Transcranial Direct Current Stimulation in Psychiatric Disorders: A Comprehensive Review

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KEYWORDS

• Transcranial direct current stimulation • tDCS • NIBS • Psychiatric disorders
• Major depression • Schizophrenia • Obsessive-compulsive disorder

KEY POINTS

- Transcranial direct current stimulation (tDCS) is a noninvasive brain stimulation modality increasingly used for psychiatric disorders treatment.
- Because of the mixed results regarding efficacy, the authors performed a review exploring the current evidence in relation to major depression, schizophrenia, and obsessive-compulsive disorder (OCD).
- Current findings indicate that tDCS is probably effective in non-treatment-resistant depressive patients.
- Regarding schizophrenia and OCD, present evidence is promising but not robust enough.

INTRODUCTION

Transcranial direct current stimulation (tDCS) is a form of noninvasive brain stimulation (NIBS), and arguably one of humanity's earliest attempts at neuromodulation, predating electroconvulsive therapy (ECT). Its use as a therapeutic intervention can be traced as far back as the first century, with the application of torpedo fish to the scalp as a cure for

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headaches,[1] as well as to manage epilepsy.[2] A more refined and contemporary form of tDCS, known as "brain polarization," was trialed in the middle of the twentieth century for the treatment of psychiatric disorders with promising results.[3,4] Unfortunately, further research into the technique languished, with greater efforts instead devoted to ECT and pharmacologic interventions. This brief period of stagnation ended in the early 2000s following a short, but influential report detailing the antidepressant effects of tDCS,[5] heralding the return of tDCS as a treatment of psychiatric illnesses.

In-depth understandings of the workings of the central nervous system, and its electrical underpinnings, in combination with advances in technology, have led to the development and growing application of tDCS, which has been steadily gaining favor as a viable tool in the psychiatric toolbox. The appeal of tDCS as a therapeutic intervention is multifactorial: it is safe and tolerable, producing only mild side effects, such as localized paresthesia and erythema at the site of stimulation.[6,7] The device itself is portable and relatively inexpensive, and application of tDCS electrodes to the scalp is a simple process that can even be done by the patients on themselves while in the comfort of their own homes.[8]

As such, the field of brain stimulation has grown exponentially, with research currently underway examining the efficacy of tDCS across a variety of conditions, including dementia, schizophrenia, sensorineural tinnitus, chronic pain, depression, and many more. The purpose of this review is to summarize the evidence for tDCS as a treatment of psychiatric disorders.

To this end, 3 separate PubMed searches were performed including the terms "transcranial direct current stimulation" or "tDCS" and the following psychiatric disorders: major depressive disorder/depression, schizophrenia, and obsessive-compulsive disorder (verbatim and in abbreviated forms). The search was conducted from the year 2000 until November 15, 2017. Also, the authors examined recent reviews and meta-analyses for potentially relevant references.

MECHANISM OF ACTION

In tDCS, a continuous electric current of low intensity (typically between 1 and 2.5 mA) is passed between 2 electrodes placed over the scalp, for 10 to 30 minutes, to stimulate the underlying brain tissue. The stimulation results in partial depolarization of neuronal cell membranes in regions near the anode, and hyperpolarization near the cathode, causing a shift in the spontaneous rate of neuronal firing,[9] thereby modulating cortical excitability.[10,11]

Anodal stimulation lowers the firing threshold for propagation of action potentials, facilitating activity,[12] whereas cathodal stimulation inhibits activity.[13] The after effects of tDCS, which can persist up to an hour beyond the cessation of stimulation, are due to changes in synaptic neuroplasticity,[14] whereby increases in postsynaptic potentials, and decreases in synaptic efficacy, result in long-term potentiation and long-term depression, respectively.[15–17]

Interestingly, the effect of tDCS is dependent on the direction of current flow (ie, parallel or perpendicular to the orientation of underlying pyramidal neurons).[17] Because of the folding of the neocortex, the dominant flow of current is perpendicular to the neuronal columns, such that the mechanism of action of tDCS is mostly driven by polarization of synaptic terminals.[18] The influence of current direction and the importance of electrode polarity with regards to facilitation or inhibition of cortical activity highlight the relevance of electrode placement ("montages") to achieve desired tDCS outcomes.

Commonly used tDCS montages produce widespread, diffuse activation of the brain.[19] As such, on the macro scale, tDCS modulates network dynamics within