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SPINAL CORD STIMULATION FOR VERTEBROSPINAL I NJURIES

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Abstract: A clinical observation of the treatment of a patient with the consequences of spinal cord injury using non-invasive electrical stimulation of the spinal cord in combination with mechanotherapy is presented.
Keywords: non-invasive electrical stimulation of the spinal cord, spinal cord injury, rehabilitation, mechanotherapy, stimulation of the supporting zones of the feet

Introduction. Rehabilitation of patients with traumatic spinal cord injuries is one of the most pressing and complex problems of modern medicine. Spinal cord injuries, which can be the result of various factors such as car accidents, falls, sports injuries or other mechanical injuries, often lead to long-term and severe consequences for the patient, including paralysis, motor dysfunction, loss of sensitivity and other serious neurological disorders. As a result, rehabilitation of patients with such injuries becomes an extremely important task that requires the use of innovative treatment methods aimed at restoring lost functions and improving the quality of life of patients. However, despite significant advances in this area, the process of recovery after spinal cord injuries remains very complex and multifaceted, which makes the search for effective therapeutic strategies one of the main problems of modern medicine. One of the main reasons for the difficulty of restoring function after traumatic spinal cord injuries is the pathogenesis of the traumatic disease itself, which includes many physiological and biochemical processes. In the case of spinal cord injury, the connections between the central nervous system and peripheral organs are disrupted, which leads to the loss of the ability to control movements and feel pain or other sensory signals. Restoring such functions requires not only mechanical rehabilitation, but also stimulation of the nervous tissue to activate the processes of neurogenesis and neuroplasticity, that is, the restoration and formation of new neural connections. Despite the variety of rehabilitation methods, most existing technologies have certain limitations in their effectiveness. This is due to the fact that traditional approaches such as physiotherapy, massage, mechanotherapy and drug treatment are not always able to significantly improve the condition of patients, especially in cases where spinal cord damage is serious and irreversible. This emphasizes the need to develop more effective rehabilitation methods that can restore at least partially lost functions and return patients to the ability to live a normal life. One of such promising methods is electrical stimulation of the spinal cord. This method aims to activate neural structures in the spinal cord to restore motor functions of the lower extremities, which can be especially useful for patients suffering from paralysis or other movement disorders caused by traumatic injuries. Electrical stimulation causes step-like movements by activating spinal centers that can function even when higher levels of the spinal cord are damaged. The method demonstrates good results in restoring motor functions and in some cases is able to restore the ability to walk in patients, which makes it extremely promising.

However, traditional electrical stimulation, despite its effectiveness, has a significant drawback - invasiveness. In order to stimulate the spinal cord, it is necessary to implant special electrodes that are placed directly on the surface of the dura mater of the spinal cord. This requires surgical

intervention, which is associated with a number of possible complications. Such risks include infections, inflammatory reactions, damage to surrounding tissues, as well as the need for constant monitoring of the state of the implanted electrodes. Such risks and inconveniences make the method less attractive for widespread use, especially in cases where patients need fast and safe solutions. In order to overcome these disadvantages, an alternative method was proposed and developed several years ago - transcutaneous electrical stimulation of the spinal cord (TESS). This method is non-invasive, which significantly reduces the risk of complications associated with surgical interventions. Within the framework of TESS, electrical impulses are supplied through electrodes placed on the patient's skin, which activates the spinal centers and causes locomotor movements without requiring surgical intervention. This approach makes the treatment much more accessible, safe and convenient for patients, especially considering that the method does not require a long recovery period after the procedure.

Studies conducted using transcutaneous electrical stimulation of the spinal cord have shown that this method is capable of inducing locomotor movements in humans and animals, as well as helping to restore motor functions in the case of spinal cord injuries. TSCS activates the neuroplasticity of the nervous system, which can help restore lost functions. Thanks to this method, patients with spinal cord injuries experience an improvement in their motor functions and an increase in the quality of life, even if the injury was significant and occurred a long time ago.

Despite the successes achieved using transcutaneous electrical stimulation, it must be emphasized that this method is still at the stage of active research and development. In order to draw final conclusions about its full effectiveness, additional clinical trials and long-term observations will be required. It is also important to study the possible long-term consequences and risks that may arise with the regular use of this method. For example, it is important to consider possible side effects such as skin irritation, discomfort from the electrical impulses, and possible long-term health consequences for the patient.

In addition, in the future, it may be necessary to supplement TECS with other treatment and rehabilitation methods, such as mechanotherapy, physical therapy, and medications, in order to achieve maximum results and help patients regain lost functions. The ideal solution would be to use an integrated approach that combines various methods aimed at restoring damaged tissue, improving neuroplasticity, and stimulating motor functions. Thus, transcutaneous electrical stimulation of the spinal cord is a promising method that may become an important part of complex therapy for patients with spinal cord injuries in the future, but this requires further development and more in-depth study.

Materials and methods: The essence of the method is to use electrical impulses of a complex shape instead of standard rectangular impulses. A special shape of stimulating impulses makes high-intensity currents necessary for effective impact on the spinal cord painless for a person with normal sensitivity. At the same time, several clinics began to use it for motor rehabilitation of spinal patients. As a result of these studies, it was shown that non-invasive electrical stimulation of the spinal cord leads to an increase in muscle strength, improvement of tactile and pain sensitivity, the occurrence of voluntary movements and restoration of body balance [7-9]. A number of studies contain data on the evaluation of the results of rehabilitation of patients with complicated spinal injuries using the method of transcutaneous stimulation of the spinal cord. However, to date, there have been no works in the literature devoted to non-invasive stimulation of the spinal cord in combination with mechanotherapy in patients after spinal cord injury using this technique. The purpose of the study is to analyze the results of rehabilitation treatment of a patient with spinal cord injury. The international ASIA scale, an international standard for neurological and functional classification of spinal cord injuries, was used to assess the neurological status. The presented classification allows for a reduction in subjective assessments of the neurological status and makes the examination results more objective and reliable. Motor activity according to this

scale was 53 points, pain and tactile sensitivity – 42 points. Electroneuromyography (ENMG) examination was performed on a 4-channel electroneuromyograph using the method of assessing the conduction velocity and determining the amplitude indices of sensory and motor responses during stimulation of the tibial, peroneal, and sural nerves, using the F-wave and H-reflex method on both sides according to the standard technique [3]. To assess the functional state of the spinal cord pathways, we studied somatosensory evoked potentials to stimulation of the tibial nerve (SSEP n. tibialis) on both sides with recording of the potentials of the lumbar enlargement P20-N22, cortical potential P38-N46, taking into account the amplitudes, absolute and interpeak latencies of the responses. According to ENMG data, a significant decrease in the amplitudes of M-responses was noted during stimulation of the tibial nerve on the left (2 mV), the absence of sensory potentials in the study of the sensory fibers of the left lower limb, which indicated damage to the motor neurons of the spinal cord at the level of S1-S2 on the left and the peripheral sensory fibers of the left lower limb. Signs of damage to the peripheral sensory and motor fibers of the right lower limb, motor neurons of the spinal cord at the level of the lumbar enlargement on the right were absent. An increase in the amplitude of the H-reflex on the right by up to 35% was noted, indicating a decrease in suprasegmental control of muscle activity. The study of the SSEP of n. tibialis with stimulation on the right showed the presence of only the potential of the lumbar enlargement P20-N22, while P38-N46 was absent, indicating a complete disruption of the conduction of somatosensory afferentation along the conduction pathways of the spinal cord above the level of the lumbar enlargement. When studying the SSEP of n. tibialis on the left, P20-N22 was not recorded, which was explained by a disruption in conduction along sensory fibers at the peripheral level.

Results: Electrical stimulation of nerve structures, in particular transcutaneous electrical stimulation of the spinal cord (TESC), is currently an actively researched and promising method for treating various neurological disorders, including the consequences of spinal cord injuries. At the moment, there is no doubt that electrical stimulation has a certain effect on the functional state of nerve structures, including both the central and peripheral nervous systems. These effects are becoming especially important in the context of restoring motor and sensory functions in patients with spinal cord injuries. However, it is important to note that even despite the positive results observed in the short term after the method is applied, the effectiveness of treatment and long-term results continue to be a topic for scientific discussion and require additional research. One of the factors that may limit the effectiveness of treatment in a particular case is the duration of the injury. The later the intervention is carried out, the more difficult and less predictable the process of restoring damaged nerve tissue becomes. The longer the time has passed since the injury, the less effective the attempts to restore neural connections and functional characteristics may be, especially in the case of deeper or more extensive spinal cord injuries. This also applies to the use of transcutaneous electrical stimulation. In later stages of damage to nerve structures, when neuroplasticity is already significantly reduced, the effect of stimulation may be less pronounced. This is explained by the fact that nerve cells and their connections may lose the ability to recover and adapt, which complicates the use of electrical stimulation for the regeneration of nerve tissue. Another important point to consider when assessing the results of electrical stimulation is the duration of the treatment course. In our study, a short course of therapy was used, which may also have affected the final results. The duration of exposure plays a key role, since the restoration of nerve structures requires time to activate neurogenesis processes, improve the conductivity of nerve impulses and restore motor functions. Electrical stimulation affects the neuroplasticity of the nervous system, activating various mechanisms, such as the growth of new nerve cells, improving their interaction and restoring the connection between nerve endings. However, in order for these processes to have a stable and long-term effect, it is necessary to conduct longer and more systematic stimulation courses.

However, despite these limitations, it should be recognized that even a short course of transcutaneous electrical stimulation in combination with mechanotherapy gave positive results.

Mechanotherapy, as a method that includes physical impact on damaged tissues for the purpose of their stimulated recovery, in combination with electrical stimulation can improve the dynamics of the patient's recovery. Such an integrated approach can have a positive effect on improving the functional abilities of patients with the consequences of spinal cord injuries. Mechanotherapy helps to improve blood supply in the area of damaged tissue, stimulates the restoration of muscle activity, and in combination with electrical stimulation can increase the effectiveness of rehabilitation by activating the mechanisms of neuroregeneration.

One of the most significant results that were recorded during the treatment is that the improvements persisted for a certain time after the completion of the course of procedures. In our case, the positive effect of the treatment persisted for 7 days after the completion of the procedure. This indicates that electrical stimulation combined with mechanotherapy can have a long-lasting effect, providing improvement in the patient's condition even after the active intervention has ended. Although more stable and long-term results will require further research and possibly longer courses, it can already be said that the combined use of these methods is an effective tool in the rehabilitation of patients with spinal cord injuries.

It should be emphasized that the effectiveness of transcutaneous electrical stimulation and mechanotherapy may vary depending on the individual characteristics of the patient. Factors such as age, the degree of spinal cord injury, the presence of concomitant diseases, as well as the general health condition, can significantly affect the final treatment outcome. That is why a personalized rehabilitation program should be developed for each patient, taking into account his/her characteristics and needs. Thus, despite the fact that at this stage the method of transcutaneous electrical stimulation in combination with mechanotherapy is not a universal solution for restoring spinal cord function, it has significant potential. This approach can significantly improve the results of conservative treatment, especially in cases where the damage is not too deep and treatment is carried out at early stages. In order to draw final conclusions about its effectiveness and possible long-term results, more extensive clinical studies and long-term observations are required, which will allow a more accurate assessment of its role in neurorehabilitation and the development of recommendations for its use in clinical practice.

Conclusion. Currently, scientific research aimed at improving or restoring spinal cord function is one of the most promising areas of medicine and neurorehabilitation. One such area is the use of isolated transcutaneous electrical stimulation, as well as a combination of this method with mechanotherapy, which, according to preliminary data, has a positive effect on the restoration of motor functions in patients suffering from various spinal cord disorders. Transcutaneous electrical stimulation is a method in which electrical impulses act on nerve endings through the skin. This technique has already proven its effectiveness in a number of cases, especially in combination with other treatment methods, such as mechanotherapy, which involves physical action on damaged tissue in order to stimulate their recovery and improve functionality. The combined use of these methods allows you to activate neuroplasticity - the ability of the nervous system to restore damaged or lost functions, creating new neural connections and helping to improve motor and sensory functions. Despite the promising results obtained in early studies, a final conclusion about the true effectiveness of these methods and their ability to significantly restore the function of the spinal cord and its elements still requires a more in-depth and comprehensive scientific analysis. It is important to note that each case of spinal cord injury is individual, and factors such as the degree of injury, the patient's age, and his general health can significantly affect the outcome of treatment. Therefore, the methods used in neurorehabilitation must be adapted to each individual patient.

In addition, it is necessary to conduct larger clinical studies that will include long-term observation of patients, as well as studying the effects of these methods in the long term. This will allow not only to assess their overall effectiveness, but also to identify possible side effects and risks

associated with the use of electrical stimulation and mechanotherapy. It is also important to clarify how the combination of these methods affects neurogenesis, the level of functional recovery and the quality of life of patients.

Another issue that requires further study is the safety of these methods. Transcutaneous electrical stimulation, despite its relative safety in some cases, can cause side effects such as skin irritation, pain, or discomfort in the area of exposure. Therefore, before using such methods, it is necessary to take into account contraindications, as well as conduct regular medical examinations of patients. Thus, although the methods of isolated transcutaneous electrical stimulation and mechanotherapy are very promising and can play a significant role in the restoration of spinal cord function, it is necessary to continue scientific research and clinical trials. This will help not only to finally assess their effectiveness, but also to develop safer, individualized approaches to the treatment and rehabilitation of patients with spinal cord disorders. In the future, such methods can become an important part of complex therapy, including innovative technologies and traditional approaches, contributing to a significant improvement in the quality of life of patients.

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