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Clinical Potential of Transcranial Micropolarization in Neurology: A Review of Current Evidence

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Abstract The increasing prevalence of neurological disorders and their significant contribution to mortality and disability rates highlight the urgent medical and social importance of developing new therapeutic and rehabilitation technologies. Despite advances in pharmacotherapy and neurosurgery, standard treatment approaches do not always ensure stable clinical outcomes, are often associated with adverse reactions, and have notable limitations in application. In this context, transcranial micropolarization (TCMP) has attracted attention as a safe, accessible, and pathogenetically grounded method of neuromodulation. **Objective.** To review current evidence on the clinical potential of TCMP in neurology and to identify its advantages, limitations, and prospects for practical application. **Materials and Methods.** The review included publications by domestic and international authors addressing the effectiveness of TCMP in cerebrovascular and neurodegenerative diseases, as well as in cognitive and psycho-emotional disorders. Special attention was paid to data from randomized clinical trials and the results of neurophysiological and neuroimaging studies. **Results.** Literature analysis indicates that TCMP facilitates the recovery of cognitive, motor, and speech functions after stroke; improves memory, attention, and emotional-volitional regulation in patients with chronic cerebral ischemia and dementia; and enhances adaptive and communicative skills in pediatric neurology. Neuroimaging studies demonstrate that the method modulates functional activity and the plasticity of neuronal networks. The advantages of TCMP include non-invasiveness, relative ease of use, high safety, and cost-effectiveness. Limitations include the necessity of individualized treatment protocols, heterogeneity of methodologies, and a lack of long-term prospective studies. **Conclusion.** TCMP represents a promising direction in contemporary neurological practice and can be considered as an adjunct to traditional therapeutic and rehabilitation methods. Future priorities include protocol standardization, expansion of the evidence base, and integration of the method into comprehensive neurorehabilitation programs.

Keywords Transcranial micropolarization, Neuromodulation, Stroke, Cognitive impairment, Dementia, Parkinson's disease, Rehabilitation

1. Introduction

The growing prevalence of neurological diseases and their significant contribution to the structure of population disability determine the necessity of searching for new therapeutic strategies. Standard pharmacological treatments and traditional physiotherapy do not always provide sufficient clinical effectiveness and are often associated with the risk of adverse reactions. In this regard, the use of transcranial micropolarization (TCMP) becomes particularly important as a safe, accessible, and pathogenetically justified method.

The relevance of this review is determined by the need for a critical analysis of modern scientific publications devoted to the clinical potential of TCMP, identifying its advantages, limitations, and prospects for use in neurology. Summarizing the available data will help to clarify the role of this method in the comprehensive treatment of neurological diseases and to define directions for further research.

Neurological diseases in the 21st century represent one of the most significant healthcare challenges, determining mortality, disability, and quality of life worldwide. According to the World Health Organization (WHO), more than 1 billion people globally suffer from various forms of central and peripheral nervous system disorders [22]. Among them, the leading conditions include stroke, chronic cerebral ischemia, neurodegenerative diseases (Alzheimer's disease, Parkinson's disease), epilepsy, multiple sclerosis, as well as cognitive and psycho-emotional disorders.

Stroke remains the second leading cause of death worldwide and the primary cause of long-term disability in adults. Epidemiological data indicate that approximately 15 million people experience a stroke annually, of whom one-fifth die, while up to 70% of survivors require long-term medical and social rehabilitation. Chronic cerebral ischemia (CCI) occupies

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a special place among the causes of cognitive decline in the elderly, increasing the risk of vascular dementia.

Neurodegenerative processes are gaining increasing importance due to the growing life expectancy of the global population. The prevalence of dementia worldwide has already exceeded 55 million cases, and, according to WHO projections, this number could reach 152 million by 2050. These diseases create a colossal medical and social burden, as they lead to loss of independence, require constant caregiving, and result in significant economic costs.

The situation in Central Asian countries, including Uzbekistan, reflects global trends but has its own specific features. In the Republic, stroke remains one of the main causes of mortality and disability. According to national studies, up to 40–45 thousand new cases of stroke are registered annually in Uzbekistan, with a significant proportion of patients being of working age. Moreover, stroke mortality in the region exceeds that of many developed countries, mainly due to delayed medical intervention, insufficient prevention of vascular diseases, and limited rehabilitation resources.

Cognitive and psycho-emotional disorders are of particular relevance in Uzbekistan, where they remain underdiagnosed and underestimated in clinical practice. According to local studies, signs of mild cognitive impairment are identified in every third patient over 60 years old who has experienced a stroke or suffers from CCI. In addition, the high prevalence of arterial hypertension, diabetes mellitus, and atherosclerosis in the region further increases the risk of neurological pathology.

Thus, neurological diseases pose a serious challenge to healthcare systems both globally and regionally. For Uzbekistan and Central Asia, this problem has particular significance due to the high prevalence of vascular risk factors, insufficient availability of specialized rehabilitation care, and limited implementation of modern non-pharmacological treatment methods. This highlights the necessity of searching for innovative approaches capable of increasing the effectiveness of comprehensive therapy and improving patients' quality of life.

2. Results and Discussion

Despite the significant progress in modern pharmacology, as well as advances in neurosurgery and rehabilitation, the treatment of neurological disorders remains one of the most challenging tasks in clinical medicine. Pharmacotherapy, while being the primary approach to the correction of neurological impairments, does not always provide sufficient effectiveness. A number of drugs are associated with side effects, restrictions on long-term use, the development of drug resistance, or individual intolerance.

Classical methods of physiotherapy and neurorehabilitation also have limitations: they require a prolonged course, high patient engagement, and often fail to ensure stable restoration of lost functions. This issue is particularly pronounced in stroke and chronic cerebral ischemia, where a considerable proportion of patients continue to experience persistent motor, cognitive, and emotional deficits that hinder social and professional reintegration.

Given the high prevalence of neurological disorders, their chronic progression, and the tendency toward worsening outcomes, non-pharmacological methods of brain modulation aimed at activating intrinsic neuroplasticity and restoring impaired functions are gaining special importance. In recent decades, growing attention worldwide has been directed toward neuromodulation technologies — including transcranial magnetic stimulation (TMS), transcranial direct current stimulation (tDCS), transcranial micropolarization (TCMP), and other approaches.

Among these methods, transcranial micropolarization stands out for its physiological mechanism of action and favorable safety profile. The application of weak direct current enables gentle modulation of neuronal network activity, enhances neuroplastic processes, and promotes the recovery of cognitive, motor, and emotional–behavioral functions. These characteristics make TCMP a promising tool in the comprehensive treatment and rehabilitation of patients with diverse forms of neurological pathology.

Thus, the necessity for implementing novel therapeutic and rehabilitative approaches is determined by the high medical and social significance of neurological diseases, the limitations of conventional treatments, and the demand for safe and effective technologies capable of improving functional outcomes and patients' quality of life.

3. Theoretical Foundations of Transcranial Micropolarization

Historical Background

The idea of applying weak electric currents to influence the brain has a long history. As early as the 18th century, L. Galvani (1791) described the phenomenon of bioelectrical activity in muscles and nerves under the influence of electrical current, which laid the foundation for subsequent studies. In the 19th century, J. F. Duchenne (1855) was the first to apply electrical stimulation in clinical practice for the treatment of motor disorders.

In the USSR, active research on the application of weak currents began in the second half of the 20th century. One of the founders of the method of transcranial micropolarization (TCMP) was N. P. Bekhtereva (1974, 1985), who demonstrated the possibility of targeted modulation of brain function using weak direct currents of low intensity (no more than 1 mA) [1,2]. Further development of the method was provided in the works of Yu. I. Rozenfeld and colleagues (1989), who demonstrated the effectiveness of micropolarization in the treatment of children with speech disorders and delayed psychomotor development.

During the 1990s and 2000s, research actively continued. A. V. Vasilieva and colleagues (2004) reported a positive effect of TCMP on the restoration of cognitive functions in post-stroke patients. Later, interest in the method grew significantly with the progress of neurophysiology and the availability of objective assessment tools such as EEG and functional MRI.

Mechanisms of Action of Transcranial Micropolarization

The application of weak direct current (usually 0.5–1 mA) through electrodes placed on the scalp leads to a gentle modulation of neuronal network activity. Unlike transcranial magnetic stimulation (TMS) or alternating current stimulation, TCMP acts in a more physiological manner and does not induce abrupt changes in brain electrical activity.

The main mechanisms of TCMP are thought to include:

1. Modulation of cortical neuron excitability. Weak current alters membrane polarization, facilitating or hindering action potential generation (Bindman et al., 1964) [5].
2. Influence on synaptic transmission. Studies by Creutzfeldt et al. (1962) demonstrated that weak direct current can modify synaptic efficiency, enhancing long-term potentiation (LTP) processes [8].
3. Activation of neuroplasticity. Research by Nitsche & Paulus (2000, 2001) confirmed that weak currents induce persistent changes in synaptic efficacy, contributing to the formation of new neuronal connections [20,21].
4. Neurochemical effects. According to Stagg & Nitsche (2011), TCMP can modulate GABAergic and glutamatergic systems, influencing the balance between excitation and inhibition in the cerebral cortex.

Differences Between TCMP and Other Neuromodulation Methods

TCMP has several key distinctions from other neuromodulation techniques:

- Transcranial Magnetic Stimulation (TMS). TMS uses magnetic fields to induce electric currents in the cortex, producing rapid and pronounced changes in activity. However, it requires expensive equipment, produces loud noise, and may cause discomfort for patients (Hallett, 2007) [14].
- Transcranial Direct Current Stimulation (tDCS). Methodologically close to TCMP, but tDCS generally applies stronger currents (1–2 mA), whereas micropolarization uses even weaker currents (0.1–1 mA), making it more physiological and gentler (Gnezdilov et al., 2010).
- Electroconvulsive Therapy (ECT). Used in psychiatry, ECT is based on inducing seizure activity and carries a high risk of side effects [12]. In contrast, TCMP does not cause significant discomfort and is considered safe even for children.

4. Application of Transcranial Micropolarization in Cerebrovascular Diseases

Stroke: Recovery of Cognitive, Motor, and Speech Functions

Cerebrovascular diseases, particularly stroke, are the leading cause of disability and cognitive impairment in the adult population (Feigin et al., 2014) [9]. Post-stroke recovery is a complex and multi-stage process that requires a combination of pharmacotherapy and neurorehabilitation techniques. In recent decades, increasing attention has been paid to neuromodulation approaches, including transcranial micropolarization (TCMP).

The first clinical observations of the positive effects of TCMP on the restoration of speech and motor functions in post-stroke patients were presented in the works of N. P. Bekhtereva (1985) and her colleagues. The authors reported accelerated formation of compensatory inter-neuronal connections and improvements in brain bioelectrical activity as evidenced by EEG.

Modern studies confirm these results. For example, Vasilieva et al. (2004) demonstrated that a course of TCMP in patients during the early recovery phase of ischemic stroke significantly improved cognitive functions (an increase of 15–20% on the MMSE scale compared to controls) and reduced the severity of motor deficits (measured by the Fugl–Meyer scale).

Ponomareva et al. (2010) reported that TCMP promotes speech recovery in patients with post-stroke aphasia. After 15 sessions, 68% of patients showed improvements in expressive speech, which correlated with changes in bioelectrical activity in Broca's and Wernicke's areas.

Furthermore, Chervyakov et al. (2015) confirmed the effectiveness of TCMP in motor impairments: stimulation of the motor cortex improved movement coordination and accelerated rehabilitation compared to standard physiotherapy [7].

Chronic Cerebral Ischemia

Chronic cerebral ischemia (CCI) is one of the most common conditions in the elderly, associated with progressive decline in cognitive functions, memory, attention, and emotional-volitional regulation (Odinak et al., 2012) [20].

The use of TCMP in this category of patients is primarily aimed at correcting cognitive impairments. In a study by Gnezdilov et al. (2010), it was shown that after a course of micropolarization, patients with CCI exhibited significant improvements in attention and working memory (as assessed by the Wechsler test), along with reduced anxiety-depressive symptoms [12,13].

Ponomarenko et al. (2013) noted improvements in brain bioelectrical activity in patients with dyscirculatory encephalopathy following TCMP: increases in alpha rhythm power and reductions in cortical disorganization were recorded, indicating stabilization of CNS functional status.

International authors have also confirmed these findings. Kuo et al. (2014) demonstrated that the use of weak direct currents in elderly patients with cognitive decline promotes improvements in memory and learning ability, associated with enhanced neuroplasticity in the prefrontal cortex [17].

Neurodegenerative Diseases

Neurodegenerative diseases, including Alzheimer's disease, Parkinson's disease, and other forms of dementia, represent some of the most pressing challenges in modern neurology. Their prevalence is steadily increasing due to the growing life expectancy of the population, while therapeutic options remain limited (Prince et al., 2015) [21].

Transcranial micropolarization (tDCS-like technique; TCMP), as a method of modulating neuronal activity by means of a weak direct current, has been considered in recent decades as a potentially effective approach for correcting cognitive and motor impairments in this category of patients.

Alzheimer's Disease and Other Forms of Dementia

Patients with Alzheimer's disease (AD) exhibit pronounced impairments of memory, attention, and executive functions, associated with hippocampal and cortical degeneration (Jack et al., 2013) [15].

Boggio et al. (2009) demonstrated that a course of weak direct current stimulation of the fronto-parietal cortex in AD patients leads to significant improvements in episodic memory and learning ability. These improvements persisted for several weeks after the completion of procedures [6].

Ferrucci et al. (2008), in a double-blind study, reported that TCMP improved working memory and attention in patients with mild to moderate dementia, as confirmed by neuropsychological assessments (MMSE, MoCA) [10].

In Russia, similar results were obtained by Shulga et al. (2012): following a course of TCMP in patients with vascular and mixed dementia, cognitive functions improved by 18–22% compared to the control group, alongside normalization of the brain's bioelectrical activity.

Parkinson's Disease

Parkinson's disease (PD) is characterized by progressive degeneration of dopaminergic neurons and manifests with motor symptoms (tremor, rigidity, bradykinesia) and non-motor disturbances (cognitive and emotional impairments) [1].

In a study by Fregni et al. (2006), stimulation of the motor cortex with weak current reduced bradykinesia severity and improved motor performance in PD patients [11].

Benninger et al. (2010) conducted a randomized placebo-controlled trial showing that TCMP contributed to improvements in gait and balance in PD patients, with effects persisting for up to three months [4].

Domestic studies (Odinak et al., 2014) also indicated that TCMP in PD patients not only reduced motor symptoms but also enhanced cognitive indicators, including attention and processing speed.

Neuropsychiatric Manifestations and Emotional-Volitional Sphere

Neurodegenerative diseases are accompanied by depression, anxiety, and apathy, which significantly worsen patients' quality of life and adaptation (Aarsland et al., 2009) [1].

Khedr et al. (2010) showed that TCMP in patients with AD and PD reduced depressive symptoms and improved emotional well-being, which was attributed to normalization of prefrontal and limbic system activity [16].

According to Gnezdilov et al. (2015), incorporating TCMP into the complex therapy of dementia patients led to a reduction in anxiety and irritability, confirmed by HADS scale results [13].

5. Conclusions

Transcranial micropolarization (TCMP) represents one of the most promising non-pharmacological interventions in modern neurological practice. A review of the literature indicates high efficacy of TCMP across a wide spectrum of central nervous system disorders—from vascular pathologies (ischemic stroke, chronic cerebral ischemia) to neurodegenerative diseases (Alzheimer's disease, Parkinson's disease) in adult neurology.

The overall analysis of its clinical potential shows that TCMP: promotes recovery of cognitive, motor, and speech functions after stroke; improves memory, attention, and emotional state in patients with dementia and Parkinson's disease; enhances the effectiveness of complex therapy in pediatric neurology by improving adaptive and communicative skills; exerts a positive influence on brain neuroplasticity, as supported by neuroimaging evidence (fMRI, EEG, MR spectroscopy).

The advantages of the method include its non-invasiveness, relative ease of application, low cost, and high safety profile. The limitations involve the necessity of individualized stimulation protocols, lack of long-term studies with large patient cohorts, and methodological inconsistencies that hinder result standardization.

Thus, TCMP occupies an important place among modern rehabilitation technologies and can be considered an effective adjunct to traditional therapeutic approaches in neurology. Promising directions include expanding clinical research, developing standardized stimulation protocols, and integrating TCMP into comprehensive neurorehabilitation programs.

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