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A survey of the monitoring and management of neonatal seizures in Nigerian neonatal intensive care units

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Abstract: *Background:* Accurate diagnosis and management of neonatal seizures are critical to ensure interventions that improve survival and long-term neurological outcomes. Electroencephalography is crucial for diagnosing and managing neonatal neurologic disorders. In Low- and middle-income countries where the burden of neonatal neurologic disorders, such as birth asphyxia, is very high, the availability and use of electroencephalography are unknown.

Aim: To determine the availability, use, and expertise on the use of EEG by Nigerian neonatal medical providers and to evaluate management protocol, drug treatment, and post-discharge follow-up for babies managed for seizures in the neonatal intensive care unit (NICU).

Methods: Participants were recruited at a national pediatric conference. Semi-structured questionnaires were administered to assess EEG availability. Associations between EEG availability in NICUs and hospital characteristics were evaluated using the chi-square test. A p-value of < 0.05 was used to determine significance.

Results: 135 participants representing 52 neonatal intensive care units (NICUs) were surveyed. There were 103 (76.3%) females, only 7.7% of 52 NICUs surveyed had access to EEG equipment, and four (3 %) respondents had formal training on EEG use. Phenobarbitone was the most used first-line drug for neonatal seizures (61.5%), followed by diazepam

(26.7%), phenytoin (5.9%), and midazolam (5.9%). 76.9% of the facilities had neurodevelopmental follow-up clinics, but most hospitals discharged patients by 6 months of neonatal clinic follow-up.

Conclusion: Critical deficiencies still exist in neonatal seizure monitoring, management, and follow-up. The availability of EEG in Nigerian Neonatal facilities is unacceptably poor.

Keywords: Neonatal seizures, EEG monitoring, NICU, Neurodevelopment, Nigeria healthcare

Résumé: Le diagnostic précis et la prise en charge des convulsions néonatales sont essentiels pour assurer des interventions améliorant la survie et le pronostic neurologique à long terme. L'électroencéphalographie (EEG) est un outil crucial pour diagnostiquer et gérer les troubles neurologiques néonataux. Dans les pays à revenu faible et intermédiaire, où le fardeau des troubles neurologiques néonataux, comme l'asphyxie périnatale, est très élevé, la disponibilité et l'utilisation de l'EEG restent mal connues.

Objectif: Déterminer la disponibilité, l'utilisation et le niveau de compétence dans l'utilisation de l'EEG chez les professionnels néonataux nigériens, et évaluer les protocoles de prise en charge, les traitements médicamenteux et le suivi post-hospitalisation des nouveau-nés pris en charge pour convulsions en unité de soins in

intensifs néonataux (USIN).

Méthodes: Les participants ont été recrutés lors d'une conférence pédiatrique nationale. Des questionnaires semi-structurés ont été administrés pour évaluer la disponibilité de l'EEG. Les associations entre la disponibilité de l'EEG dans les USIN et les caractéristiques hospitalières ont été évaluées avec le test du chi carré. Une valeur de $p < 0,05$ était considérée significative.

Résultats: Cent trente-cinq (135) participants représentant 52 USIN

ont été interrogés, dont 103 (76,3 %) femmes. Seuls 7,7 % des 52 USIN disposaient d'un équipement EEG, et quatre (3 %) des répondants avaient une formation formelle à l'utilisation de l'EEG. Le phénobarbital était le traitement de première intention le plus utilisé pour les convulsions néonatales (61,5 %), suivi du diazépam (26,7 %), de la phénytoïne (5,9 %) et du midazolam (5,9 %). 76,9 % des établissements disposaient de cliniques de suivi neurodéveloppement-

tal, mais la plupart des hôpitaux arrêtaient le suivi à six mois.

Conclusion: Des lacunes critiques persistent dans la surveillance, la prise en charge et le suivi des convulsions néonatales. La disponibilité de l'EEG dans les établissements néonataux nigériens est inacceptable.

Mots-clés: Convulsions néonatales, EEG, USIN, Neurodéveloppement, Santé au Nigeria

Introduction

Neuronal brain injury and dysfunction, often manifesting as neonatal seizures, are prevalent causes of admissions to neonatal intensive care units (NICUs) globally.^{1,2} Perinatal asphyxia remains a leading cause of neuronal brain injury in low- and middle-income countries (LMICs) like Nigeria, accounting for about one-third of neonatal mortalities.²⁻⁸ Survivors face the risk of long-term neurodevelopmental disabilities such as developmental delay, epilepsy, cerebral palsy, and cognitive impairment.^[9] Accurate diagnosis and treatment of neonatal seizures are critical to ensure timely, targeted interventions that improve survival and long-term neurological outcomes.¹⁰ As technology advances, monitoring devices have become increasingly sophisticated, enabling more nuanced assessments that enhance our understanding of neonatal brain health.

Despite integrating various physiological parameters, including electrocardiogram (ECG), heart rate, blood pressure, oxygen saturation, and body temperature, into NICU monitoring systems in Nigeria, the successful incorporation of EEG has encountered numerous challenges. The cost of purchasing and maintaining the EEG machines and the lack of trained staff to operate them and interpret EEG waveforms are identified barriers to integrating EEG into routine clinical care in Nigerian NICUs.¹⁰ While conventional EEG (cEEG) remains the gold standard for detecting and diagnosing seizures in neonates, video EEG (vEEG) enhances this by providing a visual context for interpreting EEG data. However, due to their complexity, the need for specialized equipment, and the requirement for trained neurophysiologists to interpret the data, amplitude-integrated EEG (aEEG) is often used as a more accessible alternative in neonatal intensive care units (NICUs), particularly in low-resource settings.¹¹⁻¹³ The aEEG is a simplified form of EEG that presents a time-compressed representation of raw EEG signals on a semi-logarithmic scale.^[14] It is invaluable in the evaluation of neonatal seizures, treatment planning, and prognostication in conditions such as hypoxic-ischaemic encephalopathy.^{10,15} It is therefore indispensable in the NICU setting, helping to prevent the misdiagnosis or over diagnosis of neonatal seizures and encephalopathy. The critical nature of early detec-

tion and treatment becomes apparent when considering the potential long-term consequences of overlooking or inaccurately managing seizures in neonates. Regrettably, the failure to detect and manage neonatal seizures promptly can lead to severe outcomes, including cerebral palsy, subsequent epilepsy, intellectual disability, and other chronic neurological disorders – complications that are unfortunately prevalent in our environment, indicating that many cases of seizures and neonatal encephalopathy are going unnoticed or not detected early enough for prompt treatment.^{9,16-18}

This study aims to determine the availability, use, and expertise on EEG use by Nigerian neonatal medical providers. We also aimed to evaluate the management protocol, anti-seizure medications, and post-discharge practices for babies managed for seizures in the NICU.

Methods

Study design

We employed a descriptive cross-sectional study design. Semi-structured questionnaires were administered to neonatal health workers in Nigeria on the availability and use of aEEG for monitoring neonatal seizures in their respective NICUs.

Setting and participants

This study was conducted during the Paediatric Association of Nigeria (PAN) Conference held in January 2024 in Lagos, Nigeria. The PAN conference is the premium gathering of paediatricians held yearly and includes pre-conference workshops on paediatric and neonatal medicine. The pre-conference workshops and the main conference are open to paediatricians (including neonatologists), paediatric nurses (including neonatal nurses), and postgraduate doctors undergoing residency training in paediatrics. The inclusion criteria for this study were being a health worker (nurses, consultants (attendings), paediatricians, or paediatricians in training) in Nigerian neonatal facilities.

Data collection

We used a pretested 19-point/questionnaire.

The questionnaire was segmented into 1) demographic information of the healthcare worker, 2) information on the availability of EEG, type of EEG, and if the clinician had received any formal training on EEG. 3) The availability of a written unit/department/hospital policy for managing neonatal seizures and the first and second-line anti-seizure medications used in their units. 4) The hospital policy for post-discharge management of babies managed for neonatal seizures. The questionnaire was self-administered after informed consent was obtained from participants, with each questionnaire taking approximately 7 minutes to complete

Data analysis

Respondents' demographic information was summarized using descriptive summary statistics. Continuous data were presented as mean if normally distributed or median with respective interquartile ranges for non-normally distributed data. Categorical data were presented as frequencies and percentages. Associations between the availability of EEG in the neonatal unit and hospital characteristics were determined using the chi-square test. A p-value of < 0.05 was used to assess significance. Data cleaning and analysis were done using IBM SPSS Statistics 26.0.

Results

Characteristics of study participants

The study respondents were 135 Paediatric healthcare workers. Most (75.6%) were aged 30-50 years. Thirty-two (23.7%) were males, and 103 (76.3%) were females. Ninety-eight (72.6%) participants were doctors, and 36 (26.7%) were nurses.

The participants were from 52 hospitals of which 67.3% were from public/government facilities, and only three (6%) were faith-based hospitals. Forty (76.9%) were tertiary facilities, and 12 (23.1%) were secondary facilities as shown in Table I. The median (IQR) bed capacity of the neonatal facilities was 25 (20-30) for government facilities, 15 (11.5-17.5) for faith-based hospitals, and six (6-10) for private facilities.

Aetiology of neonatal seizures

The most commonly reported cause of neonatal seizures was asphyxia (131; 97.0%), followed by meningitis (110; 81.5%) and hypoglycaemia (101; 74.8%). Only 12 (8.9%) of respondents reported other factors like hypocalcaemia and intraventricular haemorrhage as a common cause of neonatal seizures. Fig 1

Recognition of seizures in neonates and factors associated with the availability of EEG

The most reported way of recognizing neonatal seizures was visual monitoring. EEG was only present in 4 (7.7%) hospitals as shown in figure 2. One of which had a video EEG for monitoring neonatal seizures. Four

(3%) respondents reported formal EEG training and proficiency. The availability of EEG at the NICU was not associated with type of hospital or level of neonatal care provided.

Table 1: Characteristics of study participants

Variable	Frequency	Percentage
<i>Age Group</i>		
< 30 years	17	12.6
30 – 50 years	102	75.6
> 50 years	16	11.9
<i>Sex</i>		
Male	32	23.7
Female	103	76.3
<i>Profession</i>		
Doctors	99	73.3
Nurses	36	26.7
<i>Type of Hospital</i>		
Government	35	67.3
Private	14	26.9
Faith-based	3	5.8
<i>Level of care of hospital</i>		
Tertiary	40	76.9
Secondary	12	23.1
<i>NICU bed capacity</i>		
30-50	4	7.7
10 – 30	32	61.5
< 10	16	30.8

Fig 1: Reported common causes of neonatal seizures

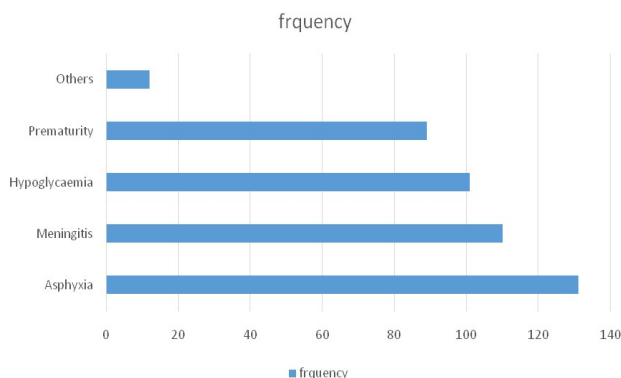


Fig 2: Availability of EEG



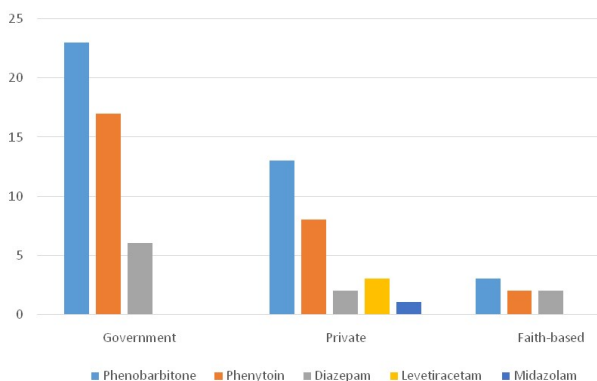
Table 2: Factors associated with the availability of EEG

Variable	Yes	No	χ^2	P
<i>Type of hospital</i>				
Government	2	33	0.6995	0.4030
Private	2	12		
Faith-based	0	3		
<i>Level of care</i>				
Secondary	1	11	0.0295	0.864
Tertiary	3	37		

Treatment of Neonatal Seizures

Most of the participants 83 (61.5%) reported phenobarbitone as the first-line drug for managing neonatal seizures. Others reported diazepam 36 (26.7%); phenytoin 8 (5.9%) and midazolam 8 (5.9%). All hospitals represented had phenobarbitone stocked for seizure control, while 14 (26.9%) stocked phenytoin and 4 (7.7%) levetiracetam as second-line anti-seizure medications. Only private neonatal facilities had levetiracetam in stock.

Fig 3: 1st line Anti-seizure medications used for neonatal seizures by hospital type



Follow-up of neonates with seizure

Neonates with seizures are usually seen within 1 week of discharge at the follow-up clinic. Most neonates are followed up for 6 months before discharge from the neonatal clinic. Forty (76.9%) of the 52 facilities have neurology follow-up clinics where those with neurological sequelae are referred to for further care.

Discussion

The finding that only about 8% of the 52 Neonatal Intensive Care Units (NICUs) surveyed have access to EEG equipment highlights a critical gap in the availability of this essential neuro-diagnostic technology. It reflects the underdevelopment of neonatal healthcare infrastructure in the country. This reveals the disparities in diagnostic capabilities and quality of care for NICU graduates across Nigeria, despite the high burden of neonatal seizures, primarily due to perinatal asphyxia. Other researchers have reported similar findings of limited EEG availability in sub-Saharan Africa.^[10] In con-

trast, neonatal units in high-income countries routinely use either aEEG or cEEG or both in most NICUs. This disparity may be attributed to the shortage of specialized neonatal care equipment, such as therapeutic hypothermia devices for managing babies with severe asphyxia in Nigeria.

The low number of respondents who have received formal training or are proficient in using EEG devices is noteworthy. The reliance on visual recognition of neonatal seizures in protocols for evaluating neonatal seizures, without the use of EEG in the NICU, is no longer evidence-based.^{10,12,19} Conventional or Video EEG and amplitude-integrated EEG are recommended gold standard for diagnosis of neonatal seizures because many seizures in newborns lack motor manifestations (electrographic-only), and some paroxysmal events do not exhibit EEG seizure patterns, complicating the distinction between seizures and other abnormal movements.^{10,19,20} For instance, Murray *et al.* demonstrated significant under-diagnosis and over-diagnosis of neonatal seizures, with only 9% of electrographic seizures being recognized by trained neonatal clinical staff, while 73% of clinically identified seizures had no corresponding electrographic seizure activity.²¹ Furthermore, while clinical seizures may cease with the initiation of anti-seizure medication, electrographic seizures may persist.²² Therefore, the absence of EEG in most NICUs in this survey suggests that many newborns may not receive optimal neurologic evaluation, monitoring, and management. This situation could potentially contribute to delays in the detection of neonatal seizures, thus leading to the high seizure burden and adverse neurodevelopmental outcomes that are prevalent in our locale.

The availability of EEG machines in neonatal care units was independent of factors such as hospital type (government or private) and the level of neonatal care offered. This finding is particularly unexpected, as tertiary public health institutions, which typically have a higher concentration of specialized personnel like neonatologists and paediatric neurologists, are generally expected to have the necessary diagnostic tools, such as EEG, for accurately identifying seizures in newborns. The absence of EEG in these tertiary centres raises concerns about systemic deficiencies. One likely explanation for our finding may be inadequate funding and prioritization of essential neurodiagnostic equipment. Research suggests that resource-limited settings, particularly in low- and middle-income countries, often struggle with inadequate healthcare infrastructure and equipment.²³⁻²⁵ This lack of funding may also extend to the maintenance and operational availability of EEG equipment, further reducing its usage, even when it is present in some institutions. Another critical issue is the shortage of trained personnel. In this survey, only 3% of the healthcare professionals reported having received formal training in using EEG, highlighting a significant gap in the technical skills necessary to operate and interpret this diagnostic tool. Previous studies have emphasized the need for increased training programs to build capac

capacity among healthcare workers in EEG usage, especially in neonatal and paediatric care.^{10,26,27} Without proper training, even when EEG machines are available, their utilization is severely limited, contributing to under diagnosis or over diagnosis of neonatal seizures, which can have long-term neurodevelopmental consequences. Addressing this gap in training and resource allocation is crucial for improving neonatal care outcomes, particularly in settings where neonatal seizures are a common risk factor for developmental delays and neurological impairments.

The predominance of phenobarbitone as the first-line drug for managing neonatal seizures, as reported by most participants, reflects the common practice among neonatal healthcare providers in the surveyed hospitals. This finding aligns with established guidelines that recommend phenobarbitone as the initial treatment option for neonatal seizures due to its efficacy and safety profile.^{10,20} However, the presence of alternative medications such as diazepam, phenytoin, and midazolam as first-line options suggests a deviation from recommended evidence-based guidelines. This non-utilization of the recommended guidelines highlights variability in clinical practice and underscores the importance of enhancing healthcare workers' awareness and adherence to evidence-based protocols. Furthermore, the discrepancy in medication availability between private and public neonatal facilities, with the 2nd line drugs such as levetiracetam and phenytoin not available in the majority of the facilities, necessitates urgent attention to ensure equitable access to pharmaceutical resources and the development of standardized protocols aligned with best practices in each NICU.

Two-thirds of the facilities have neurodevelopmental follow-up clinics for babies treated for neonatal seizures, with most discharging patients from follow-up at six months of age. However, longer follow-up is needed, at least until 18 months, to identify adverse neurodevelopmental outcomes that may develop later and to ensure referral for further care. Additionally, 25% of the institutions do not have scheduled follow-up visits at neurology clinics for their patients with neonatal seizures. This contrasts with global best practices, where newborns with seizures receive neurodevelopmental follow-up

assessments and early intervention if any deficits are identified.¹⁰ The use of aEEG could also help appropriately categorise and prioritise babies who would require long-term follow-up and interventions.¹⁶ Considering the high burden of perinatal asphyxia in Nigeria, enhancing our neurodevelopmental assessment infrastructure becomes imperative to improve the quality of life for asphyxia survivors.

Amplitude-integrated EEG (aEEG) provides continuous monitoring of cerebral function and is essential for the diagnosis and treatment of neonatal seizures, including newborns undergoing therapeutic hypothermia. The scarcity of aEEG devices in NICUs across Nigeria may reflect broader systemic challenges, such as limited funding for healthcare infrastructure and uneven resource distribution within the system. The high costs of acquiring and maintaining EEG devices, coupled with the need for specialized training for neonatal healthcare professionals, create significant barriers to their widespread adoption, particularly in resource-constrained settings like ours. A potential solution could involve regionalizing care by equipping select centers with critical neuro-monitoring infrastructure, thereby laying the groundwork for adopting therapeutic hypothermia as the standard of care for managing hypoxic-ischemic encephalopathy in newborns.

In conclusion, this study highlights significant gaps in the availability and utilization of neurodiagnostic tools such as EEG in Nigerian NICUs, further compounded by limited training on its use among neonatal healthcare professionals. The lack of access to second-line drugs such as levetiracetam and phenytoin in most facilities, and the inadequate long-term neurodevelopmental follow-up, underscore systemic challenges within the neonatal care infrastructure. There is a critical need for enhanced training and equitable access to essential neurodiagnostic equipment (aEEG, cEEG, and vEEG) and anti-seizure medications to bridge these gaps.

Limitations of the study

The reliance on self-administered questionnaires introduces the possibility of recall bias or inaccurate participant reporting.

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