattern is consistent with the recognised vulnerability of smaller and more immature neonates to haemorrhagic and white-matter injury, although the present observational data do not establish causation (Ozek and Kersin, 2020; Yates et al., 2021).

The findings also reinforce an important distinction between morphometric abnormality and clinical diagnosis. An abnormal VI or AHW measurement does not, by itself, establish hydrocephalus or post-haemorrhagic

ventricular dilatation. Interpretation should incorporate gestational age, postmenstrual age, clinical status, associated brain injury, serial change, and measurement reliability. Leijser et al. (2021) examined inter-observer reliability of ventricular size measurements and highlighted the importance of consistent technique. Afifi et al. (2022) similarly described post-haemorrhagic ventricular dilatation as a condition requiring structured surveillance. Consequently, the measurements in the present study are best viewed as quantitative descriptors rather than stand-alone diagnostic endpoints.

The practical relevance of the study is particularly clear in resource-constrained neonatal settings. Transcranial ultrasound can be performed at the bedside, repeated without ionising radiation, and used for serial surveillance. Guillot et al. (2020) and Ní Leidhin et al. (2025) described the continuing importance of cranial ultrasound in the assessment of preterm infants. MRI remains valuable for detecting subtle diffuse white-matter abnormalities and for providing more comprehensive anatomical assessment; Guillot et al. (2021) and Inder et al. (2021) emphasised the complementary roles of ultrasound and MRI. Nevertheless, where MRI is limited by cost, access, transport, or neonatal instability, quantitative ultrasound can provide clinically useful structural information.

The present findings should not be interpreted as definitive Nigerian normative standards. The cohort was relatively small, was recruited from only two hospitals in southern Nigeria, and included neonates with structural brain injury. A true normative dataset would require a larger population of neurologically normal preterm neonates, stratification by gestational and postmenstrual age, standardised measurement procedures, assessment of inter-observer reliability, and ideally comparison with MRI. Brouwer et al. (2012) illustrated the importance of reference values in neonatal ventricular assessment, while Leijser et al. (2021) demonstrated that measurement reliability is also a critical consideration.

Several strengths and limitations should therefore be considered. The principal strength was the prospective acquisition of three complementary quantitative ventricular measurements in a Nigerian clinical cohort. The study also contributes locally generated descriptive evidence in an area where published Nigerian ventricular morphometric data are limited. However, the sample size and two-centre recruitment restrict generalisability. Conventional ultrasound rather than MRI was used as the imaging modality, meaning that subtle white-matter abnormalities may have been missed. In addition, the available results do not provide sufficient evidence to derive gestational-age-specific normative equations or establish longitudinal trajectories. Future studies should incorporate serial measurements, broader multicentre recruitment, and appropriate healthy reference groups.

Overall, the study demonstrates that quantitative ventricular assessment is feasible within routine neonatal ultrasound practice and can reveal clinically relevant variation that may not be captured by qualitative descriptions alone. The findings support continued use of VI, AHW, and TOD as complementary measurements, while emphasising cautious interpretation of values outside reference ranges. The most appropriate next step is not to treat the present measurements as fixed population norms, but to use them as a foundation for larger Nigerian studies designed to establish robust, gestational-age-specific reference data and evaluate the relationship between ventricular measurements, structural injury, and subsequent outcomes.

CONCLUSION

Ventricular morphometric abnormalities were common among the 105 preterm neonates evaluated by transcranial ultrasound in this Nigerian cohort. Mean AHW was 3.62 ± 1.16 mm, mean TOD was 25.14 ± 14.26 mm, and mean right and left VI measurements were 13.07 ± 2.14 mm and 13.39 ± 2.41 mm, respectively. Using the predefined study criteria, 60.0% of neonates had abnormal VI and 47.6% had abnormal AHW. The bilateral VI values were relatively symmetrical at cohort level, whereas TOD demonstrated substantial inter-individual variability. These findings indicate that VI, AHW, and TOD can provide complementary quantitative information about ventricular morphology.

Quantitative ventricular morphometry has practical value in neonatal imaging because measurements can be documented and compared during clinical surveillance. In settings where MRI is not readily accessible, transcranial ultrasound offers a bedside method that can be repeated without ionising radiation. The findings

therefore support systematic ventricular measurement during cranial ultrasound assessment of high-risk preterm neonates, particularly where there is concern about IVH, ventricular enlargement, or evolving structural abnormalities. VI and AHW provide information about anterior and lateral ventricular calibre, while TOD contributes information about posterior ventricular configuration. However, abnormal measurements should be interpreted with gestational age, postmenstrual age, clinical status, associated brain injury, and serial change rather than used as stand-alone diagnostic endpoints.

The study also found a significant association between lower birth weight and ultrasound-detected structural brain pathology. Neonates with brain injury had a mean birth weight of $1,490.16 \pm 353.41$ g compared with $2,006.82 \pm 390.23$ g among those without detectable injury, and birth weight differed significantly across the reported pathology categories. The lowest mean birth weight occurred among neonates with PVL, followed by those with IVH. Although clinically relevant, these findings represent associations within the observed cohort and do not establish causation. Similarly, the proportion of abnormal VI measurements should not be interpreted as a prevalence estimate of hydrocephalus or post-haemorrhagic ventricular dilatation.

Notwithstanding the value of the present data, they should not be interpreted as definitive Nigerian normative standards. The study involved two hospitals, included neonates with structural brain abnormalities, and did not provide sufficient evidence for gestational-age-specific reference equations. Larger multicentre studies should recruit neurologically normal preterm neonates, stratify measurements by gestational and postmenstrual age, standardise scanning and measurement procedures, assess inter-observer reliability, and incorporate serial imaging.

Where feasible, MRI correlation would strengthen validation. Overall, this study provides descriptive evidence that quantitative ventricular measurements are feasible in a Nigerian clinical population and can complement qualitative ultrasound assessment. Future research should establish robust local reference ranges and determine how ventricular trajectories relate to neonatal brain injury and longer-term neurodevelopmental outcomes.

ACKNOWLEDGMENT

The authors acknowledge the management and staff of Meridian Hospitals, Rivers State, and Lily Hospitals, Delta State, Nigeria, for their support during the study and for facilitating access to the neonatal intensive care units. We also appreciate the parents and guardians of the participating neonates for their consent and cooperation. The authors acknowledge all members of the clinical and radiology teams who contributed to the care of the neonates and the acquisition of the transcranial ultrasound examinations.

Authors contributions

This work was carried out in collaboration between the two authors. Author UAG designed the study, performed the statistical analysis, wrote the protocol, and first drafted the manuscript. Author UAC supervised the entire study. Both authors read and approved the final manuscript, and others contributed to the success of the work to this stage

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