ТЕРАПІЯ ТА РЕАБІЛІТАЦІЯ

USE OF INNOVATIVE TECHNOLOGIES AND COMPUTER PROGRAMS FOR THE RECOVERY OF COGNITIVE FUNCTIONS AFTER STROKE

ВИКОРИСТАННЯ ІННОВАЦІЙНИХ ТЕХНОЛОГІЙ ТА КОМП'ЮТЕРНИХ ПРОГРАМ ДЛЯ ВІДНОВЛЕННЯ КОГНІТИВНИХ ФУНКЦІЙ ПІСЛЯ ІНСУЛЬТУ

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Abstracts

The use of electromechanical and robotic devices in neurorehabilitation can significantly improve the quality of life and daily activities of patients who have suffered a stroke or suffer from other movement disorders. **The purpose of this scientific work** is to study and analyze the integration of innovative methods into rehabilitation programs for patients after a stroke, and the creation of new rehabilitation algorithms for the restoration of cognitive functions in the early stages of rehabilitation.

Material. The clinical study was conducted in the period from 2022 to 2024 based on the Neurological Department of the Municipal Enterprise "Poltava Regional Clinical Hospital named after M.V. Sklifosovsky of Poltava Regional Council". A total of 103 people took part in the study, of which 44 were women (42.72%) and 59 were men (57.28%). The age of the total group ranged from 45 to 64 years, with an average age of Criteria for assignment to subgroups 1.1–1.4: age from 45 to 74 years, both men and women with ischemic stroke, first (and only) stroke in history, with moderate cognitive impairment, mild dementia, without severe aphasia, epilepsy or epileptic syndromes in the anamnesis and available informed consent to participate in the study.

Results. During stroke recovery, the use of a computer stimulation program can successfully improve cognitive function in 54.0% of patients. This is significantly different from the typical standard rehabilitation recovery (22.5%).

Conclusions. The use of innovative methods in rehabilitation programs after a stroke helps to improve the results of the recovery of motor functions and increase the quality of life of patients. For the successful implementation of innovative methods, it is necessary to ensure appropriate training of personnel, create appropriate conditions, and carry out individualization of rehabilitation programs. Research on the long-term effects of innovative methods and their impact on the quality of life of patients is necessary to provide an objective assessment of their effectiveness.

Key words: neurorehabilitation, stroke, movement disorders, innovative methods, virtual reality.

Мета. Використання електромеханічних та роботизованих пристроїв у нейрореабілітації може значно покращити якість життя та повсякденну діяльність пацієнтів, які перенесли інсульт або страждають іншими руховими розладами. Мета статті полягає у вивченні та аналізі інтеграції інноваційних методів у реабілітаційні програми для пацієнтів після інсульту, створення нових алгоритмів реабілітації для відновлення когнітивних функцій на ранніх етапах реабілітації.

Матеріал. Клінічне дослідження проводилось у період з 2022 по 2024 роки на базі неврологічного відділення Комунального підприємства «Полтавська обласна клінічна лікарня ім. М.В. Скліфосовського Полтавської обласної ради». Усього в дослідженні взяли участь 103 людини, з них 44 жінки (42,72%) і 59 чоловіків (57,28%). Вік загальної групи коливався від 45 до 64 років із середнім віком. Критерії віднесення до підгруп 1.1–1.4: вік від 45 до 74 років, як чоловіки, так і жінки з ішемічним інсультом, перший (і єдиний) інсульт в анамнезі, з помірними когнітивними порушеннями – легка деменція, не маючи тяжкої афазії, епілепсії чи епілептичних синдромів в анамнезі та наявну інформовану згоду на участь у дослідженні.

Результати. Під час відновлення після інсульту використання програми комп'ютерної стимуляції може успішно покращити когнітивні функції у 54,0% пацієнтів. Це значно відрізняється від типового стандартного реабілітаційного відновлення (22,5%).

Висновки. Використання інноваційних методів у реабілітаційних програмах після інсульту сприяє покращенню результатів відновлення рухових функцій та підвищенню якості життя пацієнтів. Для успішного впровадження інноваційних методів необхідно забезпечити відповідну підготовку персоналу, створити належні умови та здійснити індивідуалізацію реабілітаційних програм. Дослідження з вивчення довгострокових ефектів інноваційних методів та їх впливу на якість життя пацієнтів є необхідним для забезпечення об'єктивної оцінки їх ефективності.

Ключові слова: нейрореабілітація, інсульт, рухові розлади, інноваційні методи, віртуальна реальність.

Introduction. Around the world, the incidence of strokes and the proportion of people with disabilities is increasing significantly every year [9]. This has prompted a growing interest in neurorehabilitation as a means of reducing disability after stroke. In this regard, the peculiarities of neuroprotection, which are the basis of the restoration of functional disorders, are increasingly being studied, as well as new effective methods of neurorehabilitation, which are based on the use of computerized systems, are being developed.

Rehabilitation after a stroke involves the use of various methods and usually requires an early start of rehabilitation measures. This process should be systematic, interdisciplinary, and actively involve the patient's relatives following the principles of neurorehabilitation. Despite the existing innovative methods of neurorehabilitation, the search for additional non-pharmacological methods to increase neuronal synaptogenesis during recovery in stroke patients remains relevant and requires further research [10].

To date, rehabilitation programs have been developed and are actively used, which combine innovative and traditional methods (robotics, virtual reality, transcranial magnetic stimulation, biofeedback technology, electromuscular stimulation, various methods of therapeutic gymnastics, and botulinum therapy). This study is relevant to the scientific community as the challenges of neurorehabilitation after stroke are becoming more common worldwide due to the increasing incidence of stroke and the population of people with disabilities. The search for new innovative methods of rehabilitation becomes an important task for improving the results of treatment and improving the quality of life of patients. The study of knowledge about the effectiveness and potential of innovative methods of neurorehabilitation has a significant impact on clinical practice and can contribute to the development of new approaches in the treatment of patients with movement disorders after a stroke.

Numerous domestic and international studies are devoted to the issue of impaired motor skills and cognitive functions after a stroke. The prevalence of post-stroke cognitive disorders and the degree of cognitive pathology were determined [1]. The prevalence of dementia and non-dementia cognitive impairment after stroke is estimated to be approximately 7% among outpatients and 42% among hospitalized patients after stroke. At the same time, the main types of cognitive impairment after a stroke, risk factors for the development of dementia, and diagnostic criteria were determined [3]. There are data from several foreign reviews that established the effectiveness of various methods of restoring language impairment and visual agnosia in the

field of stroke. Studies of memory recovery and executive dysfunction after stroke have yielded even more conflicting results. According to Cochrane reviews [7], there is insufficient evidence to support specific treatments for cognitive impairment. At the same time, the most common pathologies of cognitive functions after a stroke are impaired executive function and impaired accommodative memory. One of the areas of cognitive rehabilitation is computer cognitive training. Several types of programs have been developed and tested to train attention, memory, vision, planning, and problem-solving skills [11]. However, the effectiveness of computer-based cognitive training has not been sufficiently studied. The topic of restoration of fine motility of the hands after a stroke is little studied. The prevalence of hand movement disorders after a stroke was studied. Several "manual" and mechanized devices have been proposed to restore the function of the upper limb, but they mainly concern the proximal part of the limb. The possibility of restoring the use of paralyzed limbs was not studied further. In many cases, even with good recovery of motor function, there is a more or less pronounced syndrome of "habitual non-use" of the hands, which is practically not diagnosed in routine clinical practice. According to various authors, the complete restoration of hand function occurs only in 5% of cases. Approximately 20% – the limb is not fully used. It is clear that in other cases there is a more or less pronounced disuse syndrome, and the prospects for recovery of hand function are good [12]. One of the challenges of modern rehabilitation is to establish the set and procedures necessary to use different methods of upper extremity rehabilitation in situations where the length of the patient's stay in the hospital and economic criteria for rehabilitation are limited. The most effective treatment methods are considered to be aimed at involving the patient's personality and are based on the principles of biological feedback. Compared to more passive training, these methods allow the patient to participate in the recovery process by indirectly monitoring recovery progress by recording specific hand features. However, since the technique of restoring the motor function of a paralyzed arm is well developed, from the point of view of a physical therapist, the question of actual non-use of the restored paralyzed limb remains relevant. Therefore, the restoration of cognitive deficits and violations of fine motility of the hands is the final stage of rehabilitation, and for patients, it is an indispensable component of the quality of life. For maximum functional recovery and use of the upper limb, it is necessary to create a clear diagnostic algorithm highlighting the main reasons for non-use and their targeted correction of the achieved results.

Materials and methods

Hypothesis: the use of an optimized diagnostic scheme (the use of analytical algorithms) and the rehabilitation of cognitive disorders of hands and fine motor skills with the help of a computer correction program will lead to the most complete recovery of the altered function in patients after a stroke and will contribute to the acquisition of independence.

The purpose of this scientific work is to study and analyze the integration of innovative methods into rehabilitation programs for patients after a stroke, and the creation of new rehabilitation algorithms for the restoration of cognitive functions in the early stages of rehabilitation.

The work is aimed at identifying the challenges faced by specialists in the implementation of new technologies in the practice of neurorehabilitation, as well as identifying the potential opportunities that these innovative methods can provide to improve the results of the recovery of motor functions and the quality of life of patients after a stroke.

The tasks of this scientific work include:

1. Conducting a literature review on neurorehabilitation and innovative methods used in rehabilitation programs after a stroke.

2. Definition of the main innovative methods, such as the use of electromechanical and robotic devices, virtual reality, biological feedback technology, etc.

3. Analysis of the effectiveness and efficiency of these innovative methods in the process of neurorehabilitation of patients after a stroke. Identification of challenges and difficulties faced

by specialists during the integration of innovative methods into rehabilitation programs.

4. Highlight the potential opportunities and advantages that these innovative methods provide for improving the quality of rehabilitation and recovery of patients. Development of recommendations on the use of innovative methods in the practice of neurorehabilitation and possible directions of further research in this area.

5. Creation of algorithms for the correction of disorders of cognitive functions and fine motor skills with the help of computer programs that stimulate cognitive functions, methods of activating voluntary movements of paralyzed hands based on the principles of biological feedback, and optimization of analytical methods to combat addiction.

The methodology of this scientific work includes the following stages:

1. Searching for scientific sources in PubMed, Web of Science, and Scopus databases using keywords related to stroke, rehabilitation, innovative methods, and neurorehabilitation. Selection of scientific sources that meet inclusion and exclusion criteria. Study and analysis of scientific articles, systematic reviews, meta-analyses, diagnostic protocols, and regulatory reports to collect information about innovative methods of neurorehabilitation, their efficiency, and effectiveness. Analysis and generalization of the obtained data on the effectiveness of innovative methods in rehabilitation programs after a stroke.

2. Identification of difficulties and obstacles faced by specialists when implementing innovative methods in the practice of neurorehabilitation, as well as determination of potential opportunities and advantages of these methods.

3. Formulation of practical recommendations for the use of innovative methods in rehabilitation programs after a stroke, as well as the use of new algorithms to reduce cognitive disorders after ischemic strokes.

The strategy of this research included the following stages:

1. Identification of databases: well-known scientific databases such as PubMed, Web of Science, and Scopus were selected for the search because these databases contain a significant number of scientific articles and publications in various fields of medicine and science.

2. Setting the search period: the search depth was 5 years from May 2018 to May 2023. This period was chosen to ensure the relevance and coverage of a significant number of scientific sources.

3. Formulation of keywords: keywords such as “stroke”, “rehabilitation”, “virtual reality”, “treadmill” and “robot” was formulated to search for information according to the research topic.

4. Literature selection: literature was selected according to certain inclusion and exclusion criteria. Included were randomized and cohort studies, systematic reviews and meta-analyses [5], full articles, papers, diagnostic protocols, and regulatory reports. On the other hand, isolated cases, theses, summaries of reports, personal messages, and articles describing abstracts were excluded.

5. Number of selected sources: after searching and selecting the literature, 161 sources were selected for further research and analysis. Of these, 128 sources were found in PubMed, 15 in Web of Science, and 18 in Scopus.

6. Analysis: the selected sources were carefully analyzed to collect information about innovative methods of rehabilitation of movement disorders after a stroke, their effectiveness, and efficiency.

Thus, with the help of the described search strategy, the study of scientific sources was carried out, which made it possible to prepare information for further research and analysis of the effectiveness of rehabilitation programs after a stroke using innovative methods.

The clinical study was conducted in the period from 2022 to 2024 based on the Neurological Department of the Municipal Enterprise “Poltava Regional Clinical Hospital named after M.V. Sklifosovsky of Poltava Regional Council”, where a course of medical rehabilitation was conducted.

The object of the study was cognitive impairment and dementia, impairment of fine motor skills of the hands in patients with carotid ischemic stroke in the acute and convalescent

stages. The subject of the study was the algorithms and methods of correction, the results of recovery of cognitive and fine motor deficits in patients in the acute and convalescent stages of carotid ischemic stroke. The unit of observation is acute and convalescent patients with ischemic stroke, medical charts of patients, and primary medical documentation.

The study followed the basic principles of bioethics, in particular the principles of honesty, confidentiality, fairness, and consent of research participants. The research was conducted taking into account ethical standards that guarantee the protection of the rights and well-being of research participants. All actions and procedures related to the research were carried out following the principles of bioethics and the legislation of Ukraine, which regulates the conduct of scientific research. The study was conducted in compliance with the main provisions of the "Rules of Ethical Principles of Scientific Medical Research with Human Participation" approved by the Declaration of Helsinki (1964–2013), ICH GCP (1996), and EU Directive No. 609 (from November 24, 1986), orders of the Ministry of Health of Ukraine No. 690 (from 23.09.2009), No. 944 (from 14.12.2009), No. 616 (from 03.08.2012). All participants were informed about the goals, organization, and methods of the survey and signed an informed consent to participate in a completely anonymous study.

A total of 103 people took part in the study, of which 44 were women (42.72%) and 59 were men (57.28%).

Results. The analysis and generalization of the obtained data on the effectiveness of innovative methods in rehabilitation programs after a stroke confirms the importance of introducing new technologies to improve the recovery results of patients with movement disorders after a stroke [8; 13]. The findings indicate a positive impact of the use of innovative methods on the quality of rehabilitation and increasing the level of functional independence in patients. In particular, the use of electromechanical and robotic devices in rehabilitation helps to improve patients' daily activities and ability to walk, and increase muscle strength and coordination of movements [3]. These devices can complement traditional therapy methods and help provide an individualized approach to each patient, taking into account their needs and abilities.

Recently, considerable attention has been paid to the implementation of interactive technologies in neurorehabilitation to improve results and increase the effectiveness of treatment. In particular, virtual reality and interactive systems with a brain-computer interface are becoming increasingly popular tools in this area [2]. Virtual reality and interactive technologies provide an opportunity to create an immersive environment for learning and training. They allow patients to practice different movement scenarios in realistic settings, such as moving around an urban environment or performing everyday tasks, which can be particularly useful for patients with significant movement limitations. Also, interactive systems with a brain-computer interface show great potential in enabling patients to control movements using thought and brain signals. This technology allows patients to actively participate in the rehabilitation process, which can increase their motivation and promote more frequent repetition of patterned movements. However, it is necessary to continue the research and development of these technologies to maximize their implementation in clinical practice and achieve the best results in the rehabilitation of patients. In general, based on the obtained data, it can be argued that innovative methods in rehabilitation programs after a stroke have a significant potential to improve the quality of life and functional capabilities of patients. The implementation of such technologies in the practice of neurorehabilitation can help improve treatment results and provide an individual approach to each patient, taking into account his needs and capabilities. However, for further development and effective use of innovative methods, it is necessary to conduct additional research and determine optimal strategies for their implementation in rehabilitation programs.

The use of electromechanical and robotic devices in neurorehabilitation can significantly improve the quality of life and daily activities of patients who have experienced a stroke or have

other movement disorders. These innovative technologies provide several advantages that contribute to the effective restoration of motor functions and the improvement of muscle strength. Therefore, such devices can be used as a supplement to traditional therapy. The field of virtual reality in the rehabilitation of movement disorders associated with neuropathy should be adopted as a standardized approach in close collaboration with advanced clinicians. Device-based VR systems offer the opportunity to expand the range of services that healthcare providers can offer but must ensure mass adoption. In this context, the need for in-depth research into the problem of rehabilitation of patients after a stroke is growing, and the problem of finding innovative methods and devices for neurorehabilitation remains relevant [2]. The implementation of innovative methods in the practice of neurorehabilitation after a stroke faces various difficulties and obstacles, but at the same time has a significant potential for improving the results and increasing the effectiveness of rehabilitation programs. Some innovative methods may be tested, but do not yet have sufficient scientific support and evidence base. This may prevent them from being widely implemented in clinical practice. On the other hand, innovative methods of neurorehabilitation have the potential to bring numerous advantages: the use of the latest technologies can help improve the results of rehabilitation and increase the chances of full or more complete recovery of functions in patients; innovative methods allow more individualized therapy, taking into account the needs and capabilities of each patient; the use of new technologies, such as virtual reality and game elements, can increase the motivation of patients to actively participate in rehabilitation classes; some innovative technologies allow training to be adapted to the needs and abilities of each patient, which can increase the effectiveness of the recovery process [4; 6].

In general, the introduction of innovative methods in neurorehabilitation is an important area of medical practice development. They can help improve the quality of life of stroke patients and ensure more successful and effective rehabilitation. However, successful implementation of these methods requires overcoming technical, financial, and socio-cultural barriers, as well as additional scientific research to provide adequate support and evidence base.

Discussions. A total of 103 people took part in the study, of which 44 were women (42.72%) and 59 were men (57.28%). The age of the total group ranged from 45 to 64 years, with an average age of Criteria for assignment to subgroups 1.1–1.4: age from 45 to 74 years, both men and women with ischemic stroke, first (and only) stroke in history, with moderate cognitive impairment, mild dementia, without severe aphasia, epilepsy or epileptic syndromes in the anamnesis and available informed consent to participate in the study. So, for the study, the authors had a group of patients (103 patients) with cognitive impairment during the acute and convalescent stages of stroke, represented by four subgroups.

This table provides an overview of the different subgroups of patients, their number, the time of examination, and the type of rehabilitation they received.

A characteristic feature of recovery in the acute stage of a stroke is a pronounced regression of cognitive impairments, and the recovery efficiency index on the MMSE scale is much higher than with conventional therapy. At the same time, unfavorable factors for cognitive recovery are the large size of the lesion and low initial levels of MMSE. In the period of convalescence, the degenerative dynamics persist, but at a slower pace. The return to a normal state without special correction during this period is 22.5% against the background of the general course of rehabilitation. The effectiveness of the elimination of cognitive impairment using the computer stimulation program was evaluated from 8–10 to 18–20 days and was increased by 2.5 times compared to standard treatment. During stroke recovery, the use of a computer stimulation program can successfully improve cognitive function in 54.0% of patients. This is significantly different from the typical standard rehabilitation recovery (22.5%).

Table 1

Distribution of persons participating in the study by type of rehabilitation

Subgroup	No. of people (n)	Experiment (days)	Type of rehabilitation
1.1. Cognitive disorders, computer stimulation.	30	2–5, 12–15	Physical therapy (according to the protocol), computer stimulation.
1.2. Cognitive impairment, standard therapy (according to the protocol).	33	2–5, 12–15	Standard drug therapy (according to the protocol).
1.3. Rehabilitation, computer stimulation.	20	8–10, 18–20	Physical therapy (according to the protocol), computer stimulation.
1.4. Rehabilitation, standard therapy.	20	8–10, 18–20	Standard drug therapy (according to the protocol).

The high efficiency of the method of rehabilitation of fine motility of hands in patients in the early and late stages of convalescence of ischemic stroke with the use of a "sensory glove" in the scheme of rehabilitation treatment based on the principle of biological feedback has been proven. Thus, in the 1.3 group, a significantly lower disability due to paralysis of the arm according to the DASH scale was found than in the control group according to the results of a follow-up examination of patients who underwent rehabilitation using biofeedback ("Sensory Glove") during early and late recovery after of stroke compared to standard treatment. Continued use of the method maintains and even increases benefits on upper extremity function scales, especially the Fugle-Mayer Scale. During the study, factors that negatively affect the complete recovery of paralyzed hands and fingers were identified (such factors include, for example, a low score on the FAB scale). Factors that have a positive effect on the successful rehabilitation of a paralyzed arm are the appearance of early movements and/or the ability to abduct the arm, extend the fingers, and lift the foot in the acute phase.

The authors formulated practical recommendations for the use of innovative methods in rehabilitation programs after a stroke: before implementing innovative methods, it is important to conduct a detailed assessment of the needs of each patient, as it is necessary to take into account the degree of loss of functions, the patient's capabilities and his individual goals; ensure proper training of personnel for the use of innovative technologies, emphasize training and practice in their use before the start of rehabilitation of patients; it is important to implement innovative methods step by step, following the sequence in the rehabilitation process. It is important to systematically monitor the progress of patients involved in innovative programs, as well as to use innovative technologies that can increase the motivation of patients for rehabilitation classes. Virtual reality, gaming elements, and feedback can be useful for patient engagement. The authors recommend paying attention to the combination of innovative methods with drug therapy and other treatment approaches. It is important to provide an integrated approach to neurorehabilitation.

Conclusions.

1. The use of innovative methods in rehabilitation programs after a stroke helps to improve the results of the restoration of motor functions and increase the quality of life of patients.

2. For the successful implementation of innovative methods, it is necessary to ensure appropriate training of personnel, create appropriate conditions, and carry out individualization of rehabilitation programs.

3. Research on the long-term effects of innovative methods and their impact on the quality of life of patients is necessary to provide an objective assessment of their effectiveness.

4. The development of innovative technologies and their availability can affect the increase in efficiency and the spread of such methods in neurorehabilitation.

5. Increasing cooperation between scientists, clinicians, and engineers can contribute to the development of new innovative methods and their wider implementation in the practice of neurorehabilitation.

Prospects for further research:

1. Conducting more randomized controlled trials to determine the effectiveness of innovative methods in comparison with traditional approaches and to find out which groups of patients benefit most from the use of such methods.

2. Long-term follow-up and effectiveness in different stages of recovery.

3. Integration of innovative technologies into rehabilitation programs affects the overall outcome and quality of life of patients and the prevention of complications.

4. Study the economic impact of introducing innovative methods into rehabilitation programs and develop a cost-effectiveness assessment of such approaches.

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