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Review Article

A Comprehensive Review of EEG Education for Nurses: Addressing Knowledge Gaps and Exploring Future Opportunities

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A B S T R A C T

Electroencephalography (EEG) is a non-invasive diagnostic technology used to detect seizure activity in the brain. It is used in a variety of clinical situations, including seizure diagnosis and monitoring, brain function evaluation, preoperative assessment, sleep and mental problems, cognitive research, and critical care brain monitoring. EEG is preferred over other non-invasive procedures because of its lower risk, decreased pain, and shorter operation timeframes. It gives critical information that enhances surgical planning, particularly for localisation and lateralisation, resulting in better seizure treatment and patient quality of life.

Nurses must have a thorough awareness of EEG, including both its benefits and limits. EEG is useful in diagnosing and managing a wide range of neurological and psychiatric problems, in addition to epilepsy. This review study discusses how developing nursing expertise in EEG is crucial for better patient care and outcomes. It analyses present obstacles in EEG education for nurses, such as a lack of formal training and inadequate practical resources, and suggests areas for improvement. These include incorporating organised EEG modules into nursing curricula, promoting multidisciplinary collaboration, and offering more hands-on training.

As EEG technology advances, nurses must be equipped with the knowledge and skills necessary to support these advancements. Addressing these knowledge gaps will enable nurses to take a more active role in EEG monitoring, resulting in improved care in both neurological and mental health settings.

Keywords: EEG, Nursing Education, Seizure Monitoring, Critical Care, EEG Training

Introduction

Epilepsy is a common and chronic neurological illness that threatens not only physical health but also emotional, social, and economic well-being, frequently resulting in a lower quality of life. The burden of epilepsy (PWE) is significant, with over 50 million individuals living with the disorder worldwide, including more than 10 million in India.[1] Epilepsy is defined by the presence of at least two unprovoked seizures separated by more than 24 hours, with seizures caused by aberrant, excessive, or synchronised neuronal activity in the brain. Seizures are further characterised according to their location and symptomatology.[2]

Epilepsy diagnosis requires a thorough evaluation that includes a medical history, a clinical examination, and a variety of diagnostic tests. Despite developments in neuroimaging and other diagnostic tools, electroencephalography (EEG) remains a key component in the diagnosis of epilepsy, notably in measuring electrical brain activity and neuronal function.[3] EEG is widely utilised in the diagnosis and treatment of neurologic disorders, but it is especially important in the therapy of PWE. EEG investigations range from short-term inpatient/ outpatient recordings to long-term EEG, which is frequently accompanied by video surveillance. Video EEG (VEEG) delivers vital insights, especially when routine clinical assessments and EEGs fail to yield definitive diagnostic results.[4] Continuous EEG (cEEG) monitoring has shown to be a very useful tool in hospitals and specialised care units. It helps detect non-convulsive seizures, ischaemia, and other neurologic abnormalities in real time, allowing for more rapid therapy modifications.[5] Despite the ubiquitous use and significance of EEG, particularly in epilepsy care, there is a knowledge gap among nursing staff that may impede optimum patient care.

This review will go in-depth on EEG, its usual applications, common artefacts, activation strategies, and the properties of both normal and abnormal EEG patterns. It also emphasises the importance of EEG knowledge for nursing staff members, filling existing educational gaps and identifying future potential to improve nursing competencies in neurodiagnostic.

Overview

Electroencephalography (EEG) has advanced greatly since its initial discovery in the late nineteenth and early twentieth centuries. The pioneering work of British surgeon Richard Caton, who discovered electrical activity in animal brains in 1875, laid the path for future research into brain electrophysiology. However, the breakthrough occurred in 1924, when German psychiatrist Hans Berger successfully recorded the first human EEG, recording brainwave patterns such as the renowned "alpha waves." Berger's research found that mental activity such as relaxation and concentration were linked to various brainwave frequencies. Despite initial suspicion, his findings transformed our understanding of brain activity and established EEG's crucial place in modern neurology.[6] The EEG devices (Figure 1) monitor electrical brain activity using electrodes, conductive gel, amplifiers, and an analog-to-digital converter. These components work together using the standardised 10–20 system to capture and transmit brain electrical impulses from electrodes placed on the scalp. Electrodes made of tin, silver, or gold are used to measure the electrical potential caused by cerebral activity. This action is then amplified and converted into a digital signal for examination. A layer of conductive gel is applied beneath the electrodes to reduce resistance and improve transmission.[7] The main goal of EEG analysis is to provide objective data to support a clinical hypothesis for diagnosis, which doctors utilise to evaluate patients.

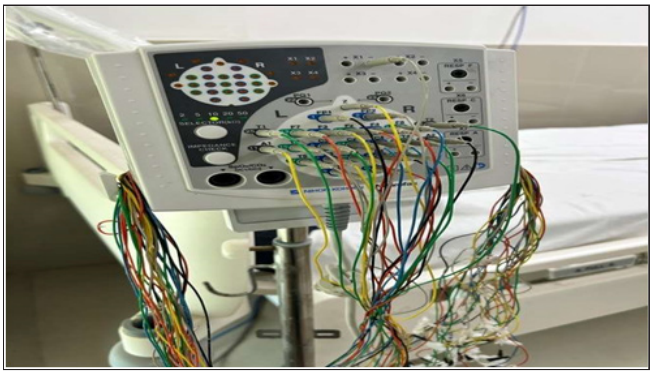

Figure 1.Electroencephalogram (EEG) Device (Adapted from AIIMS Raebareli Hospital)

Electrode Placement System

The International Federation of Clinical Neurophysiology (IFCN) established the 10-20 method for electrode placement in EEG (Figure 2). The anatomical reference points used on the skull, the nasion, inion, and preauricular points, distribute 21 electrodes pretty uniformly throughout the scalp. These landmarks divide the brain into equal parts, providing a thorough coverage of all brain regions. Each electrode is identified by a letter and a number: the letter denotes the part of the brain being measured at the time of measurement (F, frontal; C, central; T, temporal; P, parietal; and O, occipital), and the number denotes which hemisphere was measured, with even numbers corresponding to right hemisphere measurements and odd numbers corresponding to left.[8] In some circumstances, extra electrodes, such as T1 and T2, are added to improve the localisation of specific brain areas, primarily for epilepsy monitoring. Other physiological signal monitoring electrodes, such as the ECG, are also utilised in conjunction with EEG recording. These additional placements, together with the normal 10-20 method, allow for significantly more thorough and exact mapping of the brain during neurodiagnostic operations.[9]

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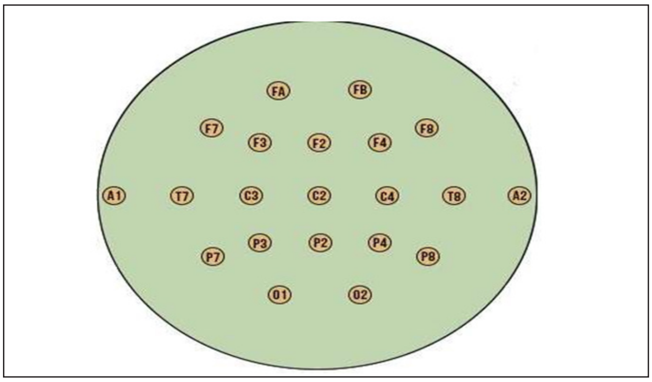

Figure 2.An IFCN-Adapted System for Placing 10-20 Electrodes for an EEG (The numbers correspond to the cerebral hemisphere (even for the right hemisphere and odd for the left), and the letter indicates the region of the brain where the electrode will be implanted (F-frontal, P-parietal, C-central, T-temporal, O-occipital)[9](Adapted from AIIMS Raebareli Hospital)

Activation Procedure

Regular EEG activation methods include hyperventilation, intermittent photic stimulation, reflex epilepsy triggers, natural sleep, and sleep deprivation. Muscle and movement artefacts are common in EEG recordings while awake. Notably, interictal epileptiform discharges (IEDs) were seen in around 40% of epilepsy patients during sleep EEG recordings, although the fact that they were absent in awake recordings.[10] Here are some common EEG activation procedures:

Hyperventilation

Hyperventilation (HV), often known as over-breathing, is a widely used EEG activation method in therapeutic contexts. During HV, the patient breathes deeply and quickly for about three minutes, changing blood gas levels and pH and triggering temporary changes in brain activity. HV is highly successful at inducing epileptiform discharges, particularly in absence epilepsy, which can result in absence seizures. Normal slowing of brain activity on the EEG is expected during HV; however, if this slowing continues after HV, it may indicate an abnormal reaction. Overall, HV is a simple, safe, and effective method for identifying interictal and ictal discharges.[11]

Intermittent Photic Stimulation

Intermittent Photic Stimulation (IPS) is a popular electroencephalography (EEG) technique for measuring photosensitivity in both children and adults. In this disease, the brain reacts improperly to flickering light, resulting in seizures. IPS is critical in routine video-EEG, particularly in the management of patients suspected of having epilepsy. The method involves exposing the patient to flashing lights at varying frequencies while evaluating brain activity with EEG. This method is especially useful for detecting abnormal brain responses, such as photoparoxysmal reactions, which are linked to certain types of epilepsy, including photosensitive epilepsy. IPS helps clinicians discover these abnormal sensitivities, allowing for a more accurate diagnosis and management of epilepsy in affected individuals.[12]

Sleep or Sleep Deprivation

Sleep EEG recording is recommended by the American Clinical Neurophysiology Society (ACNS) because it improves the detection of abnormal brain activity, particularly epileptic discharges. Sleep deprivation before an EEG examination can increase the chances of identifying these irregularities. Because certain types of seizures and disorders, such as parasomnias, are intimately related to the sleep-wake cycle, EEG can be used to detect sleep-associated abnormalities while sleeping.[13] According to a study, sleep EEG is crucial for diagnosing epilepsy when abnormalities do not appear in awake recordings.[14] Sleep EEG, like hyperventilation and photic stimulation, is a reliable and safe method of activating the brain. Specific sleep phases, particularly non-REM sleep, are extremely useful for detecting epileptiform activity, making sleep EEG an invaluable tool in epilepsy care. EEG recordings that include periods of wakefulness, sleepiness, and at least 40 minutes of sleep are the most reliable diagnostic tools.[15]

EEG Waveforms

EEG waveforms are classified based on frequency, amplitude, shape, and scalp position. Frequency, measured in Hertz (Hz), is the major indicator of whether rhythms are normal or abnormal. Alpha, beta, gamma, theta, and delta waves are frequent EEG frequencies, each representing a distinct brain state (Figure 3). Bandpass filtering is often used in clinical EEG to investigate waves ranging from 0.5 to 70 Hz. Furthermore, some waves are identifiable by their structure and dispersion, which contributes to the identification of neurological disorders. [6]

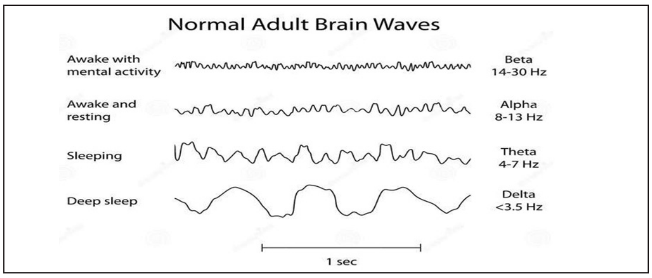

Figure 3.Normal EEG Wave Patterns (Delta waves in the range of 0.5–4 Hz during deep sleep, theta waves in the range of 4–7 Hz during drowsiness, alpha waves in the range of 8–12 Hz during relaxed wakefulness, and beta waves in the range of 13–30 Hz during mentally active periods)[16]

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The following are the various forms of EEG waves:

- **Delta (0.5–4 Hz):** Delta waves are the slowest brainwave frequencies, and they are most typically observed during deep sleep in the frontocentral areas of the head (Figure 4). They are required for adequate sleep, memory consolidation, and overall brain function. Delta waves can appear when awake, indicating possible localised brain injury caused by stroke or trauma, as well as illnesses such as extensive encephalopathy. Observing delta waves during EEG can aid in the diagnosis and assessment of neurological conditions, including specific patterns such as Frontal Intermittent Rhythmic Delta Activity (FIRDA) in adults and Occipital Intermittent Rhythmic Delta Activity (OIRDA) in children, which provide critical insights into the patient's neurological status.[17]
- **Theta (4–7 Hz):** Theta waves are brainwave patterns that appear during drowsiness, light sleep, and the first stages of non-REM sleep (N1 and N2) (Figure 5). They are often seen in the frontocentral regions. They play a vital role in memory processing, mood control, and the transition from waking to deeper sleep. The presence of focused theta activity in awake humans may indicate targeted brain injury or neurological diseases. Additionally, increased theta activity has been linked to emotional states like as anxiety.[18]
- **Alpha (8–12 Hz):** Alpha waves, notably the posterior dominant alpha rhythm, are frequently seen in awake EEG recordings from the occipital head area (Figure 6). This rhythm is a major component of regular background activity in adult EEGs and usually appears at the age of three, with a frequency of about 8 Hz lasting into the ninth decade of life.[19] The background alpha rhythm in healthy people varies rapidly. A significant decrease in alpha wave activity is frequently regarded as an indication of widespread brain damage or dysfunction, making alpha wave studies critical for detecting neurological disorders.[20]
- **Beta (12–30 Hz):** Beta waves are the most common brainwave patterns in both children and healthy adults, and they may be detected in the scalp's frontal and central areas (Figure 7). They have a frequency range of 12 to 30 Hz, an average amplitude of 10 to 20 microvolts, and rarely surpass 30. When a person is focused, concentrating, or performing cognitive tasks, beta activity is more noticeable. As sleep begins, beta waves may rise in amplitude during drowsiness and light sleep (N1), but drop during deeper sleep stages (N2 and N3).[20] Certain sedative medications, such as barbiturates, benzodiazepines, and chloral hydrate, can cause a rise in beta wave activity, suggesting their influence on the nervous system. Monitoring beta waves is important in clinical settings because it can provide information about a patient's alertness, cognitive function, and potential neurological diseases.[21]

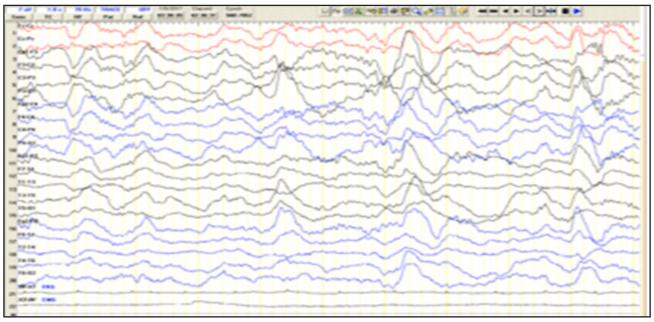

Figure 4.A 9-Year-Old Boy's EEG showing Typical Background Activity during Deep Sleep, with Noticeable Delta Wave Activity (Adapted from AIIMS Raebareli Hospital)

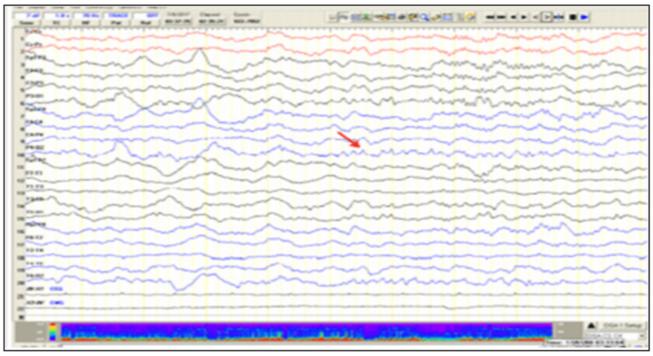

Figure 5.EEG of a 7-Year-Old Child showing Normal Background Activity during Sleep, Marked by Significant Theta Wave Activity (Adapted from AIIMS Raebareli Hospital)

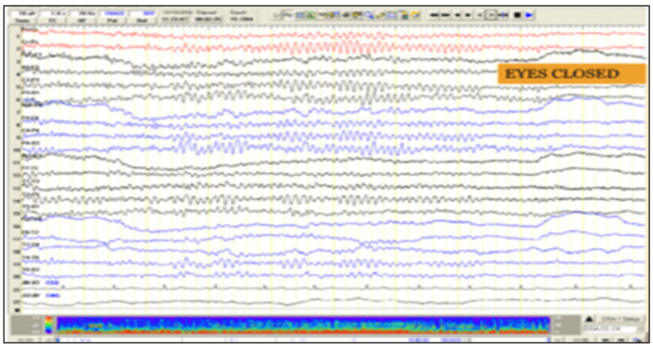

Figure 6.A 12-Year-Old Boy's EEG showing Typical Background Activity with His Eyes Closed, with a Noticeable 8–9 Hz Alpha Rhythm in the Occipital Area (Adapted from AIIMS Raebareli Hospital)

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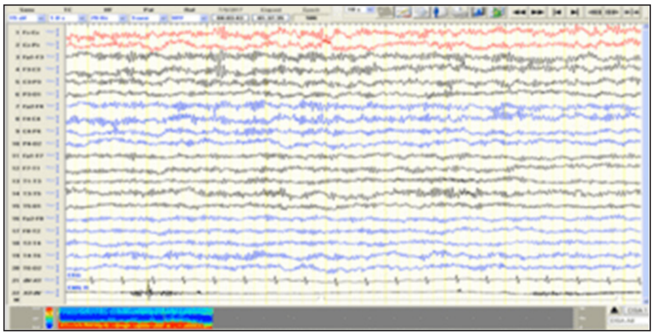

Figure 7.A 16-Year-Old Boy's EEG demonstrating Normal Background Activity with His Eyes Open, as well as Significant Beta Wave Activity, Indicating an Awake State and the Effects of Medication (Adapted from AIIMS Raebareli Hospital)

Normal EEG Variants

Patterns in an EEG that do not indicate any pathology are known as normal EEG variants, and they are believed to be a component of the brain's typical physiological functioning. Table 1 shows the notable variations in normal EEG.[22]

Table 1.Variations in Normal EEG

Normal EEG Wave Variant	Description
Mu rhythm	A variant of alpha rhythm over the sensorimotor cortex, often associated with movement
Rhythmic midline theta	Observed in a small percentage of individuals, usually seen in the central or parietal region
Rhythmic mid-temporal theta of drowsiness	Appears during drowsiness and can be unilateral or bilateral
Wicket rhythm	Observed in the mid-temporal regions, typically in bursts
Lambda waves	Triangular-shaped waves occurring in the occipital regions during visual scanning
Positive occipital sharp transients of sleep	Similar to lambda waves, seen in light sleep
K-complex	Biphasic frontal slow wave occurring in N2 sleep, often associated with sleep spindles
Posterior slow waves of youth	Delta and theta activity in relaxed wakefulness, often disappearing by age 21
Small sharp spikes	Brief spikes seen in normal EEGs, usually of little clinical significance
Cigánek rhythm	A rhythmic pattern in the alpha range observed in relaxed wakefulness
6 Hz Phantom spike-wave	A transient waveform that can be mistaken for epileptiform discharges
Subclinical Rhythmic Epileptiform Discharges of Adults (SREDA)	Benign discharges that can appear in adults without causing seizures
Slow-fused transients	Low-amplitude transients observed in relaxed states
Occipital spikes of blindness	Sharp waves from the occipital lobe in individuals who are blind
Temporal slowing of the elderly	Slower rhythms observed in older adults, considered normal

Abnormal EEG Waveforms

Epilepsy diagnosis is predicated on the detection of epileptiform discharges in interictal EEG recordings. An interictal epileptiform discharge is an abnormal, synchronised electrical discharge produced by a group of neurons around the epileptic focus. While standard 45-minute EEG recordings show moderate sensitivity to these discharges, they improve with longer and more frequent recordings.[23] According to research, the prevalence of interictal epileptiform discharges in children with new-onset seizures ranges from 18% to 56%, but in adults, it ranges from 12% to 50%.[24] This highlights the importance of long-term EEG monitoring in improving epilepsy diagnostic accuracy. PWE may experience the following pattern of interictal epileptiform discharges:

a) Spike and Wave: Brief spikes followed by a slower wave component characterise spike and wave patterns, which are frequently seen in different seizure types (Figure 8).

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Usually lasting 20 to 70 milliseconds, the spikes show up as abrupt EEG deflections and are frequently linked to the quick depolarisation of cortical neurons. Every spike is followed by a wave, which serves to bring the membrane potential back towards the baseline and is often mediated by GABA-b currents. This combination produces a rhythmic pattern that is critical for determining the presence of seizures and for the diagnosis of generalised epilepsy.

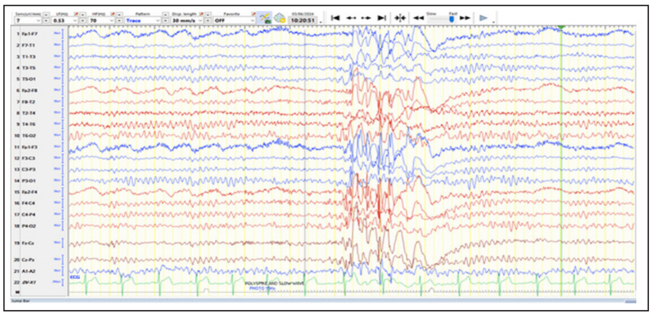

Figure 8.EEG of a 22-Year-Old Female showing an Atypical Background with Broad Spike-and-Wave Activity

b) Sharp Waves: Sharp waves are a type of epileptiform discharge that is frequently associated with neuropathological disorders. These discharges typically last between 70 and 200 milliseconds and have a particular shape, including a strong peak. A sharp wave's rising phase is typically steeper than the descending phase, giving it a distinct appearance. The dominant component of the sharp wave is frequently negative in polarity, and it may be followed by a sluggish wave with the same polarity. Sharp waves are common in focal epilepsy and other neurological conditions, where they help locate and localise epileptic foci. Despite amplitude fluctuations, epileptiform transients are easily distinguished from normal background activity by their unusual shape and duration.[25]

c) Rhythmic Delta (Slowing) Activity (RDA): Rhythmic Delta Activity (RDA) is a pattern of rhythmic, sometimes monomorphic delta waves that is commonly seen in certain clinical circumstances such as brain tumours, metabolic abnormalities, and focal brain trauma. Delta waves have a low frequency and are rhythmic, ranging from 0.5 to 4 Hz. The name "monomorphic" alludes to their homogeneous and consistent look, which distinguishes RDA from other types of delta activity. The existence of RDA frequently indicates underlying neurological disorders, providing vital clues about brain dysfunction and the scope of degenerative processes occurring within the brain.

Complications

While EEG is generally a safe and non-invasive procedure, there are some potential side effects. Electrodes can cause minor discomfort or skin irritation when placed on the scalp, and in rare cases, persons may develop allergic reactions to the glue or gel used to secure the electrodes. The procedure can be irritating or uncomfortable at times due to the length of the recording or the need to remain still. Furthermore, EEG recordings may result in false positives or negatives, complicating the diagnosis. Though uncommon, there is a small risk of causing a seizure, especially during certain treatments like hyperventilation or photic stimulation.[26] In contrast, invasive EEG monitoring, which entails the surgical implantation of electrodes on the brain's surface or deep within the brain tissue, carries more risks, including infection, bleeding, and neurological damage. These risks are weighed against the advantages of gathering highly accurate, localised data in circumstances where non-invasive EEG is insufficient for diagnosis.[27]

Nurses' Role in EEG Monitoring

Nurses play a significant role in EEG procedures by ensuring patient comfort, safety, and proper data collection. Understanding the foundations of EEG is crucial for nursing workers who want to provide the best possible care to patients before and after the treatment. Here's a detailed account of the nurse's involvement in EEG monitoring[28,29]:

Educating Patients

Patient education is a critical first step in the EEG process. Nurses clearly explain the aim of the EEG, how long it will take, and what the patient can expect during the process. They explain how to use electrodes, potential feelings, and probable discomfort, which helps to alleviate fear and create trust with the patient. Educating patients about the significance of remaining calm and avoiding specific medications or activities in advance can improve the quality of the EEG recording.

Preparing the Patients

A successful EEG requires adequate preparation. Nurses ensure that the patient's scalp is clean and dry, with no hair products, oils, or dirt that could interfere with electrode adhesion. They could also help the patient wash their hair or appropriately prepare the region with alcohol or a skin abrasive. Proper scalp preparation is extremely important in acquiring appropriate readings and minimising artefacts to guarantee that undistorted electrical impulses are sent from the brain.

Electrode Placement

Nurses usually work together with EEG technicians in putting electrodes on the scalp of patients using the International 10-20 system, a standard procedure to ensure consistency and reliability. Nurses are also very crucial in holding the electrodes tightly to avoid displacement and any other possible artefacts so that an optimal signal is ensured. They can also help replace electrodes while conducting longer studies or those already displaced by the patient.

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Comfort and Monitoring of Patients

Patient comfort is the most important consideration in EEG, and nurses monitor the patient throughout this procedure. Most patients become anxious when undergoing long-term EEG monitoring and especially invasive procedures. The nurses reassure them, attend to any discomfort, and even ensure that the surroundings remain quiet and peaceful, which is helpful for obtaining valid test results.[29] Monitoring will include the monitoring of the client's vital signs, hence responding immediately to needs.

Patient Safety

Safety is critical during EEG operations, especially when activation methods like hyperventilation, photic stimulation, or sleep deprivation are used. Nurses are trained to identify and manage potential adverse effects like seizures or respiratory difficulties. They take appropriate precautions, such as keeping seizure rescue drugs on hand and making sure the environment is safe in case the patient suffers a seizure during the study. Nurses also monitor patients for issues caused by prolonged immobility or unfavourable reactions to drugs.

Documentation

Accurate and accurate documentation is essential for providing excellent patient care. Nurses record essential information before, during, and after the EEG, including patient complaints, unusual behaviour, and clinical events such as seizures. This information is shared with the healthcare team to ensure proper clinical interpretation of the EEG data. Proper documentation helps to identify potential problems and informs any necessary follow-up treatment.

Following Procedure Care

After the EEG, nurses assist patients in removing electrodes and cleaning their scalps before giving them post-procedure instructions. Patients may have leftover gel or paste on their scalps, which nurses help to remove while ensuring their comfort before leaving. Nurses also offer guidance on any subsequent measures, such as medication changes or additional diagnostic tests. Patients are encouraged to report any unexpected symptoms, and nurses address any issues that arise after surgery, ensuring comprehensive post-surgical care.

Future Opportunities in EEG Education for Nurses

With advances in neurological care, the role of nurses involved in EEG monitoring will grow. Nurses can be trained and certified to interpret basic EEG data and manage patients in a variety of settings, including intensive care units. They can also undertake remote real-time EEG monitoring using telemedicine technologies, which will make patient treatment more flexible. AI and machine learning are increasingly being used in conjunction with EEG analysis. This means that nurses will be involved in AI-assisted interpretation, and problematic patterns will be spotted more correctly over time. In the multidisciplinary teams entrusted with providing medical care, nurses who specialise in EEG will work closer than ever with neurologists to improve the outcomes of patients. Continuous EEG (cEEG) monitoring is becoming more widespread in critical care, demanding advanced nursing training to detect subtle EEG abnormalities and manage neurological emergencies. Nurses can also conduct EEG-related research to improve treatment processes and patient outcomes, putting them at the forefront of neurodiagnostic advancement.

Conclusion

This review highlights the essential role that EEG education plays in advancing patient care and outcomes for neurology. With the rapid development of EEG technology and its applications, patients require highly competent and expert nurses to ensure safe and effective EEG monitoring. Such a study underscores that further training and certification programmes could empower nurses to better manage patients, interpret simple traces of EEG, and engage in multidisciplinary collaboration.

Conflict of Interest: None

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