The effect of transcranial direct-current stimulation on cortical coherence patterns in patients with major depression

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Abstract

Introduction: Major depressive disorder is one of the most common psychiatric disorders with cognitive, emotional, and behavioral symptoms. The disorder is associated with abnormalities in the cortical activity of the brain. The present study aimed to investigate the effect of transcranial direct current stimulation (tDCS) on the cortical coherence patterns of patients with major depressive disorder.

Methods: Thirty-six patients with a major depressive disorder based on the criteria specified in DSM-5 were selected by purposive sampling procedure based on including and excluding criteria. Participants were assigned randomly to one of the research groups (recipient of direct transcranial electrical stimulation, receiving false stimulant (sham), and waiting list group). All participants completed the Beck depression inventory, and their brain activity was recorded using a 19-channel EEG.

Results: The data showed that tDCS did not significantly affect interhemispheric coherence changes. However, the use of tDCS, compared with the sham group, caused a significant reduction in inter-hemispheric coherence, especially in the slow cortical bands (theta and alpha) in all three anterior, central and posterior regions of the brain, as it has become more impressive in the central regions.

Conclusion: The present study's findings reveal that transcranial stimulation of the brain reduces the pattern of abnormal brain activity, especially in the coherence of central regions. These changes reduce the abnormal energy loss in the brain and improve the pattern of information processing in patients.

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Extended Abstract

Introduction

Major depressive disorder is one of the most common psychiatric disorders with cognitive, emotional, and behavioral symptoms. The disorder is associated with abnormalities in the cortical activity of the brain. Many neuropsychiatric diseases, such as depression are associated with abnormal connectivity functions in the brain's neural networks. These abnormalities can be analyzed using a variety of tools, including electroencephalography

(EEG) and quantitative electroencephalography (QEEG). The coherence pattern is one of the components calculated by the QEEG, and is a scale that examines the coordination of connectivity across brain areas. There are two types of coherence abnormalities in depression, including the high intracranial coherence between bands, and the low coherence abnormality, as well as hemispheres in bands. It is hypothesized that the differences observed in the coherence patterns of depressed patients are mainly due to the increase in functional short-distance connectivity in the left hemisphere and long-distance connectivity in the right hemisphere. This increase has been interpreted as a mechanism of adaptation and compensation to overcome the inefficiency of integrating cortical activities. Studies have shown that EEG-based functional connectivity change following transcranial direct current stimulation (tDCS). The present study aimed to investigate the effect of tDCS on the cortical coherence patterns of patients with a major depressive disorder.

Methods

A sample of 36 patients was selected through a structured interview by psychiatrists based on the criteria specified in DSM-5, by purposive sampling procedure based on including (age range 18 to 40 years, at least 9th-grade education, the minimum duration of three months from disorder onset and right-handed) and excluding criteria (psychotic illness, mental retardation, history of seizures or epilepsy, head trauma, concomitant use of other disorders, concomitant use of drugs). All participants were assigned randomly to one of the research groups: recipient transcranial direct electrical stimulation (experimental group), the group receiving pseudo direct transcranial electrical stimulation (sham group), and the waiting list group (without any intervention). All participants were matched based on age, severity, and duration of the disease. All participants completed the Beck depression inventory, and their brain activity was recorded using a 19-channel EEG. Then, the data related to the subjects' brain waves for cortical coherence analysis were converted into quantitative electroencephalography by Neuroguide software. After these steps, the subjects of the experimental group and the sham stimulation group were introduced to the process of treatment sessions. The experimental group (tDCS) received electrical stimulation by the single-site method. In this stimulation, the anode electrode was placed in the left DLPFC region, and the cathode electrode was placed in the right DLPFC region. This stimulation was presented to the subjects with a current of 2 mA, for a duration of 20 minutes and ten consecutive days. EEG then re-evaluated subjects. The sham excitation group was such that the anodal electrodes were placed on the left DLPFC and the cathodal electrode on the right DLPFC. Subjects were then stimulated for 30 seconds, after which the device was turned off and received no stimulation. However, the electrodes were attached to the subjects' heads until the end of twenty minutes, and the subjects were unaware of the lack of stimulation. At the end of ten sessions, the electrical activity of the subjects in this group (stimulation sham) was re-recorded by an EEG device. The EEG device recorded the waiting list group simultaneously with the interventions on the experimental groups and the false stimulation in two separate phases (ten days) by the EEG device. To analyze the results, the researchers used the method of multivariate analysis of variance with repeated measures in the design of a 7 * 3 * 2 * 2 * 3, in which three expresses between group variables (tDCS groups, sham stimulation, and waiting list). Two represents the within group variable of experimental condition (pre-and post-test), other within-group variables, including the cerebral hemispheres (right and left), brain areas (anterior, central, and posterior), and different band of electrical activity (Delta, Theta, Alpha 1, Alpha 2 and Beta 1, Beta 2, Beta 3).

Results

At first, an attempt was made to evaluate the effectiveness of tDCS in reducing the severity of depressive symptoms in participants. The results of one-way analysis of covariance showed that the tDCS compared to the sham group and waiting list, also compared to the pretest, and significantly reduced the severity of depressive symptoms in participants. Although the sham group also showed decreased in symptoms, these changes were not as significant. Also, multivariate analysis of variance with repeated measures was used to compare the scores of intra-hemispheric and intra-hemispheric coherence and the interaction of its factors. The results show that the main effect of activity bands and brain areas was significant. The results also show that the interactive effect of hemisphere * group, condition * hemisphere * group, condition * regions, condition * hemisphere * band * group, regions * band, condition * regions * band, and condition * hemisphere * regions * band were significant. However, based on the significant interactions obtained, the interaction related to the condition * band * region * group is significant. It caused electrical differences in different brain areas between the experimental groups. They showed a reduction in symptoms, but these changes were not as significant as the stimulus-receiving group. Also, multivariate analysis of variance with repeated measures was used to compare the scores of intra-hemispheric and intra-hemispheric coherence and the interaction of its factors.

The multivariate analysis of variance test was used to follow this interactive effect. The results of this analysis showed that direct transcranial electrical stimulation caused the coherence pattern in the anterior, central, and posteriorly in different electrical bands in the experimental group (tDCS) have significant changes compared to the two groups of sham stimulation, and a waiting list. The post hoc test was used to examine more accurately the differences between the mean scores of experimental groups (tDCS), sham stimulation and waiting list in the hemispheric coherence pattern between groups. The findings of this analysis showed that the experimental group (tDCS) performed better in cerebral coherence than the sham when receiving extracranial stimulation, compared with the waiting list group. In other words, electrical stimulation significantly reduces the coherence in brain bands, especially theta, alpha, and beta bands in all three anterior, central and posterior regions, except alpha one band in the anterior and posterior regions compared to the sham stimulation group and the list group.

Conclusion

The results showed that there are significant interactions on coherence modulation based on brain areas (anterior, posterior, and central) in different bands (delta, theta, alpha 1, alpha 2, beta 1, beta 2, and beta 3) and between groups (actual stimulation, sham stimulation and waiting list) after tDCS. The findings of the present study showed that stimulation of tDCS led to a decrease in coherence in different bands of electrical activity, especially theta, alpha 2, and beta bands; this decrease in coherence was more significant in the central areas than in the anterior and posterior regions. Based on the findings of the present study, it should be acknowledged that transcranial stimulation has been effective in reducing intracranial coherence of patients in theta, alpha, and beta bands.

It has been shown that there is an inverse relationship between positive and negative emotions in brain waves, with positive emotion associated with high beta activity and low alpha activity in the left frontal cortex and low beta and high alpha activity in the right frontal cortex. In contrast, in depression, when emotion is negative, high alpha and beta activity is reported in the left frontal cortex and low alpha, and beta activity is reported in the right frontal cortex. In fact, high alpha activity in the left frontal cortex means less left frontal cortex activity and superior hemispheric activity, in which people are less affected by positive emotions, which indicates that a biological background for depression is provided.

These coherence patterns represent the activity of brain regions involved in specific sensory processing patterns in patients in a way that plays a significant role in autobiographical memory and the relationship between abstract and concepts. The excitatory effects of the anodal electrode on the areas receiving the stimulus are the product of a change in the neuron's excitability due to the polarization of the membrane-resting potassium and a rapid change in the ion density below the electrode location.

Ethical Considerations

Compliance with ethical guidelines

In order to observe the principles of research ethics, before starting the research, the informed consent form that explained the objectives and the research process was obtained from the participants. The information of all participants was coded with respect to the principle of confidentiality. This research has an ethical code from the Research Ethics Committee of Tabriz University of Medical Sciences with the ID (IR.TBZMED.REC.1396.385) and a clinical trial code (IRCT20180704040344N1).

Authors' contributions

Seyed Ali Arabi (first author) presented the initial research plan, collected information, and prepared the initial framework of the article; his contribution was about 35%. Gholamreza Chalabianloo (second and corresponding author) contributed to the data analysis, article writing, and all correspondence and correction of the article, and monitoring the research implementation process; his contribution was about 40%. Reza Abdi (third author) contributed through assistance in writing the article and supervising the performance; his contribution was about 25%.

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Conflict of interest

This study did not have any conflict of interest.