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EFFECTIVENESS OF EARLY REHABILITATION IN PATIENTS WITH ISCHEMIC STROKE

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Abstract: The study evaluates the effectiveness of early comprehensive rehabilitation in patients with acute ischemic stroke, emphasizing the role of transcranial magnetic stimulation (TMS) as part of the treatment program. Ninety patients aged 56–76 years were divided into three groups: the main group received standard therapy combined with TMS; the first comparison group received placebo TMS; and the second comparison group underwent low-intensity magnetic therapy. Clinical, neuropsychological, and duplex ultrasound assessments were performed before and after treatment. The inclusion of TMS resulted in a significant regression of motor deficits (mean NIHSS improvement from 15.2 to 10.4 points), enhancement of cognitive function (MMSE from 22.0 ± 0.3 to 27.6 ± 0.5), and reduction of anxiety and depressive symptoms (HADS scores decreased by over 40%). Duplex sonography confirmed normalization of cerebral blood flow velocity in the internal carotid artery on the affected side (up to 57.6 ± 2.5 cm/s). At six-month follow-up, 42% of patients in the TMS group reported sustained improvement. The findings suggest that early use of TMS in ischemic stroke rehabilitation accelerates neuroplastic recovery and contributes to better functional outcomes.
Keywords: ischemic stroke, rehabilitation, transcranial magnetic stimulation, cognitive recovery, cerebral hemodynamics, neuroplasticity.

ЭФФЕКТИВНОСТЬ РАННЕЙ РЕАБИЛИТАЦИИ БОЛЬНЫХ С ИШЕМИЧЕСКИМ ИНСУЛЬТОМ

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Аннотация: Проведено исследование эффективности ранней комплексной реабилитации больных в остром периоде ишемического инсульта с применением транскраниальной магнитной стимуляции (ТМС). В исследование включено 90 пациентов в возрасте 56–76 лет, разделённых на три группы: основная группа получала стандартное лечение в сочетании с ТМС, первая группа сравнения — плацебо ТМС, вторая — низкоинтенсивную магнитотерапию. Оценка состояния проводилась по клиническим, нейропсихологическим и ультразвуковым критериям до и после лечения. Включение ТМС в комплексную терапию привело к достоверному регрессу двигательного дефицита (среднее улучшение по NIHSS с 15,2 до 10,4 баллов), повышению когнитивных функций (MMSE с 22,0 ± 0,3 до 27,6 ± 0,5), снижению тревожности и депрессии (HADS уменьшился более чем на 40%). По данным дуплексного сканирования отмечено восстановление скорости кровотока во внутренней сонной артерии (до 57,6 ± 2,5 см/с). Через 6 месяцев улучшение самочувствия сохранялось у 42% пациентов основной группы. Результаты подтверждают, что раннее применение ТМС способствует активации нейропластических процессов и улучшению функционального восстановления.

Ключевые слова: ишемический инсульт, реабилитация, транскраниальная магнитная стимуляция, когнитивное восстановление, церебральная гемодинамика, нейропластичность.

ISHEMIK INSULT BILAN OG‘RIGAN BEMORLARDA ERTA REABILITATSIYA SAMARADORLIGI

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Annotatsiya: Ushbu tadqiqotda o‘tkir ishemik insult bilan og‘rigan bemorlarda kompleks erta reabilitatsiya samaradorligi, xususan transkranial magnit stimulyatsiyasi (TMS) qo‘llanilishining natijalari baholandi. 56–76 yoshdagi 90 nafar bemor uch guruhga bo‘lindi: asosiy guruh — standart davolash + TMS, birinchi taqqoslash guruhi — platsebo TMS, ikkinchi guruh — past intensivlikdagi magnitoterapiya. Davolashdan oldin va keyin klinik, neyropsixologik hamda doppler ultratovush ko‘rsatkichlari o‘rganildi. TMS qo‘llanilganda harakat buzilishlari sezilarli kamaydi (NIHSS o‘rtacha 15,2 dan 10,4 ballgacha), kognitiv funksiyalar yaxshilandi (MMSE 22,0 ± 0,3 dan 27,6 ± 0,5 gacha), tashvish va depressiya darajasi pasaydi (HADS 40% dan ortiq kamaydi). Ichki uyqu arteriyasi oqim tezligi 57,6 ± 2,5 sm/s gacha normallashdi. 6 oy o‘tgach, TMS olgan bemorlarning 42%ida sog‘lig‘i yaxshilangan holda saqlanib qoldi. Natijalar TMSning erta qo‘llanilishi neyroplastik tiklanishni tezlashtirishi va funktsional natijalarni yaxshilashini ko‘rsatadi.
Kalit so‘zlar: ishemik insult, reabilitatsiya, transkranial magnit stimulyatsiya, kognitiv tiklanish, miya gemodinamikasi, neyroplastiklik.

Introduction. Stroke is one of the leading causes of mortality and permanent disability. Each year, approximately 10 million new cases are registered worldwide, and around 450,000 in Russia. Currently, more than 1 million people in the Russian Federation live with the consequences of cerebral stroke [4]. In the structure of acute cerebrovascular accidents (ACVA), ischemic strokes predominate [3]. Post-stroke rehabilitation is an integral part of therapeutic and preventive measures, aimed at improving the quality of life of patients with ACVA and facilitating their rapid return to normal functioning [3].

In the acute period of stroke, the main objectives of rehabilitation are early mobilization of patients, prevention of pathological conditions and complications, and restoration of voluntary movements. Rehabilitation interventions for ischemic stroke should begin in the neuro-intensive care unit within the first 24 hours after hospital admission and include early verticalization, positioning therapy, and passive and active kinesiotherapy. By days 3–4, the rehabilitation program expands to include physiotherapy methods, massage, and speech therapy sessions [4, 5].

Transcranial methods involving continuous and pulsed currents, as well as electric and electromagnetic fields, are attracting increasing attention from researchers and are being actively used in medical practice [6, 7]. In recent years, studies have been published on the effects of high-intensity magnetic fields (magnetic induction above 0.7–1.0 T) in patients with ischemic stroke during the recovery period [8].

Transcranial magnetic stimulation (TMS) is a non-invasive exposure of the nervous system to a high-intensity pulsed magnetic field (magnetic induction above 1.0 T), which produces a pronounced response from brain structures and related effectors [9]. According to the literature, exposure of the brain to a high-intensity magnetic field, in addition to improving cell function by normalizing cerebral perfusion, leads to plastic regenerative changes in nervous tissue and the formation of new synapses within 10–14 days. Active reorganization of cortical motor representations is observed [9, 10]. Furthermore, stimulation of the left frontal area improves mood and positively influences cognitive functions [9, 11].

Objective: To evaluate the effectiveness of comprehensive rehabilitation in patients with ischemic stroke during the acute period using TMS. An open, prospective, randomized, controlled study was

conducted in three parallel groups at the Samarkand Branch of the Republican Scientific Center of Emergency Medical Care. All patients signed informed consent to participate in the study.

Methods of Assessment. The inclusion criteria were: acute phase of ischemic stroke, motor deficit in the form of hemiparesis ranging from 0 to 4 points, speech disturbances, acute cognitive and emotional-affective disorders. Exclusion criteria included: hemorrhagic stroke (intracerebral or subarachnoid hemorrhage), severe perceptual aphasia, psychomotor agitation, severe somatic condition, moderate to severe pre-stroke dementia, pronounced neurological deficit in the premorbid period, presence of a cardiac pacemaker, history of neurosurgical intervention with implanted metal structures, or pre-existing epileptic seizures.

A total of **90 patients** aged **56 to 76 years** (mean age 67.1 ± 1.3 years) were examined. Among them, **48 (53.3%) were men** and **42 (46.7%) were women**.

The **main group** consisted of **31 patients**, who received, in addition to standard therapy (dietary regimen, pharmacological treatment with neuroprotective agents, antihypertensive drugs, and antiplatelets), a course of **transcranial magnetic stimulation (TMS)** starting on the **third day** of hospitalization. TMS was performed using a **Neuro-MS magnetic stimulator** (Neurosoft, Russia) with a **circular coil** targeting both the ischemic focus and the contralateral hemisphere, as well as a **double-cone coil** applied to the left frontal region.

The **circular coil** operated with the following parameters:

- Stimulation frequency — **5 Hz** over the ischemic focus and **0.1 Hz** over the contralateral hemisphere;
- Burst duration — **3 s**;
- Inter-burst interval — **3 s**;
- Total session duration — **3 minutes**.

The **double-cone coil** parameters were:

- Frequency — **10 Hz**;
- Burst duration — **2.5 s**;
- Inter-burst interval — **5 s**;
- Session duration — **3 minutes**.

The **treatment course included 10 sessions**, conducted in the morning.

The **first comparison group** included **30 patients** who received the same standard therapy (diet, medications, therapeutic exercises), but instead of active stimulation underwent **placebo TMS** procedures performed under identical conditions with the device turned off.

The **second comparison group** consisted of **29 patients** who received an identical therapeutic regimen, but instead of TMS underwent **low-intensity magnetic therapy** using the *Cascade* apparatus (Russia) with a magnetic induction of **10 mT**, frequency **2.5 Hz**, duration **20 minutes daily**, for a total of **10 sessions** per course.

All three groups were comparable in terms of sex, age, baseline clinical presentation, comorbidities, and basic treatment modalities.

Upon admission, to verify the diagnosis and determine the stroke subtype, **multislice computed tomography (MSCT)** of the brain and **duplex scanning of brachiocephalic arteries (DSBCA)** were performed.

The criteria for therapeutic effectiveness included:

- Positive dynamics on **clinical and neurological examination**,
- Improved **duplex ultrasound parameters** of cerebral blood flow,
- Enhanced **daily activity** according to standardized scales:
    - Rivermead Mobility Index (RMI),
    - Modified Rankin Scale (mRS),
    - National Institutes of Health Stroke Scale (**NIHSS**).

Cognitive function was assessed using:

- The **Mini-Mental State Examination (MMSE)**,
- Visual and numeric memory tests (“Image Recall” and “Digit Memory”).

Emotional and psychological state was evaluated using the **Hospital Anxiety and Depression Scale (HADS)**.

All assessments were conducted **before** and **after completion** of the 10-day rehabilitation course.
Statistical Analysis and Results. Statistical processing of the obtained data was performed using the calculation of mean values (M), standard error of the mean (m), Student–Fisher's t-test, and the chi-square (χ^2) test for homogeneity. Differences were considered statistically significant at $p < 0.05$ and $\chi^2 > 3.7$. Before treatment, the severity of motor deficit among patients of all three groups did not significantly differ and averaged **2.6 ± 0.1 points**. In the **main group**, following the inclusion of **transcranial magnetic stimulation (TMS)** in the comprehensive rehabilitation program, the mean motor score improved to **4.0 ± 0.2 points ($\chi^2 > 3.7$)**. Muscle strength increased to full recovery in **8 (26%)** patients, reached **4 points** in **20 (64%)**, and remained at **3 points** in **3 (10%)**.
In the **first comparison group**, muscle strength also improved but to a lesser degree, averaging **3.3 ± 0.3 points ($\chi^2 > 3.7$)**, which was significantly lower than in the main group. Full recovery was observed in **1 (3%)** patient, improvement up to **4 points** in **10 (33%)**, up to **3 points** in **15 (50%)**, while **4 (14%)** patients retained a strength deficit of **2 points**.
In the **second comparison group**, which received **low-intensity magnetic therapy**, the mean motor score reached **3.9 ± 0.4 points ($\chi^2 > 3.7$)**, also inferior to the main group. Muscle strength increased to **5 points** in **3 (11%)** patients, to **4 points** in **17 (59%)**, to **3 points** in **8 (28%)**, and remained at **2 points** in **1 (2%)** patient.
At admission, nearly all patients reported **anxiety, low mood, and reduced interest in surroundings**, indicating a depressive component. The baseline **Hospital Anxiety and Depression Scale (HADS)** scores were comparable across groups: the average anxiety score was **15.5 ± 1.2**, and the depression score was **19.3 ± 1.6**.
After treatment, the **main group** demonstrated a significant reduction in anxiety and depressive symptoms — anxiety decreased to **9.2 ± 1.1 points ($\chi^2 > 3.7$)**, and depression to **12.5 ± 0.8 points ($\chi^2 > 3.7$)**.
Although the comparison groups also showed positive changes, the improvement was **statistically less pronounced** than in the main group.
Cognitive function, assessed with the **Mini-Mental State Examination (MMSE)**, revealed **mild cognitive impairment** in all groups prior to therapy. By the end of the treatment course, a marked and statistically significant improvement in cognitive performance was noted, especially in patients who received TMS, compared with the other two groups (Table 1).

Table 1. Dynamics of Cognitive Function (MMSE Scores; M ± m)

Group	Assessment Time	Before Treatment	After Treatment
Main group (n = 31)		22.0 ± 0.3	**27.6 ± 0.5***
Comparison 1 (n = 30)		22.1 ± 0.4	**23.3 ± 0.4^**
Comparison 2 (n = 29)		22.0 ± 0.3	*24.7 ± 0.5^**

Note:

- — Differences are statistically significant compared with pre-treatment values ($\chi^2 > 3.7$).

^ — Differences are statistically significant compared with the main group after treatment ($\chi^2 > 3.7$).*

Neuropsychological Testing and Functional Recovery Analysis. Neuropsychological testing using the *"Image Memory"* and *"Digit Memory"* assessments demonstrated a notable improvement in rehabilitation outcomes across all examined groups.
Before treatment, the **average number of recalled images** in the *"Image Memory"* test was **3.0 ± 0.5** in the main group, **3.6 ± 0.6** in the first comparison group, and **3.8 ± 0.4** in the second comparison group. The **average number of remembered digits** in the *"Digit Memory"* test was **3.3 ± 0.5** in the main group, **3.5 ± 0.6** in the first comparison group, and **3.5 ± 0.4** in the second. These values reflected a **moderate short-term memory deficit**, and baseline results were comparable among all groups without statistically significant differences.
After completing the comprehensive rehabilitation course, the **number of recalled images and digits increased significantly** in all study groups. In the **main group**, short-term memory improved by **about 33% ($p < 0.001$)** in the *"Image Memory"* test and by **around 29% ($p < 0.001$)** in the *"Digit Memory"* test, reaching near-normal reference values. In the **first comparison group**, the

"Image Memory" score improved by **approximately 19% (p < 0.01)** and the *"Digit Memory"* score by **about 17% (p < 0.01)**, which still corresponded to **mild organic impairment** (Grade II). In the **second comparison group**, which received **low-frequency magnetic therapy**, the improvement reached **27% (p < 0.05)** for the *"Image Memory"* test and **25% (p < 0.01)** for the *"Digit Memory"* test, also indicating mild residual impairment but less pronounced than in the main group.

Comparative Analysis of Daily Activity. A comparative evaluation of **daily activity** in patients with acute ischemic stroke across the three groups showed that **baseline indicators were similarly low** and did not differ significantly. Following therapy, **post-treatment functional recovery scores were notably higher in the main group**, confirming the advantage of adding transcranial magnetic stimulation to the rehabilitation protocol (Table 2).

Table 2. Dynamics of Daily Activity in Patients with Acute Ischemic Stroke (scores; M ± m)

Group	Test	NIHSS	Rivermead Mobility Index	Modified Rankin Scale
Main group (n = 31)	Before / After	15.2 ± 0.1 / 10.4 ± 0.2*	3.0 ± 0.1 / 4.2 ± 0.1*	4.2 ± 0.1 / 1.4 ± 0.1*
Comparison 1 (n = 30)	Before / After	15.0 ± 0.1 / 8.2 ± 0.2*, ^	2.8 ± 0.2 / 3.7 ± 0.2*, ^	4.3 ± 0.1 / 2.4 ± 0.1*, ^
Comparison 2 (n = 29)	Before / After	14.8 ± 0.2 / 9.8 ± 0.2*, ^	2.6 ± 0.1 / 4.0 ± 0.2*, ^	4.6 ± 0.2 / 1.6 ± 0.1*, ^

Note:

- — Differences are statistically significant compared with pre-treatment values ($\chi^2 > 3.7$).

^ — Differences are statistically significant compared with the main group after treatment ($\chi^2 > 3.7$).

Thus, the inclusion of **transcranial magnetic stimulation** in early post-stroke rehabilitation contributed to a **more pronounced improvement in motor recovery, cognitive performance, and everyday functional independence** compared to standard or low-intensity magnetic therapy protocols.

Doppler Ultrasound Findings and Long-Term Outcomes. Duplex scanning (DSBCA) data revealed distinct characteristics of the major cerebral blood flow in patients with ischemic stroke at the time of hospital admission. The condition of the blood flow in the main extracranial arteries of the head in all three study groups was marked by a **high incidence of stenotic lesions**. Signs of stenosis in the carotid or vertebral arteries were found in **about 82 patients (around 89%)**, with a predominance of **hemodynamically insignificant isolated stenoses** of the internal carotid arteries. According to Ivanova et al. [12], patients with ischemic stroke may exhibit **flow asymmetry** in the middle cerebral artery territory, with a reduction in velocity on the affected side. In the present study, the **blood flow velocity in the carotid system** at admission was reduced due to decreased flow in the internal carotid artery—averaging **approximately 33.8 ± 3.1 cm/s** on the affected side across all groups. In contrast, blood flow in the vertebrobasilar system remained **within normal limits**.

After completion of the treatment course, patients in the **main group** showed a significant **normalization of blood flow velocity** in the internal carotid artery on the affected side, reaching **about 57.6 ± 2.5 cm/s**, which was **significantly higher (p < 0.05)** than in the comparison groups. Predictably, the **diameter of the carotid arteries** at the extracranial level remained unchanged before and after therapy, averaging **6.2 ± 0.3 mm**. A **6-month follow-up** was conducted to assess the long-term outcomes of rehabilitation in patients with ischemic stroke who underwent comprehensive inpatient treatment. After six months, in the **main group**, **13 patients (around 42%; p < 0.05)** reported an improvement in their general condition, **3 patients (10%; p < 0.05)** noted worsening, and **15 patients (48%; p < 0.05)** reported no significant change. In the **first comparison group**, **6 patients (20%; p < 0.05)** noted improvement, **20 patients (67%; p < 0.05)** remained stable, and **4 patients (13%; p < 0.05)** reported worsening. In the **second comparison group**, improvement was observed in **5 patients (17%; p < 0.05)**, stability in **15 patients (52%; p**

< 0.05), and deterioration in **9 patients (31%; p < 0.05)**. Worsening of health status across all groups was mainly observed in individuals with **comorbid somatic diseases**, most often involving **cardiovascular pathology**.

Conclusion. The inclusion of **transcranial magnetic stimulation (TMS)** in the comprehensive treatment of patients with **acute ischemic stroke** contributes to a **reduction of motor deficits**, an **improvement in daily functional activity**, and a **decrease in cognitive impairment levels**.

TMS has been shown to **significantly normalize cerebral hemodynamics** within the **internal carotid artery territory** on the affected hemisphere, promoting the restoration of adequate cerebral perfusion.

At the **6-month follow-up**, the majority of patients who underwent TMS-based rehabilitation demonstrated **sustained improvement in well-being and neurological recovery**, supporting the role of early magnetic neuromodulation as an effective adjunct to post-stroke rehabilitation.

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