World Journal of Psychiatry

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World J Psychiatry 2024 November 19; 14(11): 1618-1622

DOI: 10.5498/wjp.v14.i11.1618

ISSN 2220-3206 (online)

EDITORIAL

Repetitive transcranial magnetic stimulation enhanced by neuronavigation in the treatment of depressive disorder and schizophrenia

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Specialty type: Psychiatry

Provenance and peer review: Invited article; Externally peer reviewed.

Peer-review model: Single blind

Peer-review report's classification

Scientific Quality: Grade C

Novelty: Grade B

Creativity or Innovation: Grade B

Scientific Significance: Grade B

P-Reviewer: Jiang YL

Received: May 13, 2024

Revised: September 23, 2024

Accepted: October 18, 2024

Published online: November 19, 2024

Processing time: 178 Days and 6.2 Hours

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Abstract

This editorial assesses the advancements in neuronavigation enhanced repetitive transcranial magnetic stimulation for depressive disorder and schizophrenia treatment. Conventional repetitive transcranial magnetic stimulation faces challenges due to the intricacies of brain anatomy and patient variability. Neuronavigation offers innovative solutions by integrating neuroimaging with three-dimensional localization to pinpoint brain regions and refine therapeutic targeting. This systematic review of recent literature underscores the enhanced efficacy of neuronavigation in improving treatment outcomes for these disorders. This editorial highlights the pivotal role of neuronavigation in advancing psychiatric care.

Key Words: Repetitive transcranial magnetic stimulation; Neuronavigation; Depressive disorder; Schizophrenia; Psychiatric care

Core Tip: Neuronavigation enhanced repetitive transcranial magnetic stimulation offers a promising avenue for treating depressive disorder and schizophrenia by addressing anatomical complexities and individual variabilities. By integrating neuroimaging data and three-dimensional positioning, neuronavigation enables precise localization of brain structures, optimizing therapeutic target selection. This article highlights its efficacy in clinical cases, indicating diverse target selection based on structural or functional alterations among patients. This innovative approach heralds a crucial advancement in mental health treatment, underscoring the importance of integrating neuronavigation technology to enhance therapeutic outcomes.

Citation: Wang XY, Zhang YB, Mu RX, Cui LB, Wang HN. Repetitive transcranial magnetic stimulation enhanced by neuronavigation in the treatment of depressive disorder and schizophrenia. *World J Psychiatry* 2024; 14(11): 1618-1622
URL: https://www.wjgnet.com/2220-3206/full/v14/i11/1618.htm
DOI: https://dx.doi.org/10.5498/wjp.v14.i11.1618

INTRODUCTION

Repetitive transcranial magnetic stimulation (rTMS) has garnered significant attention and has received regulatory approval across various countries for its efficacy in treating major depressive disorder (MDD) and schizophrenia that are resistant to conventional therapies[1]. A wealth of randomized clinical trials has solidified its therapeutic benefits[2-5]. While pharmacotherapy remains the first-line treatment option due to its accessibility and relatively lower cost, it is often limited by side effects and treatment resistance in a significant proportion of patients. Electroconvulsive therapy, despite its efficacy in treatment-resistant cases, is sometimes hindered by cognitive side effects that can impede its acceptance. In contrast, rTMS offers a non-invasive approach with a favorable safety profile and proven cost-effectiveness for patients who have not responded to other treatments[6]. With the integration of neuronavigation, rTMS has achieved enhanced precision and more reliable treatment outcomes. Previous randomized trials have indicated that the neuronavigation-guided approach resulted in a significantly greater reduction in depressive symptoms compared to traditional rTMS methods in individuals with treatment-resistant depression[7]. This suggests that neuronavigation-enhanced rTMS may provide a valuable alternative, particularly for patients who are refractory to initial treatment efforts.

This article examines recent advancements in the application of rTMS, with a particular emphasis on neuronavigation enhanced techniques. These innovations offer enhanced precision and an expanded range of intervention targets, which could lead to improved therapeutic outcomes for patients with MDD and schizophrenia. This article provides an updated overview of its clinical applications and the evidence supporting its efficacy.

NEURONAVIGATION BASED ON NEUROIMAGING DATA

Structural magnetic resonance imaging (sMRI) is a widely adopted method that is compatible with neuronavigation techniques. Mylius *et al*[8] combined sMRI data with a neuronavigation system to accurately pinpoint the dorsolateral prefrontal cortex (DLPFC), thereby refining the targeting process for rTMS. Evidence suggested that the neuro-navigational rTMS, informed by sMRI, might yield superior treatment responses in individuals with treatment-resistant depression compared to traditional targeting methods[7]. However, the enhanced treatment efficacy of sMRI-assisted neuronavigation is still under debate[9].

Functional MRI has been instrumental in shifting the focus of neuronavigation rTMS towards regions that are functionally connected to the DLPFC[10,11]. Research indicated that functional connectivity abnormalities with the DLPFC can precipitate depressive disorders[12], making the identification of effective targets based on this connectivity a significant area of investigation[13]. Resting-state functional connectivity, known for its high reproducibility, is a favored approach for selecting intervention targets and investigating underlying mechanisms[4,14-16]. Among the resting-state connectivity alterations, the subgenual anterior cingulate cortex (sgACC) has emerged as a frequently studied target due to its functional linkage with the DLPFC and its critical role in emotional regulation[17-19]. Studies have confirmed the efficacy of targeting the sgACC in personalized rTMS intervention, particularly in alleviating depressive symptoms and suicidal ideation[20-24]. The exploration of brain functional networks as individualized stimulation targets has gained momentum, given that mental disorders often involve network-level changes[16,25]. By assessing variation in the default mode network within the DLPFC[26,27] or its subregions[28], patients have demonstrated considerable symptoms relief and functional network modification after rTMS intervention. The identification of rTMS targets based on the effective connectivity has also shown promise[29].

Other strategies for identifying neuro-navigational intervention targets involve examining the functional abnormalities of psychiatric patients during various cognitive tasks. For instance, Zhang *et al*[30] targeted the task-related visual cortex and observed symptom changes that correlated with the visual cortex's functional connectivity. Another study utilized a goal-priming task on a small sample size, targeting areas with heightened activation under the task[31]. Working memory task n-back has also been employed to identify rTMS targets[32]. These studies corroborated that the connectivity between the sgACC and the DLPFC, under both resting-state and n-back task conditions, could predict treatment outcomes[24,33].

Despite demonstrating short-term efficacy, recent longitudinal studies have shown that the therapeutic benefits of neuronavigation-enhanced rTMS are sustained over a 6-month follow-up period, with patients experiencing ongoing remission from depressive symptoms and enhanced quality of life[34]. Corresponding follow-up results have been observed in the cognitive function improvements among schizophrenia patients 6 months post-neuronavigation rTMS [35]. However, the duration of these effects can vary among individuals and is influenced by factors such as the severity of the condition, the number of treatment sessions, and the patient's adherence to follow-up care protocols.

While our initial focus has been on well-established targets like the DLPFC and sgACC, emerging research has prompted us to consider additional targets. For example, simultaneous stimulation of brain regions implicated in the pathophysiology of mood disorders may offer a promising strategy, given their involvement in emotional processing and memory formation. Preliminary studies have shown that rTMS targeting these regions separately may lead to improvements in depressive symptoms, although more research is needed to confirm this hypothesis. Moreover, combining neuronavigational rTMS with transcranial direct current stimulation could represent a promising therapeutic approach [36].

SAFETY AND CHALLENGES OF NEURONAVIGATION-ENHANCED RTMS

While rTMS is generally considered safe with minimal side effects, some patients may experience transient discomfort at the site of stimulation or mild headache[37]. While serious adverse effects are rare, the importance of continuous monitoring and adherence to safety protocols cannot be overstated to minimize potential risks. The current body of evidence underscores the necessity for long-term follow-up studies to better comprehend the efficacy and to establish best practices for managing side effects associated with neuronavigation-enhanced rTMS.

The integration of neuronavigation-enhanced rTMS into clinical practice entails several challenges, including the need for specialized infrastructure to support advanced imaging and treatment equipment. Additionally, there is a requirement for trained personnel who can operate the neuronavigation systems and interpret the neuroimaging data accurately. The cost implications of implementing neuronavigation-enhanced rTMS are also significant, as it involves not only the purchase of the equipment but also the ongoing costs of maintenance and staff training. Furthermore, there are the logistical considerations, such as the time required for treatment sessions and the impact on patient flow within clinics. Potential strategies to overcome these challenges include partnerships with technology providers, training programs for clinical staff, and the development of guidelines for the effective use of neuronavigation-enhanced rTMS.

CONCLUSION

In conclusion, rTMS has increasingly become a significant treatment modality for psychiatric patients who have not responded to conventional treatments, demonstrating a moderate degree of efficacy. The combination of neuronavigation with rTMS has been shown to enhance treatment responses and improve the precision of interventions. By leveraging brain imaging data to calculate intervention targets, a wider array of options has been proven effective. Future studies should aim to enlarge the sample size and compare the efficacy of neuro-navigational rTMS with standard targeting methods. Nevertheless, neuronavigation enhanced rTMS has shown promising treatment outcomes and has contributed to the investigation of the pathological mechanisms underlying mental disorders.

FOOTNOTES

Author contributions: Wang XY and Zhang YB contributed to the writing, and editing the manuscript, illustrations, and review of literature; Cui LB and Wang XY contributed to the discussion and design of the manuscript; Cui LB and Wang HN designed the overall concept and outline of the manuscript; all of the authors read and approved the final version of the manuscript to be published.

Supported by The National Natural Science Foundation of China, No. 82271949; The Youth Project of General Items for Shaanxi Natural Science Foundation, No. 2022JQ-908; and The Key Research and Development Program of Shaanxi Province, No. 2023-YBSF-444.

Conflict-of-interest statement: All authors declare no conflict of interest in publishing the manuscript.

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S-Editor: Luo ML
L-Editor: Webster JR

P-Editor: Wang WB

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