Research Article

EEG Power Analyses: A New and Early Assessing Method For Cognitive Impairment Post Cerebral Venous Thrombosis

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Summary

Cerebral venous thrombosis (CVT) is a rare and potential fatal disease, which comprises the occlusion of the flow in the cerebral venous system and its sinuses. Electroencephalogram (EEG) characteristics can be analyzed to investigate the applied value in the assessment of cognitive impairment of the CVT patients. 100 patients (including cognitive impairment patients (CI) and cognitive normality patients (NCI)) with CVT and 50 normal health persons (CN) were received from January 2009 to January 2011 at the department of Neurology. All above of the subjects were analyzed by EEG. The EEG analyses results were compared with the MoCA scale with the methods of correlation analyses, clustering analyses and concordance analyses. The results indicated that CI patients had significantly lower EEG beta power relative to NCI or CN group (both P<0.05), but no difference was found between NCI and CN group (P>0.05). There was a better concordance (Kappa=0.837) between the beta power and MoCA scoring for CVT patients. No significant differences were discovered between beta power analyses and MoCA scoring method for the cognitive impairment post CVT (P=0.297). In conclusion, the EEG beta power analyses technique may hold a considerable promise for the early assessment of cognitive impairment post CVT.

Key words: Cerebral venous thrombosis; cognitive impairment; assessment; electroencephalogram; beta power

EEG Aktivite Analizleri: Serebral Venöz Tromboz Sonrası Bilişsel Bozuklukların Erken Değerlendirilmesinde Yeni Bir Yöntem

Özet

Serebral Venöz Tromboz (SVT) serebral venöz sistem ve sinüslerinde tıkanma ile kendini gösteren ender ve ölümçül potansiyeli olan bir hastalıktır. SVT hastalarında bilişsel bozuklukları değerlendirmek için uygulama değeri olan elektroensefalografi (EEG) özellikleri incelenmek üzere analiz edilebilir. SVT hastası olup bilişsel bozukluğu olan (BB) ve olmayan (BB-) 100 hasta ve 50 normal sağlıklı kişi (N) Nöroloji servisinde Ocak 2009 ve Ocak 2011 tarihleri arasında kabul edildi. Tümü EEG ile analiz edildiler. EEG analizleri, korelasyon analizi yöntemleri MoCA skalası ile, kümelleme ve uygunluk analizleri ve karşılaştırılmıştır. Sonuçlar BB grubu hastalarda BB- grubu hastalara ve N grubuna oranla önemli ölçüde düşük beta EEG aktivitesi gösterdiler (p<0.5). Ancak N ile BB- grupları arasında bir fark gözlenmedi (p>0.05). SVT hastalarında beta aktivitesi ve MoCA değerleri arasında daha iyi uygunluk vardı (Kappa=0.837). SVT sonrası bilişsel bozukluk için MoCA skorlama yöntemi il e beta aktivite analizi arasında önemli bir fark bulunmadı. (p=0.297). Sonuç olarak, EEG beta aktivite analiz tekniklerinin SVT sonrası gelişen bilişsel bozukluklarının erken değerlendirmelerinde önemli ölçüde etken olabilir.
**INTRODUCTION**

Cerebral venous thrombosis (CVT) is a rare (0.5% of the total number of strokes) and potential fatal disease, which comprises the occlusion of the flow in the cerebral venous system and its sinuses. The symptoms and clinical course are highly variable, despite improvements in diagnosis and treatment, it may still cause death or permanent disability. From a pathogenic viewpoint, venous thrombosis is considered to be a continuous process in which the balance between the prothrombotic and thrombolytic processes is disturbed, and caused the formation of a venous thrombus. A combination of magnetic resonance imaging (MRI) of the head and magnetic resonance (MR) venography is the most sensitive means of detecting CVT during its acute, subacute, and chronic phases. Almost 80% of CVT patients could re-gain functional independence when assessed on the modified Rankin scale (mRS). However, it is known that conventional calculation of the mRS score underestimates cognitive disability. Presently, there were even no specific mechanism and prognostic methods about the cognitive outcomes in CVT patients. Previous studies have showed that the prevalences of impairments in the mini-mental state examination were 3% and 6%, respectively for CVT patients. de Bruijn et al. found that the frequency of cognitive impairment was lower in CVT than in arterial stroke. Bugnicourt et al. discovered that cognitive impairment persists in up to one-third of cases of CVT patients. Cognitive impairment is more frequent in patients with deep CVT and persistent parenchymal lesions and is associated with failure to return to full-time employment. Cognitive impairment refers to a syndrome in which a cognitive loss, typically in the domain of semantic memory, is measurable on neuropsychological test batteries, and is of sufficient or mild strength to cause serious social, vocational or other functional impairment to the patient. In contrast to the well documented cognitive consequences of other strokes, the frequencies and diagnosis of cognitive impairment after CVT have not been systematically studied.

Electroencephalogram (EEG) is a cheap, noninvasive diagnostic tool reflecting cerebral function, and which has been applied in some aspects for the evaluation of cognitive impairment. EEG records may illustrate some valuable significance when there is diagnostic doubt. For example, signs of diffuse EEG slowing are useful in differentiating the healthy humans from Alzheimer's disease (AD) patients. So the EEG may provide biological support in terms of brain functioning for variability in cognitive impairment. Our previous research has been showed that the inter-group statistical comparisons of EEG power for cognitive impairment and no cognitive impairment patients revealed significant differences, but which only limited to beta bandwidth power. Thus, in this study, we analyzed the abnormality of EEG beta power to study the cognitive impairment post CVT. Furthermore, there are even no studies assessing the relationship between EEG abnormality and cognitive impairment post CVT. So, the EEG characteristics were analyzed in this study, and the applied value was investigated in the assessment of cognitive impairment of CVT patients.

**MATERIAL AND METHODS**

**Patients**

100 patients with CVT disease were received from January 2009 to January 2011 at the department of Neurology. All patients' family gave their informed consent. 50 cases selected from health
examination individuals at the Physical Examination Center were employed as the control group, and all of them gave their informed consent.

**MoCA score assessment and trial grouping**

All of the CVT patients underwent a Beijing version MoCA (total 30 points) assessment at 2 months after CVT, including orientation to time and place, executive functions, the short-term memory recall task, and act. The MoCA score more than 26 is assigned as normal impairment. In the study, the total score less than 26-scores, 63 cases, accounting for 63%, was classified into the cognitive impairment group (CI); 37 cases more than 26-scores, accounting for 37%, was classified into cognitive normality group (NCI). 50 cases selected from health examination individuals were employed as the control group (CN).

**Diagnostic criteria**

The inclusion and exclusion criteria for the CI and NCI group, were performed as the previous study\(^{26}\). For the CN group, no history of psychoactive or neurological disease, brain injuries and other important organ diseases, no neurological system or body abnormalities were discovered, no abnormalities were found according to the CT and MRI inspection. The Hamilton Depression Scale (HAMD) was employed to exclude the depressive disorder, Hachinski Ischemic Scale (HIS) was performed to exclude Alzheimer's disease. At the meantime, Instrumental and Basic Activities of Daily Living (IADL, BADL), Clinical Dementia Rating Scale (CDRS) were also employed. Through the above diagnostic methods, other causes of cognitive impairment were ruled out.

**EEG recordings and analyses**

EEG electrode placement (Jasper 10-20 electrode placement) was used to record the EEG activity continuously from 16 channels (Fp1, Fp2, F7, F3, F4, F8, T3, C3, C4, T4, T5, P3, P4, T6, O1 and O2). Data were recorded with a band-pass filter of 0.5-50 Hz, and digitized at a sampling rate of 250Hz. EEG data were then analyzed and fragmented off-line in consecutive epochs of 2 seconds, with a frequency resolution of 0.5Hz\(^{18}\). EEG epochs with sporadic blinking artifacts were corrected by an autoregressive method validated in a Moretti and co-author's study\(^{17}\).

According to our present research, we found that there were 6 EEG channels (1, 8, 9, 11, 12, 16) exhibited the largest differences in relative beta power between CI and NCI group. So we selected beta bandwidths signals of the above 6 EEG channels for the post CVT patients. The K-means clustering algorithm was used to classify the characteristic vector array. The K-means clustering algorithm assumes a user-specified number of classification categories, and then calculates the centroid (mean beta power) for each category (group or cluster). The value of the centroid is then iteratively adjusted until the differences between data points and the centroid for each group is minimized. The steps in the algorithm are as follows as Baker's report\(^{3}\): ① Choose K initial cluster centers (two centers, CI and NCI, K=2); ② Find the centroids of the newly created K clusters; ③ Using the centroids of step 3 as cluster centers, repeat step 2 and step 3 until the centroids no longer changed.

**Statistical analyses**

SPSS 19.0 was used for statistical analyses in this study. All of the statistical analyses were performed using the t test. All K-means clustering were conducted using MATAILAB R20120a. MATLAB function and our own K-means program algorithm were applied to determine clusters. The concordance analyses were performed using Kappa test.

**RESULTS**

**Basic data**

All of the 100 CVT patients were included in the present study. We analyzed the
average age, gender, educational level, and hypertension and hyperglycaemia of the CVT patients, and the data were showed in Table 1. There were no significant different among CI, NCI and CN groups for age, gender, educational level, hypertension. The hyperglycaemia level in the CI group were higher significantly compared with the NCI and CN group (P=0.027 and 0.013, respectively).

Table 1. Basic data of 100 cerebral venous thrombosis patients and 50 normal subjects

<table>
<thead>
<tr>
<th></th>
<th>CI (cases)</th>
<th>NCI (cases)</th>
<th>CN (cases)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (year)</td>
<td>43.26±8.6</td>
<td>44.69±9.3</td>
<td>45.57±10.2</td>
</tr>
<tr>
<td>Male (case, %)</td>
<td>55.6(35)</td>
<td>56.8(21)</td>
<td>54(50)</td>
</tr>
<tr>
<td>Educational level (year)</td>
<td>9.21±0.81</td>
<td>8.95±0.26</td>
<td>9.04±0.51</td>
</tr>
<tr>
<td>Hypertension % (case)</td>
<td>31.7(21)</td>
<td>32.4(12)</td>
<td>75(63)</td>
</tr>
<tr>
<td>Hyperglycaemia (case, %)</td>
<td>71.4(45)**,###</td>
<td>35.1(13)</td>
<td>34(17)</td>
</tr>
</tbody>
</table>

Relative beta power

The 6 channels of EEG beta power for the 100 cases of CVT patients and 50 normal controls were detected. The beta power of CI patients was decreased significantly (1.135±0.206mcV²) compared with NCI (1.648±0.107mcV²) (P<0.01) or NC group (1.701±0.313mcV²) (P<0.01) (Figure 1 and Table 2). But there was no significant difference between NCI and CN group (P>0.05).

Clustering and concordance analyses

According to the clustering method, all of the 100 CVT patients were mapped on the three highest channels, including 1, 10 and 12, to display the three-dimensional map of EEG beta power. 60 cases out of the total cognitive normality (MoCA assessment, 63 cases) post CVT distributed in the interval I ([0.8, 1.5]); and 35 cases out of the total cognitive impairment post CVT (37 cases) distributed in the interval II ([0, 1.0]). Interestingly, 3 cognitive normality and 2 cognitive impairment patients distributed in the other interval ([1.0, 1.2]), which were far apart from both convergence center. So interval I and II were selected, and compared the results with MoCA scoring (table 3). Through comparing, the clustering analyses of EEG beta power were consistent with the MoCA scoring results, and the sensitivity was 95.2% for cognitive impairment, 94.6% for cognitive normality. Kappa analyses result indicated that there was a better concordance between beta power clustering analyses and MoCA scoring method for assessing cognitive impairment (Kappa=0.837, P<0.001). The McNemar paired chi-square test showed that no significant differences were discovered between beta power analyses and MoCA scoring method for the cognitive impairment post CVT (Table 3, P=0.297).
Table 2. Relative beta power analyses of every group

<table>
<thead>
<tr>
<th>group</th>
<th>cases</th>
<th>relative beta power</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN</td>
<td>50</td>
<td>1.701±0.313</td>
</tr>
<tr>
<td>NCI</td>
<td>37</td>
<td>1.648±0.107</td>
</tr>
<tr>
<td>CI</td>
<td>63</td>
<td>1.135±0.206**,#‡‡</td>
</tr>
</tbody>
</table>

**P<0.01 and #P<0.01, represent the comparison between CI and CN, CI and NCI, respectively.

Table 3. The relationship between beta power and MoCA scoring

<table>
<thead>
<tr>
<th>MoCA scoring</th>
<th>Relative beta power</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>interval (I)</td>
</tr>
<tr>
<td>normal</td>
<td>35</td>
</tr>
<tr>
<td>cognitive impairment</td>
<td>-</td>
</tr>
<tr>
<td>total</td>
<td>35</td>
</tr>
</tbody>
</table>

DISCUSSION
Some cerebral diseases and degenerative diseases, such as cerebral hemorrhage\(^{(24)}\), cerebral infarction\(^{(26)}\), Alzheimer's disease\(^{(1)}\), Parkinson's disease\(^{(3)}\), could cause different degrees of cognitive impairment. So exploring the proper testing method has become a hot topic for the CVT research. Especially for the early
diagnostic method, it would provide an important intervention for the cognitive impairment post CVT.

In clinical, Neuropsychological scale is the most commonly used tool in the clinical for the complaints of cognitive impairment\(^{(21)}\). Neuropsychological scale can be used by clinicians to diagnose cognitive impairment or other dementia diseases, and to assess its progression and prognosis. Zhao et al\(^{(28)}\) proved that MoCA is more valuable or effective in predicting vascular cognitive impairment, and is worth of being promoted in the clinical practicing on the Chinese population. So, in the present study, the MoCA scoring was employed to assess the cognitive impairment of the CVT patients. In the previous studies, cognitive impairment of many kinds of diseases, such as cerebral infarcts, Alzheimer's disease, Parkinson disease, could be assessed by detecting the abnormality of EEG\(^{(3,13,15,24)}\). Thus, we assessed the cognitive impairment using EEG abnormalities detecting method in this study.

EEG frequency is usually described in terms of five frequency bands: delta, theta, alpha, beta and gamma\(^{(22)}\). The gamma bandwidth performs the low power and higher susceptibility to noise, the alpha and delta bandwidths appear later in the time course of some cerebral diseases, so we selected the beta power of EEG to study the cognitive impairment post cerebral hemorrhage. Thus, 6 abnormal EEG channels were employed to exhibit the differences in the relative beta power. The results indicated that the beta power of CI was decreased significantly compared with the NCI and CN group (Table 2, both \(P<0.05\)). But no difference of the beta power was found between NCI and CN group (\(P>0.05\)). So the beta power analyses can be used to distinguish the CVT with and without cognitive impairment patients. The results also showed that the number of hyperglycaemia subjects in the CI group was higher significantly than in the NCI and CN group (\(P=0.027\) and 0.013, respectively). This may illustrated that there may be some correlation between the hyperglycaemia level and beta relative power in the CVT patients, which would be discussed in the following researches.

According to the K-means clustering analyses of the EEG profiles, CVT patients were divided into two subgroups. By employing this classification algorithm, 32 of 34 CVT patients without cognitive impairment were categorized as members of subgroup 1 (interval I), and 60 of 63 CVT patients with cognitive impairment were categorized as subgroup 2 (interval II). The beta power of CVT patients was reflected on the highest channels (1, 10 and 12) displaying the three-dimensional graph to observe the difference directly. The present results indicated that the K-means clustering analyses for cognitive impairment or cognitive normality were better consistent with CoMA scoring, and the sensitivity was 95.2\% and 94.6\%, respectively. The concordance analyses result showed that beta power clustering analyses was consistent with the CoMA scoring (Kappa=0.837). The related study indicated that the Kappa value more than 0.75 was thought to be a better concordance. So there was a better concordance between the K-means clustering analyses and MoCA scoring for the cognitive impairment assessment post CVT.

In conclusion, the EEG beta power analyses technique may hold a considerable promise for the early assessment of cognitive impairment post cerebral venous thrombosis.

**Significance outcomes:**

1. Employing the EEG beta power as the assessment for the cognitive impairment post cerebral venous thrombosis.

2. Cognitive impairment patients had significantly lower EEG beta power
relative to no cognitive impairment or normal group (both P<0.05).

3. There was a better concordance (Kappa=0.837) between the beta power and MoCA scoring for cerebral venous thrombosis patients.

Limitations:
There are may be a small number of cerebral venous thrombosis patients.

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