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ORIGINAL ARTICLE

Quantitative electroencephalography performance of different brain lobe epilepsy.

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Abstract

OBJECTIVE: To investigate the quantitative electroencephalography features of different brain lobe epilepsy.
METHODS: The electroencephalogram data of adult patients diagnosed with epilepsy in the epilepsy clinic of the Second Affiliated Hospital of Shandong First Medical University from January 1, 2012 to December 31, 2016 were collected, 58 cases in total. They included 28 cases of frontal lobe epilepsy,12 cases of temporal lobe epilepsy, 9 cases of occipital lobe epilepsy, and 9 cases of parietal lobe epilepsy. Quantitative electroencephalography analysis technique was used to obtain the δ, θ, α1, α2, β1 and β2 power spectrum value in patients with different brain lobe epilepsy. The δ, θ, α, and β relative power spectrum value are obtained by calculation. By comparing the quantitative electroencephalography indicators of the affected side and the healthy side, the quantitative electroencephalography characteristics of epilepsy in different lobes were obtained.
RESULTS: θ power spectrum can be increased in the discharge lead of temporal lobe epilepsy. δ and θ power spectrum, δ relative power spectrum can be increased in the discharge lead of occipital lobe epilepsy.
CONCLUSION: The increase in slow wave power spectrum in QEEG can serve as an auxiliary diagnosis for temporal lobe epilepsy and occipital lobe epilepsy.

INTRODUCTION

Epilepsy is a common neurological disease with a prevalence of about 8.83-12.23‰ (Wigglesworth *et al.* 2023). It is a group of chronic diseases and syndromes of sudden, transient, recurrent central nervous system dysfunction caused by abnormal over-discharge of brain neurons. It seriously affects the quality of life of patients and brings heavy mental stress and economic burden to families and society. Electroencephalography is the most important auxiliary examination for the diagnosis of epilepsy. The spike wave, sharp wave, spine slow complex wave, sharp slow complex wave and explosive high wave amplitude rhythm are regarded as abnormal discharge waveform. However, the positive rate of abnormal electroencephalogram discharge is low. To improve the positive rate of diagnosis, it is widely taken to prolong the time of electroencephalography

examination or employ provocative test. Practicability proved to be less sufficient nevertheless (Frazzini *et al.* 2022). With the development of quantitative electroencephalography analysis technology, electroencephalography graphic information can be converted into numerical information, which can more objectively reflect the patient's electroencephalography situation. Studies (Zelig *et al.* 2022) showed that epileptic discharge is related to slow-wave activity in the lesion area. The EEG power spectrum between frontal lobe epilepsy and temporal lobe epilepsy shows asymmetry. The background activity of brain electrical activity mapping in primary epilepsy patients is different from normal person. We intended to conduct quantitative electroencephalography frequency domain analysis of electroencephalography data from patients who have been diagnosed with epilepsy in the epilepsy clinic of the Second Affiliated Hospital of Shandong First Medical University from January 2012 to December 2016. It is expected that the value of electroencephalography can be improved in diagnosis of epilepsy.

The Ethics Committee of the Second Affiliated Hospital of Shandong First Medical University approved the study and we obtained informed consent from patients.

MATERIALS AND METHODS

Research object

From January 2012 to December 2016, in the adult patients diagnosed with epilepsy at the epilepsy clinic of the Second Affiliated Hospital of Shandong First Medical University, 28 cases of frontal lobe epilepsy, 12 cases of temporal lobe epilepsy, 9 cases of occipital lobe epilepsy, and 9 cases of parietal epilepsy were screened. The basic information of patients is shown in Table 1.

Diagnostic criteria

Inclusion criteria: 1) met the epilepsy diagnostic criteria of ILAE (Proposal for revised classification of epilepsies and epileptic syndromes, 1989). 2) AGE ≥18 years old 3) Patiens with the mapping of EEG

Exclusion criteria: 1) Those suffering from brain trauma, brain tumor, intracranial infection, multiple sclerosis, hydrocephalus, mental retardation, dementia and systemic diseases involving intracranial. 2) children with epilepsy younger than 18 years old. 3) Those who had long time drinking habit or had the history of mental drug abuse. Those who recently accepted the treatment of anti-anxiety drugs. 4.Those who couldn't finish the mapping of EEG.

All the selected cases were diagnosed by neurologists with more than 10 years of clinical experience in our epilepsy clinic.

Research methods

1. Main research tools: Japan Optoelectronic 9200k Digital Electroencephalograph

Japanese Photoelectric electroencephalography 9000 electroencephalography Analysis Software

2. Quantitative electroencephalography Power Spectrum Analysis

In all cases, cylindrical electrode (Min *et al.* 2022) were placed according to the international 10/20 standard system, the screen display rate was set at 10s/p, high frequency filtering was 0.53Hz, low frequency filtering was 60Hz (Wu *et al.* 2018), Voltage sensitivity was set at 10μv/mm, sampling rate was set at 1000Hz. 16 - lead unipolar lead tracing was used, tracing time in consciousness for each patient was not less than 15 minutes, and electrode impedance was less than 5 kΩ (Krishnan *et al.* 2020).

Doctors who had obtained ASEPA (Asian Epilepsy Academy) electroencephalograph qualification certificate selected awake electroencephalogram of interictal period without eye movement and other pseudo errors for 10 seconds, and performed frequency domain analysis (Zhang *et al.* 2022) to obtain δ, θ, α1, α2, β1 and β2 power values. According to the power value of each frequency band, the relative power value was calculated. Calculation method of relative power value: relative power value of a certain frequency band = power of a certain frequency band / sum of power of various frequency bands. The distinguishing criteria of electroencephalography frequency bands were δ frequency band (1.0 - 3.9), θ frequency band (4.0 - 7.9), α1 frequency band (8.0 - 10.0), α2 frequency band (10.1 - 13.9), β1 frequency band (14.0 - 19.9), β2 frequency band (20.0 - 30.0). Frontal lobe epilepsy was analyzed by prefrontal leads (Fp1, Fp2), frontal leads (F3, F4), temporal lobe epilepsy by middle temporal leads (T3, T4), posterior temporal leads (T5, T6), occipital lobe epilepsy by occipital leads (O1, O2), and parietal lobe epilepsy by top leads (P3, P4).

Tab. 1. Basic information of patients with different brain lobe epilepsy

type of epilepsy	male	female	age of onset	mean age of onset
frontal lobe epilepsy	17	11	18-84	35.68±16.76
temporal lobe epilepsy	7	5	21-59	42.58±12.40
occipital epilepsy	5	4	26-58	40.56±10.73
parietal epilepsy	7	2	22-65	40.33±14.67

Tab. 2. Comparison of quantitative electroencephalography indicators in frontal lobe epilepsy

	frontal pole lead			frontal lead		
	lesion side	**healthy side**	***p* value**	**lesion side**	**healthy side**	***p* value**
δ power spectrum	5.45±2.49	5.07±2.12	0.219	4.95±2.20	4.95±2.08	0.980
θ power spectrum	8.68±3.43	8.57±3.86	0.713	8.38±3.17	8.21±3.49	0.492
α1 power spectrum	5.20±1.95	5.08±2.11	0.375	5.45±2.10	5.35±2.28	0.487
α2 power spectrum	4.09±1.51	3.87±1.51	0.036	4.29±1.44	4.14±1.50	0.180
β1 power spectrum	3.27±0.75	3.03±0.80	0.011	3.25±0.64	3.17±0.63	0.172
β2 power spectrum	2.22±0.62	2.17±0.80	0.565	2.24±0.64	2.27±0.69	0.600
δ relative power spectrum	0.19±0.06	0.18±0.06	0.524	0.17±0.05	0.17±0.04	0.718
θ relative power spectrum	0.29±0.07	0.29±0.08	0.553	0.29±0.07	0.28±0.08	0.373
α relative power spectrum	0.32±0.07	0.32±0.07	0.718	0.34±0.07	0.34±0.07	0.669
β relative power spectrum	1.97±0.05	1.96±0.06	0.711	0.20±0.05	0.20±0.57	0.711

Statistical Methods

Statistical analysis software SPSS19.0 was used to process the data, and the results were expressed by the standard deviation of mean squares. The quantitative electroencephalogram indexes of different cerebral lobe epilepsy discharge sites were compared with those of the corresponding leads at the healthy side by K-S test to determine if the results conform to the normal distribution. The results which conform to the normal distribution will be compared with t-test. The test results showed that $p < 0.05$ was significantly different and had statistical significance.

RESULTS

1.Comparison of quantitative electroencephalography indicators in frontal lobe epilepsy

The quantitative electroencephalography analysis of the prefrontal leads (Fp1, Fp2) and frontal leads (F3, F4) showed the K-S test of α2 power spectrum ,α relative power spectrum, β1 power spectrum, β2 power spectrum in frontal pole lead and δ power spectrum in frontal leads does not fit the normal distribution. The other test results were not statistically significant ($p > 0.05$)as shown in Table 2. Frequency map of a patient with left frontal lobe epilepsy was shown in Figure 1.

2. Comparative results of quantitative electroencephalogram indicators for temporal lobe epilepsy

In quantitative electroencephalogram analysis results of middle temporal leads (T3, T4) and posterior temporal leads (T5, T6) in temporal lobe epilepsy, the K-S test of δ power spectrum of temporal leads, the δ power spectrum and the θ relative power spectrum of posterior temporal leads showed $p < 0.05$, it does not fit the normal distribution. The other results showed that the lesion side of θ and α1 power spectrum of temporal leads (T3, T4) and posterior temporal leads (T5, T6) were higher than the healthy side ($p < 0.05$).

Tab. 3. Comparison of quantitative electroencephalography indicators of temporal lobe epilepsy

	middle temporal			posterior temporal		
	lesion side	**healthy side**	***p* value**	**lesion side**	**healthy side**	***p* value**
δ power spectrum	6.41±3.82	3.68±1.53	0.033	5.13±2.75	3.40±1.94	0.044
θ power spectrum	6.67±1.96	4.07±1.74	0.000	6.27±2.80	3.73±1.68	0.002
α1 power spectrum	4.51±1.81	3.21±1.58	0.009	4.33±2.22	3.35±1.67	0.017
α2 power spectrum	3.86±1.57	2.93±1.63	0.031	3.55±1.62	3.25±1.99	0.499
β1 power spectrum	3.64±1.57	2.74±1.33	0.002	2.98±1.47	2.67±1.40	0.095
β2 power spectrum	2.44±0.96	1.99±0.82	0.109	2.05±0.75	1.74±0.63	0.046
δ relative power spectrum	0.23±0.11	0.21±0.06	0.245	0.22±0.10	0.19±0.06	0.245
θ relative power spectrum	0.24±0.05	0.22±0.05	0.089	0.25±0.06	0.21±0.04	0.005
α relative power spectrum	0.32±0.07	0.36±0.08	0.057	0.32±0.07	0.35±0.08	0.057
β relative power spectrum	0.22±0.05	0.25±0.04	0.007	0.22±0.07	0.25±0.05	0.118

Tab. 4. Comparison of quantitative electroencephalography indicators of occipital lobe epilepsy

	occipital lead		
	lesion side	**healthy side**	***p* value**
δ power spectrum	6.45±3.94	4.48±2.81	0.021
θ power spectrum	7.86±2.92	5.51±2.44	0.007
α1 power spectrum	6.45±3.49	5.52±2.94	0.134
α2 power spectrum	4.34±2.23	4.25±2.76	0.825
β1 power spectrum	3.42±0.75	3.26±0.92	0.638
β2 power spectrum	2.35±0.82	2.11±0.68	0.168
δ relative power spectrum	0.21±0.11	0.18±0.09	0.030
θ relative power spectrum	0.26±0.06	0.22±0.07	0.075
α relative power spectrum	0.34±0.11	0.38±0.11	0.072
β relative power spectrum	0.19±0.05	0.22±0.03	0.038

The lesion side of α2 and β1 power spectrum of middle temporal leads (T3, T4) were higher than the healthy side ($p < 0.05$), while the lesion side of β relative power spectrum was lower than the healthy side ($p < 0.05$). The β2 power spectrum of posterior temporal leads (T5, T6) were higher at the lesion side than healthy side ($p < 0.05$) as shown in table 3. Frequency map of a patient with left temporal lobe epilepsy was shown in Figure 2.

3. Occipital lobe epilepsy quantitative electroencephalography indicators comparison results

In the quantitative electroencephalogram analysis results of occipital leads (O1, O2) of occipital lobe epilepsy, the K-S test of α1, α2, β1 power spectrum of occipital leads (O1, O2) showed $p < 0.05$, it did not fit the normal distribution. The other results showed that δ power spectrum, θ power spectrum, δ relative power spectrum of occipital leads (O1, O2) at the lesion side were higher than that at the healthy side ($p < 0.05$), and β relative power spectrum on the lesion side was lower than that at the healthy side ($p < 0.05$) as shown in table 4. Frequency map of a patient with left occipital lobe epilepsy was shown in Figure 3.

4. Comparison of quantitative electroencephalography indicators in parietal lobe epilepsy

The K-S test of α relative power spectrum showed $p < 0.05$, it did not fit the normal distribution. The t-test of other data showed no significant differences as shown in Table 5. Frequency map of a patient with left parietal lobe epilepsy was shown in Figure 4.

DISCUSSION

The essence of epilepsy is abnormal discharge of cranial nerve cells. Electroencephalography is a special technique for studying bioelectrical activity. It is of great clinical value to classify epilepsy based on electroencephalography during seizures and interictal

Tab. 5. Comparison of quantitative electroencephalography indicators of parietal lobe epilepsy

	parietal lead		
	lesion side	**healthy side**	***p* value**
δ power spectrum	7.34±5.62	5.33±3.75	0.091
θ power spectrum	8.04±4.47	6.08±3.51	0.062
α1 power spectrum	6.69±2.90	5.21±2.33	0.055
α2 power spectrum	4.96±1.97	4.16±1.79	0.168
β1 power spectrum	3.78±0.87	3.30±1.03	0.096
β2 power spectrum	2.38±0.72	2.08±0.61	0.283
δ relative power spectrum	0.20±0.13	0.20±0.11	0.587
θ relative power spectrum	0.23±0.07	0.22±0.05	0.468
α relative power spectrum	0.37±0.12	0.37±0.10	0.912
β relative power spectrum	0.20±0.06	0.21±0.04	0.321

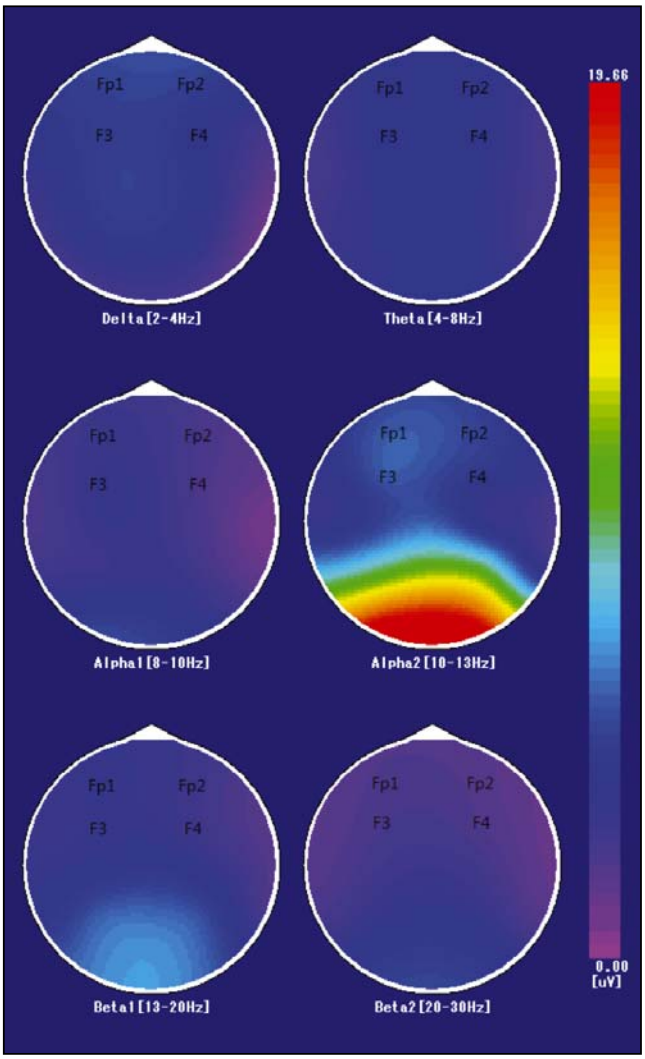

Fig. 1. Frequency map in frontal lobe epilepsy

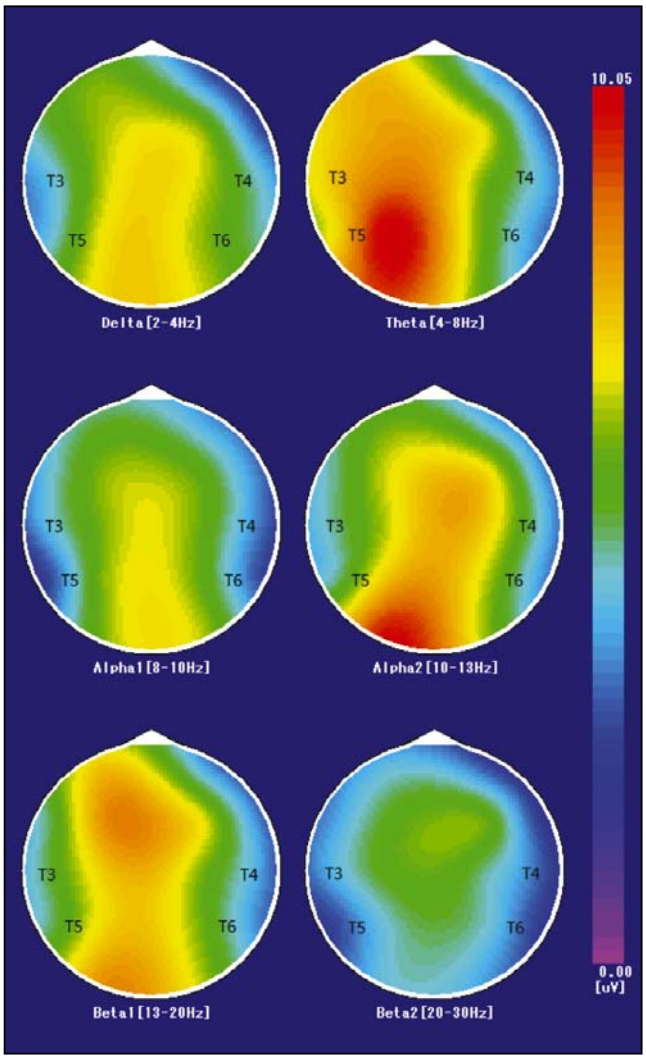

Fig. 2. Frequency map in temporal lobe epilepsy

periods, combined with etiology, lesion location and onset age. The visual analysis has been adopted in electroencephalography, mainly measuring and analyzing the basic frequency, amplitude and waveform characteristics of electroencephalogram. Substantial features and information contained in electroencephalography activities cannot be extracted by this rough, qualitative and semi-quantitative analysis method, making electroencephalography examination difficult to meet the needs of clinical affairs and research. Quantitative electroencephalogram is a technique for quantitative analysis of electroencephalogram activities. Power spectrum analysis is mainly used to analyze the frequency characteristics of electroencephalography signals. It is currently a common method for quantitative electroencephalography. There are some changes that cannot be determined by visual analysis and can be used to supplement conventional electroencephalography. Power spectrum analysis is used in fast Fourier and other methods to convert electroencephalogram shape information into numerical information so as to directly observe the distribution and changes of brainwaves in α, β, θ and δ frequency bands (AlShorman *et al.* 2022). Power spectrum analysis is further divided into absolute power spectrum and relative power spectrum. The absolute power value reflects the actual power value of each frequency band, and the relative power value is the ratio of each frequency band (Hong *et al.* 2022), which is a favorable supplement to the absolute power value. Through the quantitative analysis technology of electroencephalogram, we have conducted in-depth analysis of electroencephalogram of different lobar epilepsy, summarized the quantitative electroencephalogram characteristics of different lobar epilepsy, and obtained the quantitative electroencephalogram characteristics beneficial to the diagnosis of different lobar epilepsy, hoping to provide a new direction for improving the utilization value of electroencephalogram in epilepsy diagnosis.

Through research, we found that θ and α1 power spectrum in quantitative electroencephalography analysis results of temporal leads (T3, T4) and posterior temporal leads (T5, T6) in temporal lobe epilepsy were higher at the lesion side than at the healthy side

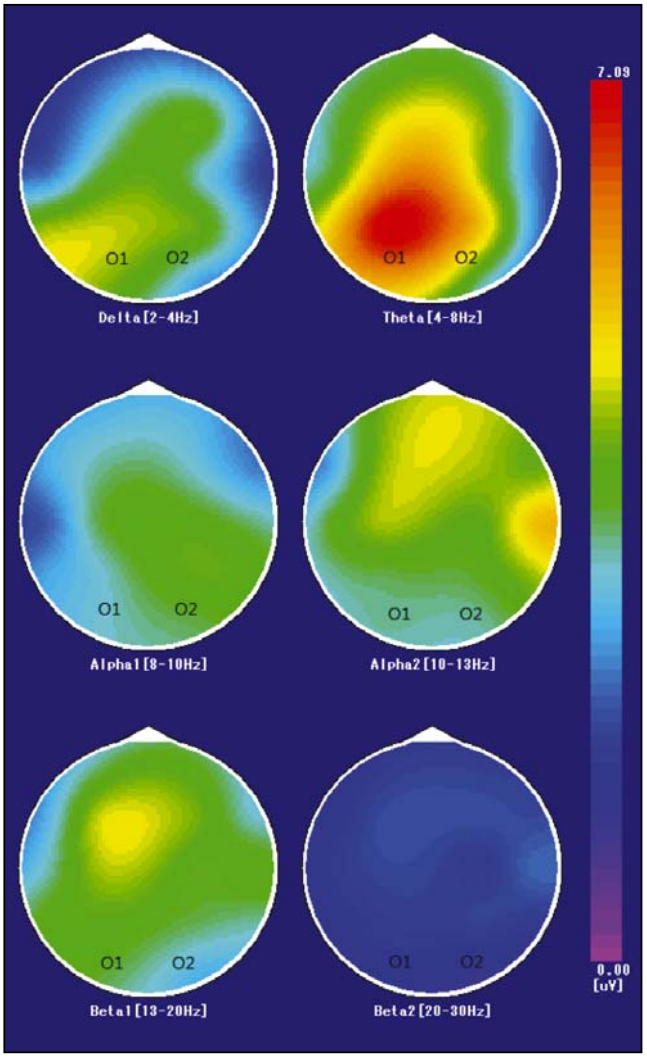

Fig. 3. Frequency map in occipital lobe epilepsy

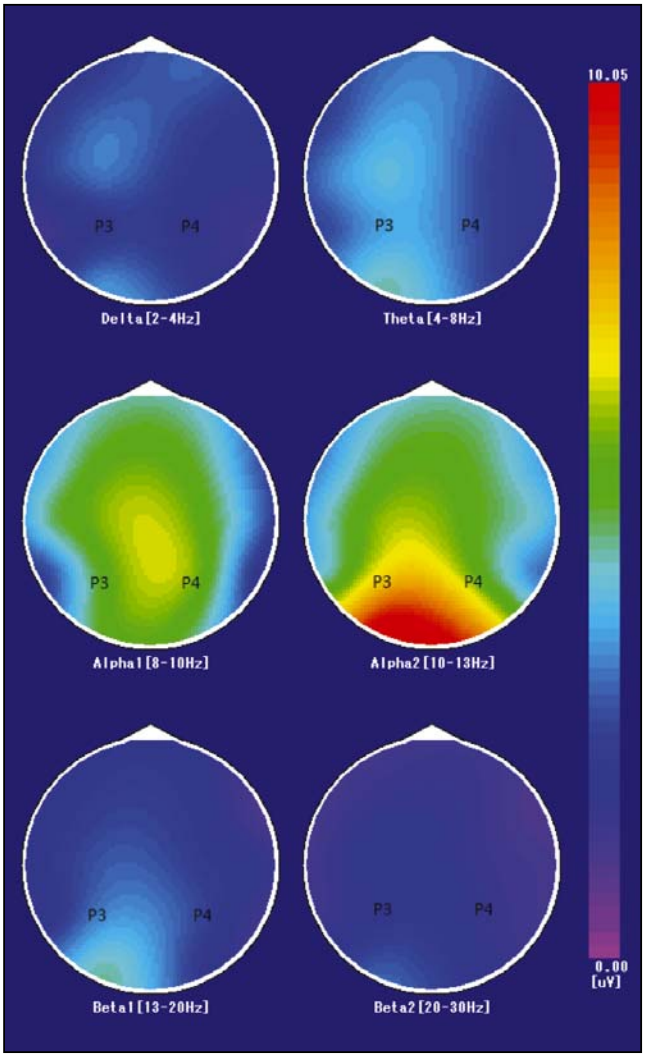

Fig. 4. Frequency map in parietal lobe epilepsy

($p < 0.05$). The lesion side of α2 and β1 power spectrum of middle temporal leads (T3, T4) were higher than the healthy side ($p < 0.05$), while the lesion side of β relative power spectrum was lower than the healthy side ($p < 0.05$). The β2 power spectrum of posterior temporal leads (T5, T6) were higher at the lesion side than at the healthy side ($p < 0.05$). Therefore, we believe that quantitative electroencephalography is valuable in the diagnosis of temporal lobe epilepsy. θ power spectrum can be increased in the discharge lead of temporal lobe epilepsy. In the quantitative electroencephalogram analysis results of occipital leads (O1, O2) of occipital lobe epilepsy, δ and θ power spectrum, δ relative power spectrum at the lesion side were higher than that at the healthy side ($p < 0.05$), and β relative power spectrum at the lesion side was lower than that at the healthy side ($p < 0.05$). Similar to the results of temporal lobe epilepsy, quantitative electroencephalography has application value in the diagnosis of occipital lobe epilepsy, and slow wave power spectrum can be increased in the discharge lead of occipital lobe epilepsy.

Meanwhile, some studies reported enhanced low-frequency activity in background EEGs in patients with epilepsy, including the frontal, parieto-occipital, and limbic lobes (Moon *et al.* 2022), that is consistent with the results of our study. It can be seen that the slow wave power spectrum of the brain regions in the corresponding discharge foci of temporal lobe epilepsy and occipital lobe epilepsy was increased. A research also shows asymmetry in the EEG power spectrum of prefrontal and temporal lobe epilepsy. The background activities of electroencephalography in primary epilepsy patients is different from normal person. At present, the pathogenesis of epilepsy is still unclear. Some studies (Elhady *et al.* 2020; Chyra *et al.* 2021) have found that inflammatory factors could affect the electrical activities of neurons and glial cells. Inflammation is one of the pathogenesis of epilepsy, and epileptic seizures can also cause neuroinflammatory reactions, further aggravating central nerve injury. Inflammation is also the pathological basis of epilepsy. Fonseca *et al.* (2022) found that the increase of slow wave frequency band on electroencephalography was the manifestation

of cerebral cortex dysfunction. Therefore, we speculate that the mechanism of the increase of slow wave power spectrum in the corresponding discharge areas of temporal lobe epilepsy and occipital lobe epilepsy may be related to inflammatory reaction, and cerebral cortex dysfunction may be caused by inflammatory reaction.

The quantitative electroencephalogram analysis results of frontal leads (Fp1, Fp2) and frontal leads (F3, F4) of frontal epilepsy only showed that the data which fits the normal distribution had no significant difference (P>0.05). Therefore, we believe that quantitative electroencephalography has no useful value in the application of frontal lobe epilepsy. There was no significant difference in quantitative electroencephalogram indexes between the top leads (P3, P4) of parietal lobe epilepsy (P>0.05). Therefore, we believe that quantitative electroencephalography has little effect in the application of parietal lobe epilepsy. As insular epilepsy cannot be recorded by scalp electrodes and intracranial electrodes are required for detection, insular epilepsy is not included in the scope of this study.

In the usage of quantitative electroencephalography with above-mentioned different lobar epilepsy cases, slow wave power spectrum increased in temporal and occipital lobe epilepsy. We concluded that the increase in slow wave power spectrum in QEEG can serve as an auxiliary diagnosis for temporal lobe epilepsy and occipital lobe epilepsy.

During the last two decades, epilepsy and seizure is one of the hot topics in QEEG research (Yao *et al.* 2022). In this study, we only applied the frequency domain analysis of quantitative electroencephalography to the diagnosis of epilepsy. Studies (Azuma *et al.* 2022; Xu *et al.* 2022; Sreenivasan *et al.* 2022) showed that besides frequency domain analysis, quantitative electroencephalography including nonlinear analysis was applied to the auxiliary diagnosis of epilepsy. The application value of quantitative electroencephalography in epilepsy was not fully studied, further study will be needed.

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