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Review Article

"Insights into SEEG: The Crucial Contribution of EEG Technicians in Neurological Monitoring and Diagnosis"

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Abstract

Stereoelectroencephalography (SEEG) is a pivotal surgical diagnostic technique, safely guiding preoperative decision-making in both adult and pediatric populations with medically refractory epilepsy. This review underscores SEEG's critical role in therapeutic interventions, particularly for patients considering brain surgery to control seizures. SEEG's superiority, attributed to lower risk, reduced discomfort, and shorter operating periods compared to alternative invasive diagnostic methods, makes it the recommended choice. Technical aspects, such as electrode placement and recording parameters, are explored, with a specific focus on the indispensable role of EEG technicians in ensuring reliable data acquisition.The unique nature of SEEG lies in its ability to provide precise data, facilitating more accurate surgical procedures and subsequently enhancing patients' quality of life and seizure control. Outcomes associated with SEEG underscore its significance in furnishing neurosurgeons with essential data for informed decision-making, leading to improved surgical results. This evaluation accentuates SEEG's positive impact on patient care, elucidating how the technique contributes to enhanced seizure management and overall quality of life.In conclusion, a comprehensive understanding of the SEEG procedure, encompassing its benefits, risks, and the pivotal contribution of EEG technicians in neuroscience, is imperative for advancing surgical patient care and optimizing outcomes. This study aims to elucidate the key components of SEEG, emphasizing its pivotal role in evolving epilepsy therapy and underscoring the necessity of collaborative efforts with skilled EEG technicians to achieve effective patient outcomes.

KEY WORDS: Stereoelectroencephalography; epilepsy; depth electrode, EEG, ILAE, ASET

Introduction

Epilepsy is one of the most frequent neurological conditions of the brain, affecting around 50 million people globally, with 90% of sufferers coming from poor nations. It is a worldwide condition that affects people of all ages. Some of the causes of epilepsy include genetic factors, brain infection, stroke, tumour, and high temperature[1]. Each year, around 125,000 new instances of epilepsy are diagnosed; 30% of these patients are under the age of 18 at the time of diagnosis. In India, the prevalence is 3-11/1000 and the incidence is 0.2-0.6/1000[2]. Neural network hypersynchrony and neuronal hyperexcitability are the characteristics of seizure production. Disproportions between excitatory and inhibitory neurotransmitters are the mechanisms behind epilepsy. Seizures caused by epilepsy may include tremors, disorientation, trouble reacting, and loss of consciousness; additional sensory problems, such as vision, may also be present. The location and symptoms of a seizure are used to categorise them[3]. Epilepsy is treated with benzodiazepines, barbiturates, and ion channel modulators. Typically, one antiepileptic medication should be used to begin treatment. The term "drug-resistant epilepsy" (DRE) refers to the condition where two sufficient trials of antiepileptic medications that are carefully selected and administered fail. Drug resistance affects roughly 30% of epilepsy sufferers[4]. Patients with epilepsy are evaluated for surgical candidature using a variety of noninvasive and invasive diagnostic approaches. The best kind of epilepsy surgery for each patient is determined primarily by seizure location. The specific position of the seizure focus can be determined with the use of intracranial electroencephalography (EEG), which is necessary in between 30 and 40 percent of patients with medically refractory epilepsy[5]. Stereoelectroencephalography (SEEG) is becoming more and more common, thus this article will address it as well as the crucial role that EEG technicians play in ensuring a successful surgical outcome.

History

Innovations in medical technology and a deeper comprehension of the human brain have fueled a remarkable journey in the history of invasive electroencephalography (EEG). Intracranial electroencephalography, or invasive EEG, is a type of EEG in which electrodes are implanted directly into or within the brain to record electrical activity. In the 1950s, the SEEG technique was first developed in France by neurosurgeon Jean Talairach and neurophysician Jean Bancaud. The evolution of the stereotactic approach was facilitated by advancements in neuroradiology imaging during the 1970s[6]. Prominent researchers like Wilder Penfield used depth electrodes for brain mapping and epilepsy imaging. Temporal lobectomy was supported by invasive EEG in the 1950s and 60s, which helped treat epilepsy. Subdural grids and strips enhanced brain coverage and were introduced in the 1980s and 1990s. A sophisticated technique known as stereoelectroencephalography (SEEG) was created in the 1990s7. Constant advancements in technology have made invasive EEG techniques increasingly accurate and successful in treating neurological disorders.

Figure 1: "In the image, an EEG technician is seen asking questions while performing stimulation and SEEG procedures, actively engaging with the patient to monitor responses and ensure a thorough and accurate neurophysiological assessment." (Permission from Manjari et al., 2023).

Overview

A specific neurosurgical technique called stereoelectroencephalography (SEEG) is utilised to properly identify and map the brain's epileptogenic zones. Through the use of stereotactic guidance, intracerebral electrodes are inserted during this invasive technique, which enables targeted investigation of deep brain regions. The primary objective of SEEG is to gather and examine electrical activity to identify the origin of seizures and facilitate surgical decision-making[8]. A.K. Shah and S. Mittal recommend intracranial monitoring for a more precise assessment of epilepsy when non-invasive testing is ambiguous. This is crucial in cases like localised seizures that do not spread laterally, lateralized seizures that are not localised, or seizures that have neither lateralized nor localised characteristics. Additionally, when the site of seizures defies other information, when there is a need to clarify the relationship between the onset of seizures and functional tissue or lesions, and when epileptic seizures are clinically suspected but not yet explained by VEEG, intracranial monitoring is advised[8]. Intracranial monitoring offers crucial information in these challenging diagnostic situations to enable accurate diagnosis and well-informed therapy choices. Standard frame-based, frameless, and robot-assisted equipment are among the tools used in SEEG monitoring. The majority of institutions use a robot-assisted stereotactic system in conjunction with a traditional frame-based method, which produces extremely high levels of safety and precision. Typically, frame-based approaches follow a three-step process. The initial stage in this medical process is for the patient to have small bone markers inserted[9]. These markers function as guidelines for the next steps. Subsequently, the physicians use computed tomography (CT), magnetic resonance imaging (MRI), and occasionally angiograms to decide where to insert electrodes deep within the brain. They basically draw out a thorough plan, akin to a route map. In order to perform the third stage, the patient must first have a specific frame attached to their head for stability, and then their skull must be slightly opened. The planned procedure is strictly followed when implanting the electrodes[7]. It's like following an exact map to make sure you're accurate. Crucially, every step of the procedure is customised for every patient according on the outcomes of non-invasive testing. In order to meet each patient's unique needs, the number of electrodes and their precise positions are adjusted, guaranteeing the most efficient and individualised treatment for their medical condition. An average patient undergoing this treatment may have up to 10 leads, each with around 12 contacts spaced approximately 2 mm apart, resulting in a potential recording space of about 100. Every lead is flexible, with a diameter of around 1 mm, and comes with a firm stylet that may be removed after insertion. Following intracranial electrode implantation, a routine postoperative head computed tomography is carried out to ensure that the electrodes were positioned correctly and to check for hematomas[7]. After being admitted to the hospital, the patient is kept under constant electroencephalogram (EEG) observation in an epilepsy monitoring unit (EMU). During this time, antiepileptic medications are gradually tapered off to induce seizures and record 4-5 seizures. An epileptologist frequently checks medication and makes necessary adjustments[8,10]. Following SEEG placement, the typical length of stay in the EMU ranges from three to twenty-eight days. Sometimes it takes several bouts to confidently identify the seizure focal or foci. Once sufficient data has been obtained, a personalised treatment plan can be developed[5].

Interpretation of SEEG recordings

Technicians that perform electroencephalograms (EEGs) are essential to the collection and tracking of stereoelectroencephalography (SEEG) data. Although neurologists or epileptologists are usually in charge of interpreting SEEG data, EEG technicians must be well-versed in the following areas of SEEG procedures: Giving a proper anatomical definition of the "epileptogenic zone," or the parts of the brain primarily responsible for the genesis of seizures, is the main objective of the interpretation[11]. Alternative definitions of the epileptogenic zone and the "seizure onset zone" (SOZ) have been provided by schools in North America.

Analysis of background

The basis for interpretation is a thorough comprehension of the brain regions that the electrodes are investigating. Bipolar montages, which capture electrical activity from two neighbouring contacts, referencial montages, and more selective montages must be used preferentially throughout analyses. For the purpose of researching inter-ictal spike topography, a monopolar montage may be helpful. Actually, it's critical to identify the distinct typical EEG patterns that each region may exhibit. It is well known that the amygdala exhibits low amplitude activity whereas the hippocampal region produces high amplitude activity. There are often distinguishable features to these unique constructions[12]. When assessing the importance of slow waves and other observed actions, it is imperative to bear this in mind. Grey matter generates different activity from white matter, and the baseline physiological activity in primary motor cortex is substantially different from that observed in mesial temporal regions, among other differences. Examining the state of alertness, including sleep stages, is very important because it may significantly affect the SEEG signals[13].

Irritative zone

The "irritative zone" (IZ)—the existence of spontaneous spike or spike wave activity—must be assessed for each electrode. This general term "IZ" encompasses a great deal of information because it is important to consider the shape, prevalence, changes over the course of the recording time, and proximity to the lesional zone of various interictal abnormalities[14].

Epileptogenic Zone: Examination of Seizures' Beginning

This is the most important step in the interpreting process. The geographic range and dynamic of the seizure onset pattern (SOP) must be considered in seizure onset analysis.Although many SOP may be revealed in SEEG recordings, low voltage fast discharges (LFD) are typically included in them.Before LFD, there may be changes in the EEG in the form of slow-wave complexes, trains of spikes, or pre-ictal spikes[13]. LFD involves a range of frequencies, from higher ones (gamma range, 30–100 Hz, often identified in neocortical seizures) to lower beta/gamma ranges (15–30 Hz), which are used in mesial temporal seizures, among other conditions[15]. A further important factor is spatial extension. Lower frequency patterns than the traditional LFD onset can sometimes trigger seizures; in fact, slower alpha and theta frequencies or patterns with spike waves can register in the EZ during the commencement of a seizure. There may be additional information regarding the location of the EZ if localised post-ictal suppression is present[16].

Electrical stimulation

SEEG electrical stimulation is a dynamic and instructive method that goes beyond brain function mapping. It actively aids in the identification of important regions, enhances surgical planning, and advances our understanding of the complicated network associated to epilepsy, all of which eventually assist to improve patient outcomes[17]. The questions provided by EEG specialists to patients during electrical stimulation in SEEG serve a variety of important functions, including crucial localization and functional information.

Here's how these questions help with overall comprehension:

1. Functional Area Localization: By asking questions concerning sensory perceptions, motor motions, or language function during stimulation, EEG professionals can identify specific functioning areas of the brain.

For example, asking the patient to explain any sensations or movements they have when a specific section of the brain is stimulated can aid in the mapping of sensory or motor cortex.

2. Identification of the Eloquent Cortex: It is possible to identify eloquent cortical areas engaged in language function or higher cognitive processes by asking patients about language-related experiences or cognitive responses.

For example, during stimulation, asking the patient to name objects or recall certain memories can help with language centre localization.

3. Memory Mapping: Understanding the role that different brain regions play in memory formation and retrieval is made easier by asking questions concerning memory recall under stimulation.

For example, during stimulation, asking the patient to recall particular facts or experiences helps map the areas of the brain associated with memory.

4. Real-Time Functional Mapping : Asking the patient questions continuously during stimulation makes it possible to observe their responses in real time, which aids in the process of functional mapping.

One way to gain dynamic insights into functional brain regions is to ask the patient to explain any changes in sensation, perception, or cognition while stimulation occurs.

However, in many epilepsies, activation of a single site is insufficient to elicit the alteration in network conditions necessary for seizure production18, so the absence of a stimulation-induced seizure has minimal prognostic importance.It is also important to remember that stimulation of contacts that are not in close proximity to the EZ can also trigger seizures (a process known as indirect stimulation).

Thus, that explains why Brain regions, electrode configurations, EEG patterns, and the variables affecting EEG data must all be thoroughly understood by an EEG technician. This information is essential for precise interpretation, recognising irritative and epileptogenic zones, and offering practical guidance for clinical diagnosis and treatment planning in patients with epilepsy.

Benefits of SEEG

The principal benefits are a reduced risk of infection, quicker recovery times, improved patient comfort, accurate monitoring of bilateral or large brain regions, and a minimally intrusive technique. Remarkably, after enough data collection, SEEG electrodes can be easily taken off at the patient's bedside, enabling patients to schedule further therapy operations whenever it suits them. With its comprehensive insights into brain activity and patient-centered approach, SEEG is a preferred option in some clinical situations because to these benefits[9,19].

Complications

Stereoencephalography (SEEG) has inherent risks even though it is generally considered safe for monitoring and diagnosis. There are differences in the criteria of complications and study methods, which results in reported rates of issues ranging from 0% to 26.3%[20]. Despite this variability, haemorrhage or hematomas are the most frequent outcome, with infections coming in second, but at lesser rates in the majority of studies. It has been discovered that morbidity associated with SEEG monitoring ranges from 0% to 7.5%, with hemorrhagic or infectious disorders accounting for the majority of cases[20]. Although they are rare, persistent neurological issues have been reported in a small number of individuals. When death is discovered, intracerebral hematoma is nearly always the cause[21].

There are several reasons why SEEG operations can become complicated. According to reports, patients who have had prior craniotomies, have more electrode implantation, and are under continuous monitoring are more likely to experience issues.

In the event that problems arise, other surgical procedures can be needed. Hemostoma evacuation, early electrode removal, and infection-control washing procedures are a few examples of this. Patients' medical histories and unique risk factors must be carefully reviewed before deciding to have SEEG, and both patients and healthcare professionals must be aware of the possible risks associated with the procedure[22].

Role of EEG Technician

The role of an EEG technician is crucial in influencing the outcomes and treatment of patients under observation, which may have an effect on the rates of morbidity. Patients with epilepsy who receive SEEG monitoring receive extremely individualised care, which includes comprehensive physical examinations, individualised drug management strategies, and a thorough review of their medical and seizure histories. Within the controlled atmosphere of the Epilepsy Monitoring Unit (EMU), patients are closely watched. This is sometimes done with the direct supervision of a carer or family member, or with the use of technologies such as cameras in their rooms for visualisation. This tailored approach is crucial for agitated and paediatric patients in particular, highlighting the technician's responsibility to address various patient needs[23].

Furthermore, technicians are responsible for being vigilant and proactive in order to detect any negative events or potential problems that may arise during SEEG monitoring. This entails closely monitoring for any indications of pain, nausea or vomiting, haemorrhage, infection, or potential electrode dislodgement. In addition to these urgent concerns, technicians are aware that there could be other negative outcomes, such as deep vein thrombosis, falls, and a pulmonary embolus due to the patient's immobility. Clinical monitoring protocols encompass comprehensive examinations, neurological evaluations, wound care, pain management, vital sign monitoring, preservation of patent IV access, implementation of seizure prevention strategies, and meticulous inspections to guarantee the ongoing integrity of monitoring apparatus[22]. The technician has a multifaceted role that extends beyond technical expertise to include a caring and sympathetic approach that is tailored to each SEEG patient's specific needs. Technicians perform an important role as frontline advocates for patient well-being in an ever-changing healthcare environment, ensuring the procedure's effectiveness while emphasising the security and comfort of patients getting SEEG monitoring.

Electrode displacement is a persistent risk for patients getting monitoring for stereoencephalography (SEEG), as electrode insertion is a multistep operation with bleeding risks after each step. It is impossible to unintentionally pull out and then replace electrodes. In order to lower the risk of electrode dislodgment, thorough wound evaluations are crucial. Additionally, measures should be taken to secure electrodes to lower the likelihood of patient error in removing them. Keeping the patient's room clutter-free, ensuring that the external EEG connections are long enough to prevent strain, and enclosing the electrodes in the head covering without hanging loops are some specific safety precautions[9].

EEG technicians are vital to patient education because they emphasise the importance of avoiding pulling on electrodes, scrubbing the skin, or removing the head covering. Instruction of patients and their families is necessary to lower the chance of electrode dislodgment following surgery. Only competent personnel—typically EEG technicians with nursing assistance—should perform wound redressing as necessary in order to ensure adequate treatment and minimise the risk of complications[8].

Patients with epilepsy and their families are thought to require ongoing education from the interdisciplinary team. Acute care EEG technicians possess a unique skill set that significantly improves the quality of care given, especially to those who monitor and care for patients with epilepsy. Their involvement has been shown to enhance patients' overall quality of life, compliance, and awareness. Specialised EEG technicians with extra training in neurology bring a higher level of expertise and experience to the table, enhancing the quality of care and offering patients with epilepsy individualised teaching. This collaborative and educational approach emphasises the interdisciplinary efforts to enhance patient outcomes and well-being in the context of SEEG monitoring[24].

Summary

In conclusion, compared to medical therapy alone, stereoelectroencephalography (SEEG) is anticipated to be 75% to 88% more cost-effective, providing patients with medically resistant seizures with more advanced therapeutic alternatives. Personalised surgical techniques are made possible by SEEG, which significantly lowers the frequency and intensity of seizures. Surgical procedures including resection and neuromodulation device implantation show extraordinary effectiveness, giving two-thirds of patients total seizure independence and significant reductions for others. In addition to improving patient quality of life, these therapies help lower rates of morbidity and mortality. EEG technicians must be registered EEG technologists (certified by ABRET R.EEG.T.) and have a strong understanding of SEEG. Their knowledge and careful attention to detail during SEEG monitoring are vital in averting complications and unfavourable events that affect morbidity and length of stay and, in the end, enhance patient satisfaction and results.

AI statement to the manuscript

During the preparation of this work, I, Sachin, used ChatGPT for paragraph writing to improve the content's quality and coherency. ChatGPT helped to generate ideas, refine language, and ensure clear expression. After using this tool, I thoroughly checked and modified the content to ensure that it was consistent with the publication's aims. As the author, I accept full responsibility for the authenticity and integrity of the information provided herein.

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