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POTENTIAL USE OF TRANSSPINAL DIRECT CURRENT STIMULATION FOR CEREBRAL CIRCULATION CORRECTION

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Research objective: to prove the potential use of Trans spinal direct current stimulation for treatment of brain systems functioning disturbance attached with regulation of vasal tonus. Identify the most effective localizations and exposure regimens, so that in the future they can be used purposefully, for the treatment of cerebral blood flow disorders. **Materials and methods.** 38 children aged 4-12 years were examined who were treated with TSDCS and who had EEG at the beginning of the course of treatment – signs of hemolytic dysfunction with ICD-10 diagnoses as mental retardation (F70-F79), disorders of psychological development (F80-F89) or as behavioural and emotional disorders with onset usually occurring in childhood and adolescence (F90-F98). The following examinations were performed: an electroencephalogram, a neurological examination. The trans spinal direct current stimulation was carried out by a constant current of 100-200 μA, during 30-40 min. At the same time, the cathode was located lateral from the spinous process of the seventh cervical vertebra C7, and the anode counterlaterally to the cathode in the lumbosacral region at the level of the spinous processes L5-S1. A total of 3 to 5 sessions of TSDCS were conducted. A repeat EEG examination with the determination of Hemolucleodynamics Coefficient (HC) was performed 7-10 days after the last TSMP session. **Result.** After the course of TSDCS, all patients significantly decreased the HC score. In 27 patients (71%) patients, HC decreased to the norm value (⩽1,2). In 23 patients (29%), HC values corresponded to the first degree of hemolytic dysfunction.

Keywords: mental retardation; behavioural and emotional disorder; disorder of psychological development; trans spinal direct current stimulation; TSDCS; direct current stimulation cerebral blood flow; electroencephalogram.

ВОЗМОЖНОСТЬ ПРИМЕНЕНИЯ ТРАНССПИНАЛЬНОЙ МИКРОПОЛЯРИЗАЦИИ ДЛЯ КОРРЕКЦИИ ЦЕРЕБРАЛЬНОГО КРОВООБРАЩЕНИЯ

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Цель исследования – обосновать возможности применения трансспинальной микрополяризации (ТСМП) для лечения нарушения функционирования мозговых систем, связанных с регуляцией сосудистого тонуса. Выявить наиболее эффективные локализации и режимы воздействия с тем, чтобы в будущем использовать их целенаправленно для лечения нарушений церебрального кровотока. **Материалы и методы.** Исследовано 38 детей в возрасте 4–12 лет, которым было показано лечение с применением ТСМП и у которых в начале курса лечения обнаруживались ЭЭГ-признаки нарушения гемоликвородинамики с диагнозами, характеризующимися по МКБ-10 как умственная отсталость (F70-F79), расстройства психологического развития (F80-F89) или как эмоциональные расстройства и расстройства поведения (F90-F98). Проводились электроэнцефалограмма и осмотры невролога. Поляризация спинного мозга осуществлялась постоянным

током 100–200 мкА в течение 30–40 мин. При этом катод располагался латеральнее от остистого отростка седьмого шейного позвонка, а анод контрлатерально катоду в пояснично-крестцовой зоне на уровне остистых отростков L_5-S_1. Всего проводили от 3 до 5 сеансов ТСМП. Повторное ЭЭГ-обследование с определением коэффициента гемоликвородинамики (Кг) выполняли на 7–10-й день после последнего сеанса ТСМП. **Результат.** После курса ТСМП у всех пациентов значительно снизился показатель Кг. У 27 пациентов (71 %) Кг снизился до значения нормы (≤1,2). У 23 пациентов (29 %) показатели Кг соответствовали первой степени нарушения гемоликвородинамики.

Ключевые слова: микрополяризация; ТСМП; ТКМП; гемоликвородинамика; церебральный кровоток; электроэнцефалограмма.

Approximately 20–50% of children with perinatal ontogenesis suffer from various morphofunctional disorders of the central nervous system (CNS). Diseases leading to CNS dysfunction are often characterized by residual and dyscirculatory manifestations of cerebral blood supply disorders. The high prevalence of these morphofunctional changes in the circulatory system emphasizes the necessity for effective methods of treatment and prevention of progression of hemo- and fluid-dynamic disorders [2–4, 13].

An effective method for the treatment of a number of disorders associated with dysfunction of brain systems, affecting the regulation of the vascular tone is micropolarization.

Transcranial micropolarization (TCMP) is a therapeutic procedure based on a controlled change in the functional state of the CNS through direct exposure to a low-intensity direct current [9].

"The general physiology of the nervous system does not have a better factor as an irritant, that changes gradually and, most importantly, adaptively (depending on the initial state of the neural substrate) the functional state of the nervous tissue" [11].

The physiological basis of the clinical use of TCMP for the treatment of CNS disorders, including safety, was established through research conducted at the Institute of Experimental Medicine of the Russian Academy of Medical Sciences in the 1970s and 1980s [6, 10].

Micropolarization techniques have been used since 1989 in the clinical practice of the City Center for the Restorative Treatment of Children with Psychoneurological Disorders (CCRTCPD). Presently, in addition to TCMP, polarization of the spinal cord (PSC) is widely used at the center. Specialists at the center may use the term "trans-spinal micropolarization" (TSMP) when referring to the effect on the CNS through the spinal cord. Although this term is not entirely appropriate, it emphasizes the ability of this method to influence the CNS and is associated with the term TCMP established in the Russian medical literature. Nowadays, TSMP is used for the treatment of severe forms of motor disorders. Moreover, it is used as a preparatory procedure, aiming at the normalization of the neurodynamic characteristics of cerebral activity in patients with various forms of psychoneurological pathology, prior to conducting TCMP [5, 9–11].

The use of certain micropolarization regimens for the treatment of various psychoneurological disorders showed that some patients experience reduction and often elimination of the clinical symptomatology associated with disorders of hemo- and fluid-dynamics (headaches, dizziness [often non-systemic], a feeling of heaviness in the head, tinnitus, general weakness, increased fatigue, emotional lability, sleep disturbances, decreased memory and attention, meteosensitivity, motion sickness, etc.). This encouraged the investigators of the present study to conduct a retrospective analysis of such cases. The analysis reviewed the results of clinical trials which involved the use of micropolarization in the CCRTCPD. Since an electroencephalographic examination (EEG) is a prerequisite prior to micropolarization, the scoring scale developed by I.A. Svyatogor and N.L. Guseva was used for the quantitative assessment of the state of hemo- and fluid-dynamics [6]. In particular, the coefficient of hemo- and fluid-dynamics Kh was calculated as a ratio of the average power of theta waves in the frontal leads (Fp1, Fpz, Fp2, and Fz) to the average power of theta waves in the parietal leads (P3, Pz, and P4). It is generally accepted that the normal value of Kh should not exceed 1.2 in both the background recording of the EEG and under the influence of functional loads. A coefficient value exceeding 1.2 denoted deviation from the norm. The degree of hemo- and fluid-dynamics disorder of the brain is proportional to the value of its coefficient [7, 8].

However, the above scale was developed for research involving adult patients. The aim of the first stage of the present study was to assess the applicability of the use of the Kh in the quantification of the state of hemo- and fluid-dynamics in children

More than 470 case histories of patients aged 3–14 years were reviewed. The case histories of all the patients included EEG-examination protocols using the scoring scale developed by I.A. Svyatogor, which were compared with other studies determining the state of hemo- and fluid-dynamics of patients. CHs were selected, including ultrasound (US) of the neck and/or brain vessels, neurosonography, magnetic resonance

imaging (MRI), computed tomography (CT), and X-ray (Rg) scan of the cervical spine. A time interval of ≤ 3 months was allowed between studies, provided that during this period the patients did not receive any medication or other treatment that could potentially affect their hemo- and fluid-dynamics (e.g., drugs of the nootropic group, massage, physiotherapy procedures, micropolarization, etc.). In accordance with the selection criteria, 54 CHs were selected. The CHs included US duplex examination of the transcranial arteries of the head using color mapping of the blood flow (17 patients); transcranial dopplerography (21 patients), or both (16 patients). In addition, CHs included CT or MRI examinations (14 patients) and neurosonography (31 patients). The statistical software Statistica 6.1 was used to rank and analyze all the data intended for computer processing. The standardization of US data was conducted with the assistance of E.V. Panteleeva, a specialist in the Department of Ultrasound Diagnostics of CDC. The data arrays were added in the summary table, which were indicated in the survey protocols according to the analyzed traits of "venous outflow," "blood flow velocity asymmetry," "blood flow dependence on rotation," "signs of a dysregulatory disorder," "tortuosity," and other vascular deformities. Neurosonography, CT, and MRI data were also included in the summary table for analysis. The revealed signs (dilatation of the subarachnoid space and/or ventricle dilatation), and other signs of residual disorders were ranked according to the degree of influence on fluid-dynamics. Descriptions of the pathologies of the cervical region using Rg, US, CT, or MRI approaches were also ranked according to the degree of influence on hemodynamics. The data were distributed as follows:

0 — no signs of disorder;

1 — changes not affecting hemodynamics and/or those not indicating a disorder of hemo- and fluid-dynamics;

2 — changes influencing hemodynamics and/or those indicating a disorder of hemo- and fluid-dynamics;

3 — changes influencing hemodynamics significantly and/or those indicating a significant disorder of hemo- and fluid-dynamics.

The analysis and evaluation of hemo- and fluid-dynamics and the Kh of patients according to the EEG protocol and the examination were performed by the developers of the method I.A. Svyatogor and N.L. Guseva. The EEG data were distributed according to the value of the Kh:

0 — no indirect signs of hemo- and fluid-dynamics disorder;

1 — first degree ($1.2 < Kh \leq 2.0$) in the background recording with rhythmic photostimulation or hyperventilation, $Kh > 1.5$;

2 — second degree $2.0 < Kh < 3.0$ in the background recording with rhythmic photostimulation or hyperventilation, $Kh \geq 0.2$;

3 — $Kh \geq 3.0$.

The statistical software Statistica 6.1 was used to process the data.

In the non-parametric correlation analysis (gamma statistics), high correlation coefficients ($r = 0.82$) were obtained at a statistically significant level ($p < 0.001$) between the presence of hemo- and fluid-dynamics signs (Kh) using EEG and signs of hemodynamic disorder according to US examination data, as well as signs of hemo- and fluid-dynamics disorder according to CT and MRI data. Based on these results, it was concluded that the indirect signs of hemodynamic disorder determined using EEG are comparable with the results of US of the cerebral blood flow.

The use of computer EEG for the assessment of hemo- and fluid-dynamics permitted the post factum application of previously obtained data for the identification of the most effective localization and modes of exposure. This information may be used in the future for the treatment of cerebral blood flow disorders. This was the aim of the second stage of this study.

For this purpose, the CHs of 44 patients aged 4–12 years with indirect signs of hemo- and fluid-dynamics disorder ($Kh \geq 1.2$) according to EEG prior to treatment were selected. Most of the cases were children with residual and organic lesions of the CNS with emotional and psychological development disorders. All the patients received a course of micropolarization, the technique of which depended on the nature of the disorders. TSMP was performed at the initiation of the treatment. The laterality of active electrodes depended on the patient's initial condition. The number of sessions (range: 3 to 5) was determined during treatment via a number of symptoms, depending on the dynamics of the patient's clinical status. The zones for TCMP were selected individually for each patient, depending on the specific dysfunction and clinical indications. EEG analysis prior to and after treatment revealed normalization of the Kh in 27 patients (61%). An analysis of the treatment protocols revealed that TSMP was conducted in all the patients in a similar manner, with minor variations in localization and the number of sessions. In accordance with a number of factors, it was suggested that an improvement in the Kh values (indicating normalization of the cerebral blood flow) is a consequence of TSMP normalizing the neurodynamic characteristics of brain activity.

The aim of the final stage of this study was to analyze the possibility of using TSMP in the treatment of impaired functioning of brain systems associated with regulation of the vascular tone.

Table 1

Indices of blood and CSF circulations in the groups before and after transparallel of micropolarization

Group	The average value of Kh before TSMP	The average value of Kh after TSMP
I (1,2 < Kh < 2,0)	1,81 ± 0,25	1,15 ± 0,15
II (2,0 < Kh ≤ 3,0)	2,19 ± 0,24	1,24 ± 0,19
Only two groups	1,89 ± 0,33	1,18 ± 0,16

A total of 38 patients aged 4–12 years, with indication for treatment using TSMP and signs of hemo- and fluid-dynamics disorder according to EEG at the initiation of treatment ($1.2 \leq Kh \leq 3.0$ in the background record with rhythmic photostimulation or hyperventilation, $Kh \geq 1.5$). All the patients had various symptoms of impaired mental function, characterized according to the ICD-10 as mental retardation (F70–F79), psychological development disorders (F80–F89), or emotional and behavioral disorders (F90–F98) [12]. Examination using EEG and the calculation of Kh were performed prior to the course of micropolarization (≤ 30 days). Prior to the first session (1.5 months) and during the course of treatment, the patients did not receive any medication or other treatment that could potentially affect the functional state of the CNS. This is an obligatory condition for treatment using micropolarization at this center, determined by the expediency of treatment. PSC was performed using a constant current of 100–200 μA for 30–40 min. The cathode was placed laterally to the nuchal bone, whereas the anode was placed contralaterally to the cathode in the lumbosacral region at the level of the spinous processes L5–S1. A total of 3–5 sessions of TSMP were performed. A repeated EEG examination with calculation of the Kh was conducted 7–10 days after the last TSMP session (Table 1).

Prior to the initiation of TSMP, hemo- and fluid-dynamics disorder of the first degree ($1.2 < Kh \leq 2.0$) was observed in 23 patients (60%). The average value of the Kh for this group was 1.81 ± 0.25. Hemo- and liquor-dynamic disorder of the second degree ($2.0 < Kh \leq 3.0$) was noted in 15 patients (40%). The average value of the Kh in this group was 2.19 ± 0.24. The average value of the Kh for both groups was 1.9 ± 0.33.

Table 1 shows that after the course of TSMP, the Kh value decreased significantly in all the patients. In 27 patients (71%), the Kh decreased to the normal value (≤1.2). In 23 patients (29%), the Kh values corresponded to hemo- and liquor-dynamic disorder of the first degree ($1.2 \leq Kh \leq 1.6$). The average value of the Kh for both of the groups was 1.18 ± 0.16. These data indicate normalization and significant improvement of hemo- and fluid-dynamics in 71% and 23% of patients, respectively.

Limitations of this study being the lack of a control group, the indirect signs of hemodynamic changes are used with modern possibilities of more accurate and direct diagnostics. Moreover, the possible physiological mechanisms involved in the observed changes were not considered in this study. Nevertheless, the findings of the present study lead to the conclusion that TSMP may be used as an effective tool for the normalization of cerebral blood flow. Considering the urgency of identifying effective therapeutic options for the treatment of cerebral blood flow disorders and the relative simplicity and physiology of the TSMP method, further studies using modern examination methods are warranted to clarify the indications and technique of TSMP in patients with cerebral blood flow disorders.

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