Letter to the Editor. Conclusions from the applications of transcranial magnetic stimulation regarding the psychopathology of depressive syndromes and the essence of self-consciousness

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Summary

The authors draw attention first to the contemporary attempts of the application of transcranial magnetic stimulation (TMS) in the treatment of cognitive impairment, personality disorders and sleep disturbances. Then they widely discuss available data related to the results of several years of application of TMS in the treatment of severe depressive episodes. They refer to the findings concerning changes found in these individuals and recall the basic data about so-called connectivity and default mode network (DMN). The results of these attempts of treatment allow to draw conclusions about psychopathological mechanisms of depressive syndromes and even the essence of self-consciousness. Dealing with these conclusions was the main goal of the authors. They are convinced that they should be familiar to every doctor.

Key words: transcranial magnetic stimulation, treatment of cognitive impairment, treatment of depression, default mode network, consciousness

Introduction

Transcranial magnetic stimulation (TMS) is a relatively new way of influencing the human brain [1]. In the last several months, the first reports of its beneficial effect on cognitive impairment of older persons were published [2, 3]. This method has also been used recently for attempts to modify borderline personality disorder [4] and in the treatment of sleep disturbances [5]. For several years this method has been used to treat depression. In this area the therapeutic effectiveness of this method was assessed objectively in many clinical trials.

Data about usefulness of this method in the clinical practice are not widely wide-spread. At the same time the essence of the method is astonishing, and the way it works seems to be amazing or even mysterious. Therefore it is worth to spread the knowledge about the essence of this method, which should be known to each physician. It is all the more justified that the essence of the discussed method and the observed consequences of its use are also related to the problem of worldview-related questions concerning the phenomenon of consciousness.

What is TMS?

The wire coils of the engine produce a directed, variable magnetic field with the induction range of several Tesla. The alternating magnetic field causes the formation of a circular electric current [1]. This electric current circulates in a plane perpendic-ular to the magnetic field force lines. If we will place the coil flat over the skull, the induced electric current circulates in the plane parallel to the coils and skull surface.

Detailed data on equipment used in TMS produced by such companies as: Brain-sway, Langer Medical, eNeura, MAG & More, Magstim, MagVenture or Neuronetics, can be found on the "Medical Expo" website [6].

Data on current TMS applications in the treatment of depressive syndromes

The method of transcranial magnetic stimulation has been used in various attempts to treat depressive syndromes for several years [7, 8]. Some authors also discuss com-parisons of performance with other kinds of treatment for depressive syndromes. For example, Zyss et al. [9, 10] believe that TMS is effective in treating severe depressive episodes that are resistant to treatment by other methods, but it is less effective than so-called electroconvulsive therapy. Some authors argue that effectiveness depends on where the application of stimuli is targeted using so-called navigation methods implemented on the basis of fMRI images [11].

Just the settlements related to the optimal location of the sites that should be chosen for TMS to be effective in treating severe depression have led to discoveries that are important for a better understanding of the essence of depressive syndrome and significance of the default mode network and even the essence of mechanisms important for the self-consciousness.

Concept of connectivity

The term 'connectivity' refers to the actually detected neuronal connections, i.e., simultaneous activity, established by functional brain imaging (fMRI). In other words, sometimes topographically distant groups of neurons in certain behavioral or perceptual situations can cooperate simultaneously and then one can say that they show 'high connectivity'. The map of such connections is called 'connectom'. fMRI

imaging can be performed under a variety of task conditions. It is important to study this connectivity for cognitive reasons – and, as it turns out, for clinical reasons – in resting conditions. In this situation, brain imaging reveals neuronal structures called 'default mode network'.

The term 'default mode network'

The default mode network (DMN) is active when the person is not focused on the outside world – during sleep and during daydream or mind-wandering. The network activates in a default mode, when a person ceases to search for solutions, when stop to be engaged in any task.

Recent neurophysiologic studies have shown, however, that DMN is also activated in some thought processes related to the past, to the future, to autobiographical remembrances and even to moral and social judgments [12].

DMN consists of many anatomical structures. Among the most important one should enumerate the posterior cingulate cortex (PCC), precuneus, medial prefrontal cortex (mPFC), angular gyrus, dorsal media prefrontal cortex (dPPP).

Changes in DMN function found in people with severe depressive episodes

Liston et al. [13] found that people with severe depressive episodes are characterized by excessively high 'connectivity' within their default mode network (DMN) and decreased 'functional connections' in the frontoparietal central executive network (CEN). Fox et al. [14] have described the efficacy of TMS targeted to the left dorsal-lateral prefrontal cortex (DLPFC), which usually coexists with decreased activity of the subgenual anterior cingulate cortex. On the contrary, Hamilton et al. [15] emphasize, in particular, the finding of increased connectivity between major parts of DMN and the subgenual prefrontal cortex (sgPFC), which is responsible for the emotional withdrawal.

Similar changes have been reported by other researchers. Georg Northoff [16] concludes the results of the above-mentioned findings in people with severe depression and states that ruminations and excessive self-directed thinking results from malfunctioning of particular parts of DMN. Also other depressive symptoms such as anhedonia, suicidal thoughts and disorganization of thinking should be attributed, according to him, to thoughts over-focused on the past and it is also due to the dysfunction of particular DMN subsystems [16]. One of titles of Georg Northoff's article captures the metaphorical quintessence of depressive disorder as follows: "No rest for the brain's resting state activity" [17].

Numerous researchers conducting controlled clinical studies using the brain imaging have reported that the application of TSM stimuli results in a reduction in over-activity of DMN subsystems [11].

The worldview-related importance of knowledge on the resting activity of the brain

The findings about the key role of the altered function of the 'default mode network' (DMN) in depressive syndrome has led to a significant credibility of the theory, which has been developing since the 1990s, that the basic process underlying self-consciousness consists in the self-excitation of neuronal circuits in cerebral subcortical structures and thalamo-cortical pathways (thalamo-cortical re-entrant processing). One of the precursors of this theory was Rodolfo Llinás, who formulated the theory of thalamocortical-resonance (oscillation) [18]. Georg Northoff developed this theory and distinguished several levels of so-called 'neural prerequisites' and 'neural substrates' of self-consciousness [19]. According to him, one of the necessary factors, though not sufficient for self-consciousness, is neuronal oscillation in the brainstem and midbrain [19].

Therefore, already at the onset of ontogenetic and phylogenetic development, not by reason of stimuli from external world, but because of the structural necessity of 'conscious information processing systems', the neural circuits which trigger themselves are formed. This is emphasized by Giulio Tononi, a researcher of the effects of TMS and the creator of the theory of consciousness resulting from the integration of information [20, 21]. The mathematician Marcus Du Sautoy, after the presentation of the discussion with Tononi, states that the basic characteristic of 'more or less conscious' systems is the existence of numerous asymmetric 'feedback connections' (which is expressed or can be measured by the value of Φ parameter) [22].

Recognition of Rodolfo Llinás and Georg Northoff's reasoning as credible also opens the door to serious consideration of the hypothesis of Hales, which assumes that secondary electromagnetic field is likely to be generated on the basis of the electric impulses circulation [23].

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