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Application of different electroencephalograms in the diagnosis of neurological diseases

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Abstract:

This research will explore the differences between three different types of electroencephalogram (EEG), conventional EEG, dynamic EEG, and video EEG, as well as the advantages and disadvantages of each. This research will explore the application of three different types of EEG in these different neurological diseases. This research will analyze the symptoms, causes, and causes of epilepsy, Parkinson's disease, central nervous system infection, and other diseases. This research also used bioinformatics methods to evaluate the diagnostic results of different types of EEG. In the diagnosis and treatment of epilepsy, long-term detection of dynamic EEG can have a more accurate clinical diagnosis rate. In the diagnosis and treatment of central nervous system infection, video EEG can record and playback the patient's onset behavior. Higher timeliness and accuracy can also reduce misdiagnosis and missed diagnosis to a certain extent; in the diagnosis and treatment of Parkinson's disease, through EEG monitoring, the diagnosis and treatment effects of early patients can be improved.

Keywords: Electroencephalogram; epilepsy; Parkinson's disease; Central nervous system infection.

1. Introduction

Most mental illnesses, as well as neurological disorders, can be diagnosed through electroencephalogram (EEG) [1]. Mental illness refers to diseases with varying degrees of impairment in cognitive, emotional, volitional, and behavioral mental activities caused by brain dysfunction under the influence of various biological, psychological, and social-environmental factors, such as schizophrenia and other psychotic disorders. The scope of neurological diseases is relatively wide, including cerebrovascular diseases, neuroimmune diseases, central nervous system infections, and movement disorders [2]. These include schizophrenia and other psychotic disorders, epilepsy, Alzheimer's disease, and Parkinson's disease. Mental and neurological diseases that cause abnormal changes in brain waves during the onset of the disease can all be diagnosed through electroencephalography. When the nerve cells in the human brain are active, there will be rhythmic potential changes, and the nerve cells will spontaneously generate electricity. This phenomenon is brain waves. Currently, patients are tested clinically through electroencephalography. The electrode pads are pasted on the patient's head and connected to the wires. After being processed by the instrument, the electric waves are displayed through the computer, and the relevant waveform can be seen. This is Brainwaves.

EEG is a technique for measuring and recording the brain's electrical activity by placing multiple electrodes on the scalp to capture the electrical signals from the brain's neurons. Since first being used by scientists in the early 20th century, EEG has become an indispensable tool in neuroscience research and clinical diagnosis. EEG plays an increasingly important role in the diagnosis and management of mental illness, providing a non-invasive and relatively economical way to monitor changes in brain activity. By analyzing various parameters of brain waves in detail, such as frequency, amplitude, phase, and distribution patterns, doctors and researchers can identify EEG characteristics associated with specific mental illnesses, thereby aiding diagnosis, monitoring disease progression, and evaluating treatment effectiveness.

In terms of treatment monitoring, EEG provides a means of assessing the effectiveness of medication or psychotherapy. By comparing brain wave changes before and after treatment, doctors can determine whether the treatment has caused the expected changes in brain function and adjust the treatment plan to achieve the best results. For example, antidepressant drug treatment usually causes changes in specific brain wave frequency bands. These

changes can be monitored through EEG, allowing doctors to understand whether the drug treatment is effective, which can further help with subsequent diagnosis and treatment.

The application of EEG in the diagnosis of mental illnesses extends beyond traditional methods of brainwave analysis. With the advancement of computational technology, more sophisticated analysis techniques have been applied to EEG data, such as quantitative electroencephalography (qEEG), EEG connectivity analysis, and machine learning algorithms. These techniques provide deeper insights into brain function and structure, thereby enhancing the accuracy and efficiency of diagnosing mental disorders. Moreover, not only are analysis techniques being innovated, but clinical applications of EEG technologies beyond conventional EEG are also continually evolving, such as ambulatory EEG (AEEG) and video-EEG (VEEG).

Ambulatory EEG (AEEG) is a method of monitoring brain activity over a long period (typically 24 hours or more), allowing doctors to observe patients‘ brain activity during normal daily activities. This method is particularly suited for capturing intermittent or irregular brain activity abnormalities, such as epileptic seizures. In the field of mental health, AEEG can help identify EEG patterns related to sleep disorders and monitor the impact of certain medications on brain activity, providing support for diagnosis and treatment. Video-EEG (VEEG) combines EEG recording with synchronized video monitoring, enabling doctors to observe both the patient‘s behavior and brain activity simultaneously. This is particularly valuable for studying epilepsy and other neurological disorders, as it can help doctors identify the correlation between specific behavioral manifestations (such as seizures) and EEG patterns. In mental health, VEEG is especially useful for diagnosing conditions closely related to behavioral presentations, such as certain sleep disorders, non-epileptic seizures, and abnormal behaviors caused by mental illnesses. In the diagnosis and treatment of mental illnesses, AEEG and VEEG offer a means to deeply understand the complex relationship between brain function and behavior. For instance, they can be used to assess the impact of medication treatment on brain activity, especially when adjusting medication regimes. For challenging diagnoses, these technologies help differentiate mental illnesses from other neurological disorders, such as epilepsy, ensuring that patients receive the most appropriate treatment.

EEG plays a crucial role in the diagnosis of mental illnesses. It not only provides direct observations of brain electrical activity but also reveals deeper neurobiological information through advanced analysis techniques. With continuous technological advancements and deeper research, EEG‘s application in the field of mental health will become even broader and more precise in the future. The main purpose of this article is to explore the application of three different EEGs in the diagnosis of mental diseases and central nervous system infections. Taking epilepsy, Parkinson‘s, and central nervous system infections as examples, this research analyzes three different types of electroencephalograms. The advantages and disadvantages of EEG in terms of diagnostic accuracy, misdiagnosis rate, missed diagnosis rate, and clinical application for doctors and patients.

2. Application of EEG in neurological diseases

2.1 Epilepsy

Epilepsy is a neurological disease with six categories, including immune, metabolic, hereditary, infectious, structural, and unexplained [3]. Its etiology is complex and changeable, and the pathogenesis has not yet been fully elucidated clinically. Epilepsy is both primary and secondary. Currently known causes of secondary epilepsy include disorders of cortical development, brain tumors, head trauma, central nervous system infections, cerebrovascular disease, parasitic infections, inherited metabolic diseases, neurodegenerative diseases, and secondary brain disorder. Before an epileptic seizure occurs, some patients will have a suspicion of an impending seizure hours or even days in advance. These suspicions may include abnormal limb sensations and changes in taste, smell, and hearing. Epilepsy has various forms of seizures and different clinical manifestations. They can be distinguished according to the clinical seizure conditions. A generalized seizure is a grand mal seizure disorder, which is characterized by loss of consciousness and generalized convulsions, confusion, yelling, and fainting. Lying on the ground, with a blue complexion, eyes turned up, clenching teeth, biting lips and tongue, and foaming at the mouth. Some patients may experience incontinence or suffocation. Partial seizures, also known as Petit Mal, manifest sudden Loss of consciousness, muscle spasms or twitching, and word seizures lasting about 10 seconds. Simple partial seizures, manifested by stiffness, spasm, or abnormal sensation in local or one limb [4]. After the seizure, the patient may experience temporary paralysis, but Usually, the time is short, and the consciousness is clear during the process. During an epileptic seizure, six types of abnormal brain waves, also known as epileptiform discharge, will appear, namely spike waves, sharp waves, spike-slow complex waves, polyspike waves, sharp-slow complex waves, and polyspike-slow complex waves [5].

2.2 Central nervous system infection

The central nervous system is divided into two parts: the brain and the spinal cord. Infections of the central nervous system have many causes and may include infections caused by bacteria, viruses, fungi or parasites, chlamydia, and mycoplasma [6]. Central nervous system infections generally include encephalitis and meningitis, which are common in children with low immunity, especially children with imperfectly developed blood-brain barrier. For children with imperfectly developed blood-brain barrier, infection at any site may cause blood to act as a medium to invade the brain, thereby causing infection of the central nervous system. Common central nervous system infectious diseases include bacterial diseases, viral diseases, and spongiform encephalopathy. Generally, symptoms of central nervous system infection include fever, abdominal pain, and limb abnormalities. After the virus invades the central nervous system, it may cause the body temperature regulation center to malfunction, easily leading to fever symptoms. It may also cause discomfort in the digestive system. This abdominal pain, bloating, diarrhea, and other uncomfortable symptoms may occur. If the infection affects the vestibular, it may cause abnormal behavior, sensory impairment, mobility impairment, etc. In addition, symptoms such as nausea and vomiting may also occur. In clinical diagnosis and treatment, the electroencephalogram of patients with central nervous system infection can detect destructive changes in brain tissue, thereby helping the attending physician discover the parts of the brain damaged by the infection, find calcification, and also troubleshoot other problems in the brain at the same time. It is helpful for doctors‘ diagnoses.

2.3 Parkinson’s disease

Parkinson‘s disease, also known as palsy shaking, is a degenerative disease of the nervous system that is common in the elderly. It is rare in people under the age of 50. The average age of the disease is about 60 years old. As age increases, the number of sick people has increased significantly, and the incidence rate among men is slightly higher than that among women. At this stage, research believes that the onset of Parkinson‘s disease is related to the degeneration and death of nigral dopaminergic neurons. However, the cause of the degeneration and death of nigral dopaminergic neurons has not been determined. Genetic factors, environmental factors, and aging of the nervous system are all factors. It is the main subject of suspicion. The symptoms of Parkinson‘s disease vary from person to person. Significant early symptoms include resting tremors, bradykinesia, and myotonia [7]. In the middle and late stages, patients will have postural balance disorder and even some non-motor symptoms, such as sensory impairment and autonomic nervous system dysfunction. For patients with early-stage Parkinson‘s disease, most patients are treated with medication, usually anticholinergic drugs, amantadine, and compound levodopa. For patients with mid-to-late-stage disease, surgical methods mainly include neuronal destruction and brain surgery. Parkinson‘s disease is still incurable so far. Most patients in the early stage can maintain a good quality of life and lead a normal life after treatment. Patients in the late stage may suffer from general stiffness and difficulty in moving. The electroencephalogram of Parkinson‘s patients shows that the rhythm is slowed down and the 0 wave activity is enhanced. During sleep, a slow rhythm appears at the top of the forehead, and a few patients have small sharp waves or slow spike waves.

3. Application of EEG in the diagnosis of clinical psychiatric disorders

In the contemporary field of clinical medicine, EEG technology plays a crucial role in the diagnosis and treatment of various neurological diseases due to its unique advantages. This technique provides doctors with a non-invasive, dynamic, and cost-effective diagnostic method by recording changes in brain electrical activity. Particularly in the diagnosis of psychiatric and cerebrovascular diseases, the application of EEG has greatly enriched doctors‘ understanding of disease mechanisms and guided the formulation of treatment plans. Therefore, this article will comprehensively review the application and value of EEG technology in clinical settings, relying on the use of AEEG in epilepsy diagnosis and lesion localization, digital VEEG in the diagnosis of central nervous system diseases, and EEG in the diagnosis of Parkinson‘s disease.

3.1 Application of AEEG in the diagnosis and lesion localization of epilepsy patients

Conventional EEG is widely used in the diagnosis and treatment of epilepsy. However, due to the episodic nature of epilepsy and the requirement for patients to remain awake during conventional EEG monitoring, there is a risk of misdiagnosis or missed diagnosis. AEEG, on the other hand, offers the advantages of dynamic monitoring and being non-invasive. AEEG allows for significantly longer monitoring times and superior diagnostic efficacy compared to conventional EEG.

In addition, skull magnetic resonance imaging (skull MRI) is an important imaging tool in the diagnosis and treatment of epilepsy. By collecting data on the patient‘s brain structure using the magnetic resonance imaging system and further reconstructing and analyzing the collected brain structure at the scanner workstation, the patient‘s brain structure abnormalities can be observed for diagno-

sis and treatment.

Research has shown that whether in diagnosing pediatric epilepsy with psychiatric disorders, analyzing the efficacy, or in the results analysis of lesion localization in patients, the diagnostic and localization value of AEEG is superior to the traditional skull MRI method [8]. This indicates that in terms of diagnostic value, the lower detection rate of MRI may be due to the subtle lesions in some children, the current limitations of MRI technology, or the fact that some children do not show morphological abnormalities in the brain structure but only functional and metabolic changes. AEEG, however, can accurately reflect the abnormal discharges in children through long-term recording of brainwaves, and it does not rely on changes in the brain‘s morphological structure for diagnosis, thus achieving a more accurate diagnosis rate. In terms of lesion localization value, AEEG has the advantages of large storage capacity and replayability, which can accurately provide a basis for the analysis of epileptiform discharge timing [9].

3.2 Application of digital VEEG in the diagnosis of central nervous system diseases

Infections of the central nervous system refer to acute or chronic inflammatory diseases caused by various biological pathogens such as viruses, bacteria, spirochetes, and mycoplasma that invade the central nervous system‘s substance, membranes, and blood vessels. These infections can manifest in various disease forms, such as meningitis, encephalitis, cerebral edema, and myelitis, and have been on the rise in recent years. Therefore, prevention and early diagnosis of neural system infections are crucial. The common diagnostic methods for central nervous system diseases primarily involve cerebrospinal fluid cytology (CSFC). However, due to the specificity of cerebrospinal fluid cytology findings in central nervous system infections and the difficulty in detecting pathogens, along with long testing times, there are high rates of misdiagnosis and missed diagnosis, and diagnoses are not timely.

The advent of digital VEEG has become another powerful method for monitoring and diagnosing central nervous system diseases. VEEG involves long-term video monitoring of patient behavior and diagnosing by combining abnormal behaviors observed during seizures with EEG data. Its major advantage is that VEEG can synchronously record the EEG waveforms with the patient‘s seizure behavior during the monitoring process, compared to traditional EEG monitoring. It also features playback functionality, which significantly enhances its timeliness and greatly reduces the rates of misdiagnosis and missed diagnosis. Unlike traditional long-duration recordings of over 24 hours, VEEG records all seizure behaviors. Since most seizure behaviors appear within 5 hours, VEEG monitoring can appropriately shorten the recording time, improving patient comfort during monitoring. It also helps distinguish false differences during monitoring by analyzing seizure behaviors, thereby increasing the positive rate [10].

3.3 Application of EEG in the diagnosis of Parkinson’s disease

Parkinson‘s disease is a common chronic neurodegenerative disorder. In the early stages of Parkinson‘s disease, due to the concealed nature of the condition, the initial symptoms are not easily noticed, and clinical symptoms often include indistinct symptoms such as bradykinesia, making early prevention and diagnosis of Parkinson‘s disease challenging. However, Parkinson‘s disease is often accompanied by several non-motor symptom precursors, such as cognitive impairment and sensory abnormalities. Research into these non-motor symptoms can enhance our understanding and prevention efforts for Parkinson‘s disease.

The current clinical diagnostic application of EEG is mainly to monitor the characteristics of the brain functional network in patients with Parkinson‘s disease mild cognitive impairment (PDMCI). PDMCI is a typical non-motor symptom precursor of Parkinson‘s disease. It is a precursor syndrome of neurodegenerative dementia with a high prevalence rate. EEG, reflecting the brain‘s physiological activities, is the most evident and direct expression of whether these activities are abnormal, containing rich band rhythm information. In patients with PDMCI, EEG can focus on differences in the efficiency density, average number of nodes, resting state signals, and other aspects of the brain‘s functional network connections compared to healthy individuals. Thus, it plays a helpful role in the early diagnosis and intervention of Parkinson‘s disease [11, 12], as shown in Fig. 1.

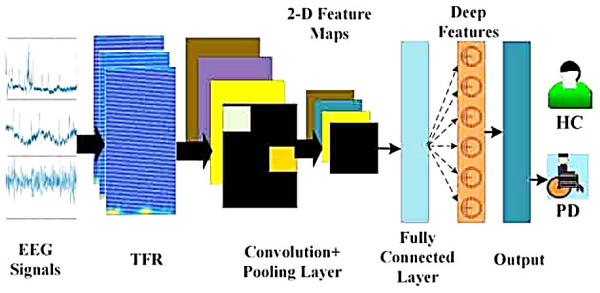

Fig. 1 Detection of Parkinson’s disease based on EEG signals [12].

4. Conclusion

Currently, neurological diseases are characterized by rapid onset, long latency periods, and difficulty in diagnosis. The advent of EEG has leveraged its inherent superiority in the fields of diagnosis and monitoring. By recording changes in brain electrical activity, EEG provides doctors with a non-invasive and easy-to-operate method for diagnosing and treating neurological diseases. In the diagnosis and treatment of epilepsy, compared to traditional cranial magnetic resonance imaging (MRI), ambulatory EEG offers more accurate diagnosis rates by monitoring patients‘ brain waves over an extended period. It identifies abnormal brain discharges without relying on changes in the patient‘s brain structure morphology. In treating central nervous system infections, VEEG enhances timeliness and accuracy over traditional EEG monitoring. Recording long-duration video captures patients‘ abnormal behaviors during seizures, allowing for replay and retrieval at specific onset times, combined with real-time brain electrical signals. For Parkinson‘s disease, EEG is primarily used to monitor the brain functional network characteristics of patients with Parkinson‘s disease-related cognitive impairments. By recording brain electrical signals and comparing parameters such as efficiency density and resting-state signals between patients with PDMCI and healthy individuals, EEG can improve early diagnosis and treatment outcomes for Parkinson‘s disease. In summary, EEG holds significant importance and immense clinical value in diagnosing and treating neurological diseases. With further development of EEG and future research, especially by incorporating findings from popular fields such as deep learning algorithms, the level of diagnosis and treatment for neurological diseases is expected to improve significantly.

Authors Contribution

All the authors contributed equally, and their names were listed alphabetically.

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