Perspective of Neuroimaging-Based on Epilepsy Monitoring Technology

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Abstract. Epilepsy is a long-standing illness defined by short episodes of aberrant brain activity caused by abrupt cell discharges. The illness is not communicable and might linger for a long period. Epilepsy affects roughly 50 million individuals worldwide, making it a prevalent neurological illness. Epilepsy monitoring is the most significant element of epilepsy diagnosis and also plays an important role in diagnosing the origin of epilepsy, assessing prognosis, and directing therapy. This paper details the principles and basic algorithmic models of commonly used neuroimaging techniques and describes the role of different monitoring techniques in the diagnosis and treatment of epilepsy. The paper compares the advantages and disadvantages of different monitoring techniques in their application and explores a comprehensive and less restrictive epilepsy monitoring protocol for readers and relevant researchers. Currently, electroencephalography (EEG) is the most common technique for monitoring epilepsy, and its most basic algorithmic models are independent component analysis (ICA) and discrete wavelet analysis (DWA), which are used for aspects such as noise removal and feature extraction. This article is dedicated to helping the reader or relevant researcher to gain a more comprehensive and systematic understanding of current neuroimaging techniques and medical devices. Furthermore, it seeks to forecast future research directions based on current difficulties in the area. The purpose of this study is to give a useful reference for future research in the field of epilepsy monitoring.

Keywords. EEG, Intracranial electroencephalogram (iEEG), Magnetic resonance imaging (MRI), Computed tomography (CT), Positron Emission Tomography (PET)

1. Introduction

Epilepsy is a common neurological disorder that afflicts many people around the world[1]. Epilepsy can cause physical convulsions, mental interruptions, and loss of consciousness, leading to distress and disruption in daily life[2]. The exact cause of onset is often unknown, with potential causes including genetic factors, brain injury, infections, metabolic abnormalities, and adverse drug reactions[3]. Monitoring is important due to the irregularity of seizures.

Many neuroimaging techniques are now being used in the diagnosis and treatment of epilepsy. EEG can extract EEG signals from seizures using algorithms such as ICA and DWA to provide an objective reference for the assessment of epilepsy[4]. However, its spatial resolution is too low and its use is limited. iEEG is more accurate than EEG in detecting high-frequency brain activity by using the autoregressive model and has a higher spatial resolution than EEG[5]. iEEG is generally used for short-term acute signal

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recording during the resection of epileptic lesions[6]. It can further identify the epileptogenic focus and guide the extent of surgical resection [7]. However, iEEG is invasive and may be affected by factors such as anesthesia[8]. MRI and CT are structural imaging techniques that both use resolved reconstruction and iterative reconstruction algorithms to clearly show the structure of the brain [9]. However, neither MRI nor CT can detect electrical signals during a seizure. Therefore, they are often used in conjunction with EEG to determine the exact location of seizures. PET techniques are based on the maximum likelihood expectation maximization (MLEM) algorithm and allow observation of human metabolism and physiology. PET has high sensitivity and spatial resolution and can detect functional epileptic foci that are undetectable on MRI and CT. A closed-loop neurostimulator, an implantable chip based on a proportional-integral-derivative control (PID) algorithm, is currently being investigated to capture the first signs of seizures and suppress seizures[10]. Implantation of such a chip holds promise as it can significantly reduce the damage of craniotomy compared to conventional epileptic focal resection[10]. Epilepsy monitoring techniques can help doctors track seizures, including frequency, duration, type, and severity, to understand a patient's condition and plan treatment[11]. This technology can also reduce seizures, ease pain, and improve the quality of life for people with epilepsy.

The purpose of this paper is to explore the application of neuroimaging techniques and medical devices in the field of epilepsy in order to improve the quality and efficiency of medical care. The Introduction section begins by introducing the background and purpose of this paper, presenting the research questions, and outlining the methodology and framework of this paper. The related work section begins by describing the origins of the invention of EEG and outlines its far-reaching impact in the field of brain science. This is followed by a detailed description of the principles of the different neuroimaging techniques and their application in epilepsy monitoring. The Discussion section provides a detailed comparison of the role and limitations of different epilepsy monitoring techniques, both in principle and in practice, and explores a comprehensive and less restrictive approach to epilepsy monitoring. Finally, the Conclusion section will summarize the currently available epilepsy monitoring techniques and discuss possible future research directions and applications.

2. Related works

2.1. Berger's EEG: a revolutionary discovery

Hans Berger (1873-1941) was a notable German psychiatrist and physiologist who discovered the human electroencephalogram (EEG) in 1924[12]. This breakthrough in clinical neurology allowed for the non-invasive recording of the brain's electrical activity, which has greatly contributed to our understanding of brain function[13]. Berger's development of the EEG provided a significant leap in neuroscience by allowing direct monitoring of brain activity without intrusive procedures[12]. This breakthrough established the groundwork for several research exploring brain electrical patterns and their relationship to cognitive processes, resulting in significant advances in our knowledge of brain function as well as the diagnosis and treatment of neurological illnesses. The neurological community regards Berger's finding as "one of the most surprising, noteworthy, and crucial developments in the history of clinical neurology"[14]. Berger's seminal work in neuroscience continues to have an impact and
shows the value of scientific curiosity and devotion in furthering our understanding of the human brain.

2.2. EEG in epilepsy monitoring

BCI technology currently plays a significant role in neurological disease monitoring. EEG is the most common type of non-invasive BCI technology, which usually measures electrical signals in the cerebral cortex by placing electrodes on the scalp. The EEG principle is based on the transmission and distribution of electrical currents generated by neuronal discharges in the scalp and brain tissue and uses a series of electronic instruments (electroencephalographs, electrode caps, etc.) to amplify and record this spontaneous bioelectrical signal[15]. The EEG signal contains waves of multiple frequencies, such as alpha, beta, and delta waves, which exhibit different temporal and frequency characteristics in different brain regions and states[16]. EEG signal analysis requires preprocessing and signal processing, such as noise removal, filtering, and spectral analysis, to extract information about the EEG activity.

The most important algorithmic models used in EEG signal processing are ICA and DWT. These algorithmic models can be used for noise removal and feature extraction. The basic idea of ICA is to find a set of orthogonal projection matrices so that the projected signals are independent of each other, usually using optimization algorithms such as gradient descent or Newton iteration. DWT is a multi-resolution analysis technique that decomposes a signal into different frequency sub-bands, each with a different time and frequency resolution[17]. The basic formula for DWT is as follows:

\[ w_{j,k} = \sum_{n=0}^{N-1} x_n \psi_{j,k}(n) \]  

Where \( w_{j,k} \) is the k-th wavelet coefficient of the j-th layer, \( x_n \) is the original signal and \( \psi_{j,k} \) is the wavelet function. Here \( j \) denotes scale and \( k \) denotes translation. The basic idea of DWT is to decompose the signal into sub-bands of different frequencies, and then perform further processing such as noise removal and feature extraction for each sub-band[17]. This method can extract important features from the signal while retaining the original signal information[17]. In conclusion, ICA and DWT play an important role in EEG signal processing.

EEG assumes a crucial role in the diagnosis and monitoring of epilepsy[4]. It can detect scattered slow waves, spikes, or irregular spikes emanating from the epileptogenic focus of the brain during seizures, guiding preoperative diagnosis and surgical removal of the epileptogenic focus[4]. These days, EEG is frequently used in conjunction with video recording, a process known as video electroencephalography (VEEG). VEEG is appropriate for patients with epilepsy who require long-term monitoring. During a VEEG test, the patient wears an EEG electrode cap, which records the patient's EEG signal and is combined with a video recording of the patient's behavior and symptoms during a seizure. VEEG provides more accurate information about seizures, and physicians can combine the patient's behavior and EEG signal to more quickly determine the type and origin of the seizure and assess the effectiveness of treatment[18].

2.3. iEEG in epilepsy monitoring

iEEG is an invasive brain monitoring technique in which electrodes are surgically placed...
directly on the surface of the brain or inside brain structures to record electrical activity[5]. In comparison to ordinary EEG, iEEG data are high-dimensional, time-series data with a high spatial and temporal resolution that need time-series analysis to explore their dynamics. An autoregressive model is a time series model that predicts future values based on the time series' previous values. The algorithmic formula for the autoregressive AR model:

\[ y_t = \sum_{i=1}^{n} a_i y_{t-i} + e_t \]  

where \( y_t \) represents the observed value at the present time, \( a_i \) represents the autoregressive coefficient, \( n \) represents the autoregressive order, and \( e_t \) represents the random error term. The autoregressive AR model can be used to iEEG data to characterize the dynamics of the signal. This model can be used, for instance, to investigate the degree of information transmission and network connection across different brain areas.

Researchers may use iEEG to capture electrical activity directly in the brains of persons suffering from epilepsy, offering a more precise and complete picture of the location and type of seizures[6]. This approach is especially beneficial when non-invasive imaging techniques do not give sufficient information to establish an accurate diagnosis[8]. Despite its invasive nature, iEEG remains a valuable tool for studying electrical activity in the brain and improving our understanding of brain dysfunction[7].

2.4. CT in epilepsy monitoring

CT is a type of medical imaging that creates three-dimensional pictures of the inside of the body using X-rays or other types of radiation[19]. A huge number of slices are produced during a CT scan by spinning an array of X-ray beams and sensors around the body[19]. These slices are then combined using computer algorithms to create three-dimensional pictures[19]. This technique provides more accurate diagnostic information than conventional X-rays and can detect smaller bodily abnormalities[20]. The most important algorithm in CT technology is the CT image reconstruction algorithm, which refers to the process of mathematically restoring the internal structure and density distribution of the scanned object based on the projection data acquired by the CT scanner. Analytical reconstruction and iterative reconstruction are the two basic categories into which CT image reconstruction methods fall.

The filtered back-projection (FBP) algorithm is the most widely used algorithm in the analytical reconstruction approach, which works by back-projecting the projection data into the picture space after filtering it by a Fourier transform or another filter[21]. It considers it an integral transformation issue and presumes a linear relationship between the projected data and the picture[21]. The formula for the filtered back-projection (FBP) method is:

\[ f(x, y) = \frac{1}{2\pi} \int_0^{2\pi} g(x \cos \theta + y \sin \theta, \theta) |\omega| e^{-j\omega(x \cos \theta + y \sin \theta)} d\omega d\theta \]  

\( f(x,y) \) is the reconstructed image, \( g(s,\theta) \) is the projection data, \( \omega \) is the spatial frequency and \( \theta \) is the projection angle. Compared with other algorithms, the FBP algorithm has the advantages of fast computational speed, high image quality, and easy implementation.
The most commonly used algorithm in iterative reconstruction is the MLEM method. The basic idea of the MLEM algorithm is to reconstruct an image from projected data through the theory of maximum likelihood estimation and expectation maximization\[22\]. It assumes a model that relates the image to the projection data and treats it as a statistical problem that is solved optimally by an iterative algorithm. The formula for the MLEM method is:

\[
f^{(k+1)} = f^{(k)} \sum_{i=1}^{N} \frac{p_i A_i}{\sum_{i=1}^{N} A_i^T A_i}
\]

(4)

\(f^{(k)}\) is the image of the k-th iteration, \(p_i\) is the projection value of the i-th ray, \(A_i\) is the coefficient vector corresponding to the i-th ray and N is the total number of rays. The advantage of the MLEM algorithm is that it can handle problems such as noise and artefacts, and the quality of the reconstructed image is relatively high.

CT is widely used for epilepsy lesion detection and localization, pathological analysis, and treatment monitoring[9]. CT can diagnose the cause and type of lesions effectively, and improve the accuracy of diagnosis and treatment of various diseases such as cancer, stroke, and traumatic brain injury. Real-time observation of brain activity using CT can provide important supporting information for the treatment and management of epilepsy[9]. Computer algorithms play a vital role in reconstructing images from CT scans, allowing clinicians to visualize and analyze complex data sets in three dimensions.

2.5. MRI in epilepsy monitoring

MRI is a non-invasive imaging technique that uses the principles of nuclear magnetic resonance (NMR)[23]. This technique applies a gradient magnetic field to the body in order to detect the energy released in various structural contexts. The gradient magnetic field then catches the electromagnetic signals released and, depending on the signal’s intensity, determines the location and type of tissue cell nuclei[23]. The most important algorithms for MRI include adaptive control and pulse sequences. Adaptive control algorithms allow real-time control of pulse sequences to adjust the quality and speed of MRI imaging to suit different scanning needs. Pulse sequence algorithms in MRI include excitation pulses, echo pulses, and gradient pulses. The excitation pulse is used to excite the nuclei in the sample and is given by:

\[
B_1(t) = B_1 \cos(\omega_0 t)
\]

(5)

\(B_1(t)\) represents the magnetic field strength of the excitation pulse at time t, \(\omega_0\) represents the rotational angular frequency of the excitation pulse and \(B_1\) represents the magnetic field strength of the excitation pulse. The echo pulse is used to record the NMR signal and is given by:

\[
S(t) = M_0 \cdot e^{-\frac{t}{T_1}} \cdot \cos(\omega_0 t + \varphi)
\]

(6)

\(S(t)\) denotes the NMR signal recorded at time t, \(M_0\) denotes the static magnetic moment in the sample, \(T_1\) denotes the spontaneous out-of-phase time, \(\omega_0\) denotes the
rotational angular frequency of the NMR and $\varphi$ denotes the initial phase. The gradient pulse is then used to encode position information in space, and is given by:

$$G(x) = G_{\text{max}} \cdot \frac{x}{\text{FOV}}$$  \hspace{1cm} (7)

$G(x)$ denotes the gradient magnetic field strength at position $x$, $G_{\text{max}}$ denotes the maximum magnetic field strength of the gradient pulse and FOV denotes the scan range. These equations are used to describe the pulse sequence algorithm in MRI, which can be adjusted by adjusting the parameters to achieve an adjustment of the MRI image. Together, these algorithms form the basis of MRI technology, enabling high-quality imaging and accurate diagnosis of MRI images.

MRI can be used to diagnose localized brain damage or other structural abnormalities in patients with epilepsy[9]. MRI can detect abnormalities such as atrophy, cysts, and inflammation of brain structures or abnormal structures such as malformations and tumors in the brain’s blood vessels[9]. In addition to detecting structural brain abnormalities, MRI techniques can also be used to assess functional brain abnormalities in patients with epilepsy. For example, functional magnetic resonance imaging (fMRI) utilizes strong magnetic fields and radio waves to measure changes in the blood oxygen level-dependent (BOLD) signals in the brain[24]. By detecting BOLD signal changes, fMRI enables the assessment of the level of brain activity in epileptic patients during various cognitive, sensory, emotional, and language tasks. The application of fMRI in epileptic patients can provide valuable insights into the pathological mechanisms of epilepsy, leading to a better understanding of the underlying neural processes involved in this neurological disorder[24].

2.6. PET in epilepsy monitoring

Positron Emission Tomography (PET) is a non-invasive medical imaging procedure that monitors physiological changes in the body by using radioisotope-labeled bioactive molecules (glucose, neurotransmitters, etc.) to identify changes in metabolism[25]. The concept behind PET imaging involves the emission of positrons from radioisotopes, which upon encountering electrons in the body, undergo annihilation and generate two photons traveling in opposite directions[25].

In PET techniques, the MLEM algorithm or the OSEM (Ordered Subset Expectation Maximisation) algorithm is commonly used to process data generated by positron annihilation. The MLEM algorithm, which has been described above, is based on a probabilistic model that assumes that the positron emission and annihilation processes are random and optimizes the image according to the statistical principle of maximum likelihood[22]. The OSEM algorithm is an improved algorithm based on the MLEM algorithm that speeds up convergence and improves image quality by partitioning the reconstructed image into subsets. The OSEM algorithm divides the data set into subsets, performs one MLEM operation on each subset, and then updates the reconstructed image by weighting the results of all subsets and repeating the execution several times until convergence[26]. The formula for the OSEM algorithm is as follows:
\[
X_{k+1} = \frac{1}{N} \sum_{i=1}^{N} y_i x_k + \sum_{j=1}^{M} a_{ij} x_k(j)
\]

(8)

\(x_k\) is the reconstructed image of the kth iteration, \(y_i\) is the projection data corresponding to the i-th detector, and \(a_{ij}\) is the sensitivity of the i-th detector at the j-th pixel. The OSEM method, which can be used in a variety of medical imaging modalities, is more effective and accurate than the MLEM algorithm and can significantly increase imaging quality and speed[26].

PET imaging has high sensitivity, it enables the observation of metabolism and physiological functions in the human body at a biomolecular level. PET observes brain metabolism and neuronal activity in patients with epilepsy by labeling metabolic and functional molecules[9]. Typically, the radiolabelled glucose analog 18F-fluorodeoxyglucose (18F-FDG) is injected into the patient and PET scans measure the amount of 18F-FDG metabolized in the brain region, thus reflecting the neuronal activity in that area, as well as showing areas of abnormal metabolism in the epileptic part of the brain[27]. In addition, PET can be used to study the effects of epilepsy medication. For example, if the metabolic rate at the epileptic site decreases after treatment, this indicates that the drug treatment is working well.

2.7. Closed-Loop neurostimulator for personalized epilepsy treatment

The closed-loop neurostimulator is one of the most popular epilepsy monitoring technologies in recent years. It is based on the closed-loop concept of the brain-machine interface and allows for simultaneous neurophysiological diagnosis and neuroelectrical stimulation therapy[10]. The technology consists of several components, including an intracranially implanted pulse generator, multi-contact electrodes (both cortical and deep brain electrodes), a wireless charging kit, and a patient programmer.

In a closed-loop neurostimulator, a PID control algorithm is applied to regulate the output of the neurostimulation current[28]. The algorithm automatically adjusts the output intensity and duration of the stimulation current by measuring the feedback signal of neuronal activity and the desired neurostimulation effect in order to achieve the optimal stimulation effect[28]. The equation for the PID control algorithm is shown below:

\[
u(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{d}{dt} e(t)
\]

(9)

\(u(t)\) is the controller output, \(e(t)\) is the current error, \(K_p, K_i, \) and \(K_d\) are the coefficients of proportional, integral, and differential control respectively, \(t\) is the time and \(\tau\) is the variable of integration. The equation represents the PID control algorithm that adjusts the current error in three ways: proportional, integral, and differential control to achieve the desired control effect[28]. To smooth out the stimulation response, differential control is used to modify the rate at which the stimulation current changes, while integral control is used to rectify the system's steady-state error. Proportional control is used to modify the amplitude of the stimulation current. By using the PID control algorithm, the closed-loop neurostimulator and, subsequently, neurostimulation treatment, may both be made more successful.
Numerous studies have now demonstrated that closed-loop neurostimulators can decrease the frequency and length of seizures[10]. In detail, it records the onset of a seizure and suppresses it by precisely stimulating the patient's brain while continually monitoring the electrical activity of the brain[10]. The closed-loop neurostimulator also allows for adjustment and customizes care. To get the greatest treatment outcomes, patients can modify the stimulator's settings in accordance with their needs and their doctor's recommendations. Additionally, the closed-loop neurostimulator may be modified in real-time in response to alterations in the environment and the patient's physiological condition, improving the efficacy and security of the treatment[10].

3. Discussion

Epilepsy usually requires multiple medical treatments for monitoring and treatment. The advantages and disadvantages of commonly used neuroimaging techniques (EEG, VEEG, iEEG, MRI, CT, PET) and closed-loop neurostimulators in epilepsy monitoring will be compared in detail here.

EEG is a straightforward, non-invasive, and cost-effective neuroimaging technique capable of detecting the electrophysiological signals of epileptic discharges[13]. EEG avoids the use of radiation or chemicals, making it a remarkably safe approach. However, EEG also presents certain drawbacks. For one, the EEG signal can be influenced by muscle movement, electromagnetic interference, and voltage drift, necessitating proper signal processing and analysis. Moreover, EEG primarily offers insight into surface brain activity, lacking the ability to provide in-depth information on brain structure due to its limited spatial resolution.

Contrastingly, VEEG and iEEG offer a higher spatial resolution, enabling more precise epileptic focus localization. VEEG, unlike traditional EEG monitoring, incorporates behavioral, movement, and emotional video recordings alongside EEG data, aiding physicians in diagnosis[18]. VEEG monitoring can be conducted under varying conditions and times, facilitating the comparison of data to track condition changes. iEEG records electrical activity from specific brain regions, delivering detailed functional analyses. Additionally, iEEG yields high spatial and temporal resolution, capturing subtle EEG signal variations[7]. However, both techniques face challenges. VEEG necessitates extended monitoring, incurring potential environmental and subjective factor interference. iEEG involves a craniotomy, increasing infection risk. Consequently, VEEG and iEEG may not be suitable for all epilepsy patients.

MRI offers high resolution and contrast for epilepsy diagnosis and localization, presenting clear brain structures and tissues. By selecting distinct sequences and parameters, MRI detects various abnormal signals, such as gray matter, white matter, and vascular abnormalities, making it vital for epilepsy etiology[9]. Although MRI identifies structural brain abnormalities due to epilepsy, it cannot directly detect seizures. Additionally, MRI requires costly equipment and lengthy scanning times, limiting its clinical application. Conversely, CT imaging is rapid, cost-effective, and suitable for emergencies. In epilepsy monitoring, CT detects lesions such as hemorrhages or tumors. However, CT has lower resolution compared to MRI, potentially overlooking minor lesions. Furthermore, CT X-rays cause radiation exposure, requiring careful dose control. Neither MRI nor CT can detect epileptic discharge electrophysiological signals, so they are typically combined with EEG or VEEG for precise seizure localization.

Unlike CT and MRI, PET examines local metabolic states at the molecular level.
PET can locate lesions and generate three-dimensional images for quantitative analysis, enabling early diagnosis when epilepsy's initial stages exhibit no morphological abnormalities, and MRI and CT examinations are inconclusive[9]. Moreover, a PET whole-body scan involves significantly less radiation than a traditional single-region CT, ensuring a safe and reliable procedure.

Closed-loop neurostimulators present several advantages for epilepsy monitoring. First, these devices enable real-time monitoring of patients' brain biological signals, rendering treatment more precise and effective compared to traditional open-loop neurostimulators[10]. Second, closed-loop neurostimulators facilitate neurostimulation during early seizure stages, mitigating subsequent seizures and reducing patient discomfort and adverse reactions[10]. However, closed-loop neurostimulators necessitate surgical implantation, incurring surgical risks and costs. Additionally, uncertainties persist, such as stimulation accuracy and the impact on healthy neurons. The long-term stability and safety of closed-loop neurostimulators require further clinical studies and practical validation. Although still experimental, this technology demonstrates considerable potential for application.

In this paper, we propose a multimodal integration scheme for epilepsy monitoring (see Figure 1), taking into account the advantages and disadvantages of various techniques. Initially, EEG is used for preliminary screening of the lesion in epileptic patients, combined with VEEG to monitor the patient's behavior and neural activity patterns, capturing seizure signals in real-time and enabling precise localization. If the spatial resolution of the EEG is insufficient to support further diagnosis, MRI and CT scans provide detailed information about the lesion's anatomy. Furthermore, PET scans reveal local metabolic information, offering additional insights into the lesion's localization. In cases where conventional methods struggle to localize the lesion, iEEG can deliver a more in-depth perspective, allowing clinicians to pinpoint the epileptogenic focus accurately. After sufficient information on the epileptogenic focus has been obtained, the need for stereotactic surgery is assessed. Lastly, a closed-loop neurostimulator is incorporated into individualized treatment, monitoring the patient's EEG activity in real-time and automatically adjusting stimulation parameters as needed. This multimodal integrated approach harnesses the full potential of various neuroimaging technologies, ensuring comprehensive monitoring and effective intervention for epilepsy patients.

Figure 1. Flow diagram of the multimodal integration scheme

4. Conclusion

This article reviews the currently available epilepsy monitoring techniques, including EEG, VEEG, iEEG, MRI, CT, PET, and closed-loop neurostimulators. Each technique
has its pros and cons, yet all contribute valuable information for epilepsy monitoring, aiding clinicians in diagnosing and treating patients.

The multimodal integration scheme proposed at the end of this paper utilizes the advantages of different monitoring techniques and can provide comprehensive screening and treatment for patients with different conditions of epilepsy. In the future, as technology and research advance, epilepsy monitoring techniques will become more accurate and convenient. For example, with the popularity of the Internet and artificial intelligence, EEG monitoring can be improved in efficiency and accuracy through remote transmission and automated analysis. Meanwhile, with the development of single-cell and multimodal imaging techniques, MRI and CT techniques will become more refined and comprehensive. In addition, closed-loop neurostimulators based on neuroplasticity may become a more personalized and effective treatment.

Overall, the development of epilepsy monitoring technology will lead to improved treatment outcomes and quality of life for epilepsy patients. However, we must protect patient privacy and data security to ensure safe and reliable technology applications. The progress of these technologies requires increased research and cooperation in related fields, continuous improvement, and innovation to cope with a complex disease like epilepsy. The application of these technologies will offer hope and opportunities for epilepsy patients to enjoy a healthier life.

References
