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Effect of Repeated Transcranial Magnetic Stimulation Therapy Combined With Rehabilitation Training on Nerve Function Recovery in Patients With Different Degrees of Spinal Cord Injury

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Abstract: Spinal cord injury seriously affects the neurological function of patients, so it is very important to explore effective treatment methods. This study focused on the effect of repeated transcranial magnetic stimulation combined with rehabilitation training on the recovery of nerve function in patients with different degrees of spinal cord injury. Firstly, the types and mechanisms of spinal cord injury and the path of damage to nerve function were analyzed, and the principle and synergistic mechanism of repetitive transcranial magnetic stimulation and rehabilitation training were expounded. For patients with mild spinal cord injury, to develop a combination treatment plan and evaluate the recovery effect. For moderate to severe patients, the treatment strategy was adjusted and the effect was compared. The results showed that the combination therapy could effectively promote the recovery of nerve function in patients with different degrees of spinal cord injury, and the effect of strategy adjustment was significantly improved in moderate and severe patients. The research results provide a new idea and scientific basis for the clinical treatment of spinal cord injury, and have important application value.
Keywords: Spinal cord injury; Repeated transcranial magnetic stimulation; Rehabilitation training; Neurological recovery

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1. Introduction

Spinal cord injury is a kind of serious trauma, which often leads to the impairment of motor, sensory, and other neurological functions, greatly reduces the quality of life, and brings a heavy burden to the family and society of patients. Although the traditional rehabilitation therapy has some effect, but the promotion degree of the recovery of nerve function is limited. Repetitive transcranial magnetic stimulation (TMS), as a non-invasive neuroregulatory technique, has been gradually applied in the treatment of spinal cord injury in recent years, bringing new hope to patients. Combined with rehabilitation training, it is expected to improve nerve function through different mechanisms of action. At present, although there are studies on the application of repetitive transcranial magnetic stimulation or

rehabilitation training alone, there are few systematic studies on the effects of the combination of the two on the recovery of neurological function in patients with different degrees of spinal cord injury. It is of great significance for optimizing clinical treatment plan and improve the rehabilitation level of patients to explore this combined treatment mode deeply and clarify its effects and differences, and can also fill the relevant research gaps.

2. Principle of spinal cord injury and nerve function

2.1. Types and mechanisms of spinal cord injury

Spinal cord injury can be classified according to the mechanism and location of injury. According to the mechanism, traumatic spinal cord injury is caused by spinal fracture, dislocation, compression, or injury of spinal cord caused by external forces such as traffic accidents and falling from high places. Non-traumatic injury is due to myelitis, tumor, and other diseases, such as the inflammatory response of myelitis, tumor mass effect damage the spinal cord. According to the location, cervical spinal cord injury caused quadriplegia, affecting the function of breathing. Thoracic cord injury caused lower limb paralysis and segmental sensory disturbance. The injuries of lumbar and sacral pulp affect the sensation and movement of the lower extremities. The mechanism of spinal cord injury is complex, the initial mechanical injury destroys nerve cells and fibers, and then the secondary injury such as inflammation and oxidative stress aggravates nerve function damage, seriously affecting the life of patients.

2.2. Constitution and function of nerve function

Neural functions include sensory, motor, and autonomic functions. The sensory nerve function is responsible for transmitting sensory information from various parts of the body, such as pain, touch, temperature, etc., to the central nervous system, so that the human body can perceive changes in the external environment and its own state. For example, when the hand touches a high-temperature object, the sensory nerve quickly converts the thermal stimulus into a nerve impulse, which is transmitted to the brain, making the person feel heat and make a hand withdrawal response. The motor nerve function innervates the muscle contraction to realize the body's autonomous movement and posture maintenance. The brain sends out movement instructions, which are transmitted to the corresponding muscles through the motor nerves, and the muscles contract and dilate according to the instructions to complete the actions such as walking and lifting hands. Autonomic nervous function regulates the activities of human internal organs, such as heartbeat, blood pressure, gastrointestinal peristalsis, glandular secretion, etc., and maintains a stable internal environment, which is not directly controlled by consciousness [1]. These neural functions work together to ensure normal physiological activities and behaviors of the human body, and any impairment will affect the quality of life.

2.3. Damage path of spinal cord injury to nerve function

After spinal cord injury, nerve function is impaired through multiple pathways. Mechanical injury directly disrupts the nerve conduction pathway, obstructing the transmission of sensory and motor signals. For example, a spinal cord transection injury causes the upper and lower nerve fibers to break, and the sensory and motor function below the injury plane is completely lost. Local bleeding and edema caused by injury will compress peripheral nerve tissue, resulting in ischemia and hypoxia of nerve cells, affecting nerve conduction and metabolism. Inflammatory response is activated

after injury, and a large number of inflammatory cells infiltrate, release inflammatory mediators, attack normal nerve cells, and aggravate nerve injury. At the same time, oxidative stress produces excessive free radicals, damages nerve cell membrane, proteins, and nucleic acids, and interferes with the normal function of nerve cells. In addition, spinal cord injury may also trigger nerve cell apoptosis, reduce the number of nerve cells, and further weaken nerve function. These damage pathways affect each other, forming a vicious circle and hindering the recovery of nerve function.

3. Repeat transcranial magnetic stimulation and rehabilitation training

3.1. Treatment principle of repeated transcranial magnetic stimulation

Repetitive transcranial magnetic stimulation (rTMS) works using the principle of electromagnetic induction. When an electric current passes through the winding coil, it creates a rapidly changing magnetic field that passes through the skull without attenuation, creating an induced current in the cerebral cortex. The electrical activity of neurons in the cerebral cortex can be regulated by the induced current, thus affecting nerve function [2].

Different frequencies of rTMS stimulation produce different effects. High frequency rTMS (greater than 5Hz) usually play an excitatory role, can increase the excitability of the cerebral cortex, promote the release of neurotransmitters, such as dopamine, glutamate, etc., and enhance the transmission of information between neurons. Low frequency rTMS (less than 1Hz) mainly plays an inhibitory role in reducing cortical excitability. For patients with spinal cord injury, rTMS can regulate the neural pathway between the brain motor cortex and the spinal cord, reshape neuroplasticity, and promote the recovery of nerve function after spinal cord injury. For example, stimulating the motor areas of the brain can activate descending fibers connected to the spinal cord and help reestablish motor control in patients with spinal cord injury [3].

3.2. Common methods and key points of rehabilitation training

Rehabilitation training is an important part of the comprehensive treatment of spinal cord injury. Common approaches include physical therapy, such as joint range of motion training, to maintain and improve joint flexibility through passive or active movement to prevent muscle atrophy and joint contracture. Muscle strength training is the use of equipment or their own weight, targeted exercise of the damaged parts of the relevant muscles, improve muscle strength. Occupational therapy focuses on daily living ability training, such as training patients to dress, eat, wash, etc., to enhance their self-care ability.

The key point of rehabilitation training is early intervention, carried out as soon as possible after the patient's condition is stable, and seize the golden period of neurological function recovery. The training should be gradual, and the intensity and difficulty of the training should be gradually increased according to the patient's physical condition and recovery progress to avoid excessive fatigue and injury. At the same time, the training needs to be personalized, fully considering the degree of spinal cord injury, plane, and individual differences. For example, patients with cervical spinal cord injury focus on training respiratory function and upper limb function, while patients with thoracic spinal cord injury focus on lower limb function and balance training.

3.3. Synergistic mechanism of joint application of the two

The combined application of repetitive transcranial magnetic stimulation and rehabilitation training can synergically promote the recovery of nerve function in patients with spinal cord injury. rTMS regulates cerebral cortex excitability,

improves nerve conduction pathway, and creates a good neural environment for rehabilitation training. Exercise stimulation in rehabilitation training can also enhance the regulatory effect of rTMS on neuroplasticity [4].

In terms of remodeling neural pathways, rTMS promotes the enhancement of neuronal activity in the cerebral cortex, and rehabilitation training continuously gives feedback to the nervous system through limb movement. The combination of the two can promote the germination, growth, and synaptic reconstruction of nerve fibers more efficiently. From the perspective of neurotransmitters, the neurotransmitters stimulated and released by rTMS can improve the sensitivity of neurons to incoming signals during rehabilitation training, and rehabilitation training can in turn affect the secretion and regulation of neurotransmitters, forming a virtuous cycle. For example, when patients undergo rehabilitation training after receiving rTMS treatment, sensory information generated by muscle movement is transmitted to the brain and interacts with neural activity regulated by rTMS to further promote nerve function repair.

4. Effect of combination therapy on patients with mild spinal cord injury

4.1. Characteristics analysis of patients with mild spinal cord injury

Mild spinal cord injury is relatively mild, and the spinal cord structure is usually only partially damaged, without complete nerve conduction blockade. From the perspective of clinical manifestations, patients may have local pain, slight limb weakness or paresthesia, such as numbness and tingling of the limbs, but most of the motor functions of the limbs can still maintain a certain degree of autonomous activity, and there is generally no complete paralysis of the limbs.

In terms of sensory function, patients may have partial decline in shallow senses such as touch, pain, and temperature, but deep senses such as position and vibration may be basically normal. At the same time, due to the mild degree of injury, the psychological state of the patients is mostly relatively stable, but there may still be a certain degree of anxiety due to worry about the recovery situation. These physiological and psychological characteristics determine that in the selection and implementation of treatment programs, it is necessary to focus on early intervention to help patients recover their neurological function as soon as possible and reduce complications, while paying attention to their psychological state and providing necessary psychological support [5].

4.2. Design and implementation of combination therapy program

For patients with mild spinal cord injury, repetitive transcranial magnetic stimulation can be used to select low-frequency stimulation, which is mainly concentrated in the motor and sensory areas of the cerebral cortex, to regulate the excitability of the cerebral cortex and promote nerve remodeling. The treatment is performed five times a week and lasts about 20 minutes each time.

Rehabilitation training starts from the early stage of joint motion training, and gradually transitions to muscle strength training and balance training. In joint motion training, the rehabilitation therapist helps the patient to carry out passive movement of each joint to prevent joint contracture. Muscle strength training starts with simple isometric contraction training, and gradually develops isotonic contraction training and resistance training to enhance muscle strength as the patient recovers. Balance training includes sitting balance, standing balance training, etc., to improve the patient's body control ability [6]. The rehabilitation training is carried out 1–2 times a day for about 60 minutes each time. In the process of implementation, the treatment intensity and training content are dynamically adjusted according to the patient's tolerance and recovery progress, to ensure the safe and effective treatment.

4.3. Assessment and interpretation of the effect of neurological function recovery

The International Standard of Neurological Classification of Spinal Cord Injury (ISNCSCI) was used to evaluate neurological function in patients with mild spinal cord injury who received combination therapy. Before treatment, 4 weeks after treatment and 8 weeks after treatment were evaluated, including motor scores and sensory scores.

The results showed that after 4 weeks of treatment, the patients' motor scores and sensory scores were improved to some extent, the limb strength was enhanced, and the range of paresthesia was reduced. After 8 weeks of treatment, the improvement was more obvious, and the motor function of most patients basically returned to normal, and the sensory function was also significantly improved. This indicates that repetitive transcranial magnetic stimulation combined with rehabilitation training can significantly restore nerve function in patients with mild spinal cord injury. Repetitive transcranial magnetic stimulation regulates cerebral cortex function, rehabilitation training promotes muscle strength and joint function recovery, and the two work together to effectively promote nerve function repair. Moreover, with the extension of treatment time, the effect was more prominent, indicating that early and continuous combined treatment is crucial to the recovery of nerve function in patients with mild spinal cord injury [7].

5. Effect of combination therapy on patients with moderate to severe spinal cord injury

5.1. Characteristics of patients with moderate to severe spinal cord injury

Patients with moderate and severe spinal cord injury have higher injury level and more serious injury degree. This leads to serious damage to the nerve conduction pathway, obvious motor dysfunction, often difficult to autonomically complete basic movements such as turning, sitting, standing, walking, and even complete loss of limb movement ability. In terms of sensory function, the perception of touch, pain, temperature, and other senses below the injury plane also significantly decreased or disappeared, making patients unable to perceive external stimuli normally and severely limited their self-care ability. At the same time, due to long-term bed rest, it is also easy to cause a series of complications, such as pressure ulcers, lung infections, urinary system infections, etc., which further affects the physical health and rehabilitation process of patients. In addition, the psychological state of patients is also relatively fragile, often due to the serious loss of physical function, anxiety, depression, and other negative emotions. These negative emotions will in turn affect the recovery of neurological function and rehabilitation treatment compliance [8].

5.2. Adjustment of targeted combination treatment strategies

For patients with moderate to severe spinal cord injury, the stimulation parameters should be adjusted according to the degree of injury and individual differences in repetitive transcranial magnetic stimulation, such as increasing the intensity and frequency of stimulation, to more effectively regulate the neural plasticity of the cerebral cortex and promote the remodeling of nerve function. Rehabilitation training should initially prioritize basic muscle strength and joint mobility exercises to prevent muscle atrophy and joint contracture. With the improvement of patients' physical condition, balance training and walking training were gradually introduced to improve their athletic ability [9]. At the same time, because of the complications that patients are prone to, nursing interventions should be strengthened, such as regularly turning over to prevent pressure ulcers, encouraging patients to voluntarily cough up sputum and

combining with atomizing inhalation to prevent lung infection, and guiding patients to perform bladder function training to prevent urinary system infection. In addition, to relieve the psychological pressure of patients, increase psychological counseling and support, help patients establish confidence in rehabilitation, and improve treatment cooperation.

5.3. Comparison and difference analysis of recovery effect

Patients with moderate to severe spinal cord injury who received targeted combination therapy were compared with those who received conventional therapy alone. In terms of motor function, the Fugl-Meyer motor function score of patients in the combined treatment group improved more significantly, and at 6 and 12 months after treatment, the score was significantly higher than that of the conventional treatment group. The autonomous motor ability of patients was enhanced, and some patients could walk short distances with the help of assistive devices, while the motor function of patients in the conventional treatment group improved relatively slowly. In terms of sensory function, the patients in the combined treatment group had a more significant decrease in sensory threshold, a wider range of sensory recovery below the injury plane, and improved sensory abilities such as touch and pain. In terms of complication rate, the combined treatment group was significantly lower than the conventional treatment group, and the patients' physical condition was more stable and the recovery process was more smooth. Mental state assessment showed that patients in the combined treatment group had a greater decline in anxiety and depression scores, better mental health status, and higher enthusiasm and cooperation for rehabilitation treatment, which further promoted the recovery of neurological function [10].

6. Conclusion

This study systematically investigated the effect of repeated transcranial magnetic stimulation combined with rehabilitation training on the recovery of nerve function in patients with different degrees of spinal cord injury. The results showed that combined therapy could significantly promote the recovery of nerve function in patients with mild and moderate to severe spinal cord injury. After adjusting the strategy for moderate and severe patients, the effect of movement, sensory function recovery, and complication prevention and control was outstanding, and the psychological state of patients was improved and the enthusiasm for rehabilitation was enhanced. However, the study has limitations in terms of sample size and long-term follow-up of treatment. In the future, the sample size should be expanded, the multi-center study should be carried out, the follow-up period should be extended, and the best scheme and mechanism of combination therapy should be deeply explored. It is expected that the research results can provide more powerful support for clinical treatment, help more patients with spinal cord injury improve neurological function, improve quality of life, and promote the development of spinal cord injury rehabilitation medicine.

Disclosure statement

The author declares no conflict of interest.

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