The Change of Resting EEG in Depressive Disorders

Zhizhou Liao[1,2], Haiyan Zhou[1,2], Chuan Li[1,2], Jun Zhou[1,2], Yulin Qin[1,2], Yuan Feng[3], Lei Feng[3], Gang Wang[3], and Ning Zhong[1,2]

[1] International WIC Institute, Beijing University of Technology, China
[2] Beijing Key Laboratory of MRI and Brain Informatics, China
[3] Beijing Anding Hospital of the Capital University of Medical Sciences, China
liaozhizhou109@sina.cn

Abstract. Recent research suggested that the resting EEG could provide a biomarker for the depressive disorders and an objective index for the respond effect to treatment. To provide further evidence of the relationship of EEG signal and depression, we reported a pilot result based on the resting EEG. By recording the resting EEG signals in the three groups of normal control, unmedicated depressed patients and medicated depressed patients, after the analysis of fast fourier transform (FFT) to change time base signal into frequency information, we found that signals in many frequency bands of brain waves were related to the value of Beck Depression Inventory (BDI), especially in the Beta frequency band and in the frontal area in the unmedicated depressed group. Furthermore, we also found that comparing to the normal controls, the unmedicated depressed patients showed a stronger asymmetry in many frequency bands both in the frontal and parietal regions, which meant that the EEG signals were weaker in the left brain than in the right in the unmedicated depressed group.

1 Introduction

Depression will become the first mass disease in 2020, due to its high lifetime deformity and its bad effect to daily life and high fatality rate. Discover early and treatment early can increase the rate of recovery, avoid the obsession of the depression, and return society earlier. So people find all kinds of simple methods to distinguish depression and evaluate the reaction of treatment. EEG is made of the active of mass nerval organise synchronization. It can be spontaneity without stimulating or produce with stimulating. There is a big development direction now. People design stimulate tasks, then use it to bring out especial EEG. After that use statistical method to get mean amplitude and latency. It is called ERP method. Its classical experiment is Oddball experiment. The defect of ERP method is that it needs stimulation, the experiment design is complex. So it is not a simple way. Researchers try to get EEG without stimulating. Some experiments record sleeping EEG, the other record resting state EEG, then use methods which is different from ERP method to analyse. Depression has many subtypes. For example, hypochondria, melancholia and so on and it has notable general characteristics, especially

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anxiety [1, 2]. Sleeping EEG is considered to be a way to distinguish subtypes of depression experimentally [3]. Antidepressant can change sleeping parameter. It has proved that antidepressant can restrain REM sleeping. Though we can use the way of analyzing sleeping EEG to research depression, analyzing resting EEG is also very practicality. Many researches show that the result of analyzing resting EEG is contributive to understand pathology of depression and results are very practicality, when they are used in clinical treatment. It is no stimulation inflict on subject when recording resting EEG, and let subject relax himself or herself, make them in quiet, awake state. Subject can open eyes or close eyes, but EEG is different in two situations. Different from getting ERP from time base and considering amplitude and latency, resting EEG analysis can use all kinds of delicacy signal analyse methods. For example use Fast Fourier Transform (FFT) to analyse EEG, it can change EEG from time base to frequency spectrum. Then use the characteristic quantity of frequency spectrum to analyze it. Seeing about the signal of frequency spectrum, usually divide the frequency spectrum into several bands, for example, delta (1 to 3Hz), theta (4 to 7Hz), alpha (8 to 13Hz), beta (14 to 30Hz) (there is not a criterion to divide bands in academe), then observe the state of subject in each band. Delta band, frequency is 1 to 3Hz. When a person is in babyhood, intelligence agenesis or adult is very tired and doze, the band will appear. Theta band, frequency is 4 to 7Hz, the frequency is very notable when adult meets with frustration or depression. But the band is the main component in electroencephalogram of youngster(10 to 17years). Alpha band, frequency is 8 to 13Hz. It is the basic frequency band in normal person. If there is no stimulation, the frequency is very invariableness. When people is quiet, awake, closing eyes, the frequency is most distinctness. When a person is opening eyes or is stimulated, alpha disappears. Beta band, frequency is 14 to 30Hz. The band is notable, when emotion is excited, strong or exhilaration. when someone is waked from dream, the band produces at once. Alpha band is considered to be the rhythm under the cortex in tradition. Currently, activation of cortex is related with the amplitude and frequency of alpha. Low level activation of the cortex is related with high amplitude and low frequency activity of alpha. High level activation of the cortex is related with low amplitude and high frequency activity of alpha. Delta and theta activity is related with margin system [4]. The system plays an important role in keeping awake [5]. There is a relation between power of each band and brain active. Some researches find that brain activity is an inverse measure of alpha power activity, mean doing more brain activity is related to less alpha power. Other researches find that power of beta, theta, delta band is related with intensity of brain active which is similar with power of alpha band, but it is different from power of alpha band. The active intensity of cortex can be reflected by power of EEG frequency power. So comparing power value of the same band in different channels can compare brain activity in different channels. Some researches compare power of symmetry hemisphere channels, then find power ratio is asymmetry especially in depression. A lot of evidence show that major depression is related with the descensive activity of left hemisphere relative to right hemisphere [6–8]. Some evidence shows that compare to normal people, left frontal activity decline in

depression [9, 10]. In the patients selected by BDI, their EEG show that their left front activity is lower than normal persons [11]. Some critics hypothesis that anhedonia reflects neural bug. Part of the bug is left prefrontal cortex [12]. Some theory hypothesis that left prefrontal cortex disorder is the core neural base of major depression. For example, it is accord with asymmetry model [13]. Some research show that the prefrontal asymmetry is a dangerous symbol, it is very stabilization, and it can last out from babyhood to manhood [14, 15]. But the above research which compare activity of left and right hemisphere use the power of each band. Our research will use voltage density which comes from EEG FFT. Voltage density is a lot of bigger than power, so it can compare without taking the logarithm. Using voltage density can make the program simpler and increase precision. People use all kinds of methods to test which part of brain relating with depression. we can also use the method of analyzing EEG, when it does not need high resolution. Our research will try to use the method of analyzing EEG. We use voltage density after EEG FFT which comes from the normal controls, the unmedicated depressed group and the medicated depressed group to correlated with BDI.

2 Methods

2.1 Participants

All participant are satisfied with the following selecting standard: If a person has one point underside, he or she will be excluded: 1. not right-hander; 2. Having alcohol, medicine abuse; 3. brain, heart, liver, lung has severity disease; 4. having uncontrol diabetes; 5. having severe suicide trend; 6. having other psychopathy, for example, schizophrenia, double way mood disorder; 7. age is out of 10 to 70 years. The basal information of normal controls group is in Table 1. Everyone has been surveyed by BDI. The point of everyone is under 10, and average is 5.36. So they are not depression.

Data of Depression is collected in March 2013. The experiment place is Beijing Anding hospital. These patients are selected by seasoned psychiatrist doctors. All of them are reach DSM-IV. All of the patients has been surveyed by BDI, CGI-S, HAMD, QIDS-SR, T-AI. BDI, QIDS-SR, T-AI are filled in by patient. CGI-S, HAMD are filled in by doctors. BDI average of the unmedicated depressed group is 16.43, higher than the average of the normal controls group. The two groups are distincted different by T test. Scales points of the unmedicated depressed group and the medicated depressed group are in Table 1. We can find that the point of all scales from the medicated depressed group is lower than the point from the unmedicated depressed group.

2.2 EEG Recordings

When recording EEG, the subject sits in a soft chair, in a dim small room. The room is very quiet. Let the subject close eyes, sit quietly. Recording time is 8 minutes. To avoid the stimulation from event or environment before experiment, we only analyse EEG which the segment is from the fifth minute to the eighth

Table 1. Detail information of three groups

Group	Normal controls	Unmedicated depressed	Medicated depressed
Subject total	10	7	5
Gender	5 females	2 females	2 females
Age	23.32(2.55)	30.43(6.63)	46.25(8.88)
Handedness	10 right-handed	7 right-handed	5 right-handed
Education level	graduate	pupil to ungraduate	high school to graduate
Medicated situation	unmedicated	unmedicated	medicated
BDI	5.36(2.58)	16.43(5.86)**	14.75(6.75)
CGI-S		4.57(0.53)	4.25(0.96)
HAMD		20.86(4.18)	20.25(5.12)
QIDS		16.29(1.80)	14.50(5.45)
T-AI		59.29(4.03)	51.00(10.65)

(Note: **means T test result shows that BDI of the normal controls group is significant different from the unmedicated depressed group.)

minute. The channels which recording EEG are Fp1, Fp2, F3, F4, P3, P4 in 10-20 international system. These channels are on forehead or on parietal. Fp1, Fp2, F3, F4 is on forehead, and P3, P4 is on parietal. Fp1, F3, P3 is on left hemisphere, Fp2, F4, P4 is on right hemisphere, they are left and right hemispherical symmetry. All resistance between electrode and scalp is below 5000 ohm. The recording equipment is Brain Vision Recorder. The sampling frequency is 500Hz.

2.3 Data Analysis and Statistics

The software which uses for data analyse is Brain Vision Analyser. First, input the originality data. Second, setup ocular correction, set Tp9, Tp10 two channels for reference. Third, ocular correction, correction the muscle electricity which brings by blink or eyes move. Fourth, raw data inspection, remove the signal which brings by equipment or body moving. Fifth, filters, eliminate unnecessarily signal, after setting the necessarily signal frequency and band width. Sixth, segmentation, signal which is need to advanced analyse is distilled. We will analyse the last 3 minutes EEG.. Seventh, Fast Fourier Transform (FFT), we change time base EEG into frequency spectrum. Y-axis is voltage density. Ninth, set off frequency bands, then output data. These bands are delta (0.5 to 3.5Hz), theta (4 to 7Hz), alpha1 (7.5 to 9.5Hz), alpha2 (10 to 12Hz), beta1 (13 to 23Hz), beta2 (24 to 34Hz), gamma (35 to 45Hz). After that output the area of each band and use SPSS to correlation analyse and asymmetry analyse.

3 Results

3.1 Correlation Analysis

In the normal controls group, correlation analysis has done between their 6 channels of each band and BDI mark. The result is : some correlation coefficient is

high, but others is low. Both of them are not significant after test. The correlation between age, gender, education level and BDI is also not significant.In the unmedicated depressed group, many channels are significant correlated with BDI in many bands ($P < 0.05$). Seen in Table 2. 12 channels of alpha2 band and gamma band are significant correlated with BDI ($P < 0.05$). 6 channels of theta band are not significant correlated with BDI ($P > 0.05$). In other bands, some channels are significant correlated with BDI ($P < 0.05$), other channels are not significant correlated with BDI ($P > 0.05$). The correlation between age, gender, education level and BDI is not significant ($P > 0.05$). The correlation coefficients which are evidently correlate with BDI are negative. In the medicated depressed group, there is not any channels in each band which are significant correlated with BDI. The correlation between age, gender, education level and BDI is not significant too ($P > 0.05$).

Table 2. The correlation between BDI and voltage density in each band in each channel in normal control group

Band	Fp1	F3	P3	Fp2	F4	P4
Alpha1	-0.309	-0.756*	-0.731	-0.521	-0.849*	-0.660
Alpha2	0.237	-0.472	-0.482	-0.009	-0.423	-0.292
Beta1	-0.576	-0.774*	-0.822*	-0.657	-0.760*	-0.558
Beta2	-0.859*	-0.860*	-0.862*	-0.860*	-0.863*	-0.869*
Delta	-0.704	-0.712	-0.688	-0.661	-0.760*	-0.751
Gamma	-0.860*	-0.861*	-0.861*	-0.861*	-0.862*	-0.866*
Theta	0.199	-0.140	-0.092	0.102	-0.182	-0.065

(Note: * means correlation is significant.)

3.2 Asymmetry Analysis

Channels Fp1, F3, P3 are on left hemisphere, symmetrical channels Fp2, F4, P4 are on right hemisphere. Calculate (Fp1-Fp2)/Fp1, (F3-F4)/F3, (P3-P4)/P3 at each band. Except (Fp1-Fp2)/Fp1 (-0.015), (F3-F4)/F3 (-0.019) in alpha1 band; (Fp1-Fp2)/Fp1 (-0.005) in alpha2 band; (Fp1-Fp2)/Fp1 (-0.001) in beta2 band; (Fp1-Fp2)/Fp1 (-0.019) in delta band. Other value in each band is positive. And the above negative values are very near 0. Seen in Table 3.

Table 3. The asymmetry in each band in the normal control group

Band	(Fp1-Fp2)/Fp1	(F3-F4)/F3	(P3-P4)/P3
Alpha1	-0.015(0.053)	-0.019(0.064)	0.014(0.090)
Alpha2	-0.005(0.046)	0.004(0.064)	0.029(0.090)
Beta1	0.011(0.175)	0.052(0.204)	0.017(0.039)
Beta2	-0.001(0.200)	0.025(0.215)	-0.013(0.048)
Delta	-0.019(0.078)	0.082(0.191)	0.012(0.077)
Gamma	0.052(0.078)	0.088(0.085)	0.040(0.036)
Theta	0.009(0.101)	0.117(0.158)	0.029(0.056)

(Note: standard deviation in the bracket)

Table 4. The asymmetry in each band in the unmedicated depressed group

Band	(Fp1-Fp2)/Fp1	(F3-F4)/F3	(P3-P4)/P3
Alpha1	-0.161(0.123)	-0.183(0.173)	-0.200(0.531)
Alpha2	-0.200(0.137)	-0.215(0.306)	-0.340(0.848)
Beta1	-0.246(0.155)	-0.267(0.402)	-0.364(0.930)
Beta2	-0.276(0.142)	-0.296(0.556)	-0.366(1.021)
Delta	-0.165(0.178)	-0.079(0.073)	-0.009(0.166)
Gamma	-0.153(0.219)	-0.247(0.481)	-0.338(0.955)
Theta	-0.188(0.111)	-0.133(0.123)	-0.137(0.128)

(Note: standard deviation in the bracket)

Table 5. The asymmetry in each band in the medicated depressed group

Band	(Fp1-Fp2)/Fp1	(F3-F4)/F3	(P3-P4)/P3
Alpha1	0.046(0.248)	-0.257(0.070)	-0.070(0.175)
Alpha2	0.027(0.186)	-0.241(0.077)	-0.098(0.095)
Beta1	-0.019(0.145)	-0.248(0.091)	-0.105(0.092)
Beta2	0.024(0.156)	-0.411(0.596)	-0.188(0.140)
Delta	-0.187(0.165)	-0.063(0.160)	-0.096(0.064)
Gamma	0.208(0.250)	-0.750(0.957)	0.000(0.000)
Theta	0.056(0.361)	-0.280(0.154)	-0.188(0.112)

(Note: standard deviation in the bracket)

Table 6. Result of T test between the normal controls group and the unmedicated depressed group in each band

Band	(Fp1-Fp2)/Fp1	(F3-F4)/F3	(P3-P4)/P3
Alpha1	2.657*	2.739*	1.144
Alpha2	2.688*	2.160*	1.256
Beta1	3.112*	2.157*	1.313
Beta2	3.116*	1.674	1.108
Delta	2.302*	2.108	0.341
Gamma	1.432	1.532	1.074
Theta	3.801*	3.497*	3.658*

(Note: * P value is smaller than 0.05.)

The mean of each band of the unmedicated depressed group is negative, and most of values are smaller than -0.1. Seen in Table 4.Asymmetry analysis of the medicated depressed group show that (Fp1-Fp2)/Fp1, (F3-F4)/F3, (P3-P4)/P3 of beta1 band, delta band are negative. There are positive values and negative values in other bands. Seen in Table 5.The value of (Fp1-Fp2)/Fp1, (F3-F4)/F3, (P3-P4)/P3 in normal controls group and the unmedicated depressed group after independent samples test show: in the symmetrical channels of Fp1 and Fp2, alpha1, alpha2, beta1, beta2, delta, theta band are significant differentin the symmetrical channels of F3 and F4, alpha1, alpha2, beta1, delta, theta band are significant differentin the symmetrical channels of P3 and P4, theta band is significant different. Seen in Table 6.

In Table 3 and Table 4, we know that the activity of left hemisphere is weaker than right hemisphere in unmedicated depressed patients in normal controls, and it is contrary in normal controls. The difference is significant after T test. Seen in Table 6.

4 Discussion

In former researches, people output power of each channel to do farther analysis. In our research, we output voltage density of each channel to do farther research. Both power and voltage density can get after EEG FFT. Both of them can be divide bands, for example, alpha, beta, theta etc. But the value of voltage density is far bigger than the value of power. So it is not need to take the logarithm and simplify data processing.

From the result of correlation analysis, we know that voltage density of the normal controls group and the medicated depressed group is not significant correlated with BDI. Voltage density of the unmedicated depressed group is significant correlated with BDI. From detail information of three groups, we know that the point of the normal controls group and the medicated depressed group is markedly lower than the unmedicated depressed group. BDI can measure depressive degree, and severity degree increases with BDI point linearity, so the EEG character reflected by voltage density can inosculate with depressive degree in a scope. This scope is after a severity degree. There is a boundary. What is the value of the boundary of voltage density or the BDI mark ? It needs farther research in the future. In the result of our correlation analysis, voltage density of all channels of alpha2 band and gamma band from the unmedicated depressed group is markedly correlated with BDI. Alpha band is a especially band, when people is quiet, awake, eyes closed. Maybe it can reflect a especial state in depression. Gamma band is a high frequency band. Some researches show that it is dangerous, if a person is in this band for a long time [16]. So depression has enormous negativity affect on health. In the group, voltage density of all channels from theta band is not markedly correlated with BDI. A research shows that theta band is very significant in teen-age EEG. Our result may duo to the reason that teen-age subjects are very few. Voltage density of all channels from the unmedicated depressed group is markedly correlated with BDI. Voltage density of different channels reflects the activity of different nerve troops. The BDI point of depression patient represents the degree of depression. So we can infer that depression pervades all brain cortex. It is not the result of several brain areas disfunction, it is the result of all cortex disfunction. Hemispheric EEG activation asymmetry in subclinically depressed college students and clinically depressed patients has been frequently observed with findings of relative excess left mid-frontal (F3 is bigger than F4), and lateral-frontal (F7 is bigger than F8), in alpha-band power [17, 18]. Specifically, it has been found that individuals exhibiting left frontal EEG asymmetry (greater left versus right frontal brain activity) are more likely to display behaviors associated with approach motivation and positive affect, while those exhibiting right frontal EEG

asymmetry (greater right versus left frontal brain activity) are more likely to display behaviors associated with withdrawal and negative affect [19]. These inordinate negative behaviors and negative affect is similar to the symptom of depressed patient, and positive behaviors and positive affect is similar to the representation of normal person. In our research, we find that voltage density of left hemisphere is smaller than right hemisphere in the unmedicated depressed group. But we find the contrary result in the normal group. The result means that the activity of left hemisphere is smaller than right hemisphere in depression. Research can not distinguish asymmetry in depression, it is the reason of depression or the outcome [20]. There is a result of investigating anthropoid. It is that pressure can change asymmetry of nerve transfer function. The function is correlated with anxiety [21]. According to society factor theory, biologic and environmental factors contribute to psychopathy, whereas psychopathy can take people to lower society economy estate [22]. There are evidences supporting both of the two views. A lot of other factors which is not chronic pressure and society economy estate are correlated with brain asymmetry. These factors include maternal mildness, instability of accompanier colony, social support and cognitive stimulation [23]. In some researches, society economy estate has a direct effect on prefrontal asymmetry. But maternal depression history only has a slight direct effect [24, 25]. There is not relation between prefrontal asymmetry, quality of life and depression in old age in other results [26]. In the future, we should consider the age effect in asymmetry research. There are some researches about asymmetry genetic effect. They find the hypothesis that asymmetry in alpha band which left parietal lobe is less activity than right lobe is an important family indicate of the major depression. They find the subjects offspring which is high risk person and not lifetime major depression support the hypothesis [27]. In recent decades, people try to find the way of treating depression. Antidepressant plays an important role in treating depression. However, only 50 percent to 70 percent depression patients response to medicine to see a doctor at the first time and less than 40 percent get well. Some new findings bring hopes to emotional neurophysiology, reveal the brain asymmetry pattern (especially electrophysiological asymmetry) and the relation amount several emotions (for example, depression, anxiety) [28]. We find that the asymmetry number of the medicated depressed group is less than the unmedicated depressed group and many negative values in the unmedicated depressed group have changed to positive values in the medicated depressed group. The result shows that EEG is a very useful technology which is used to forecast the treated response. It is very sensitive to the process of antidepressant response. And EEG asymmetry is a useful character in depression division.

Our research is pilot study of depression, more in-depth exploration is expected to do. In future, We can also compare asymmetry degree of three groups, to inspect whether asymmetry degree of the depression group is stronger than the normal controls group, whether asymmetry degree of the unmedicated depressed group is stronger than the medicated depressed group.

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