

The Application of Percutaneous Nerve Electrical Stimulation in Various Diseases

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Abstract. Transcutaneous electrical nerve stimulation (TENS) is widely used for analgesia in various diseases in current clinical and rehabilitation treatments, and also serves as an extended rehabilitation approach. With advances in medical science, the application of this technology has become increasingly complex. Therefore, comparing its applications in various common diseases and summarizing relevant findings is of great significance. This paper lists five common diseases, analyzing the efficacy and application methods of TENS in each scenario. TENS shows favorable analgesic effects in conditions such as osteoarthritis, post-total hip replacement, and during or after childbirth. Beyond analgesia, it can also promote lymphatic regeneration and enhance peripheral nerve regeneration, as observed in cases of idiopathic facial paralysis. Studying the application of TENS in various diseases helps to improve understanding of this therapy, providing non-pharmacological alternatives for pain management, reducing drug dependence and side effects, facilitating basic research in rehabilitation medicine, and lowering medical costs.

Keywords: Transcutaneous electrical nerve stimulation, childbirth pain, knee osteoarthritis, central facial paralysis, stroke

1. Introduction

Transcutaneous Electrical Nerve Stimulation (TENS) is a non-invasive physical therapy technique that uses skin surface electrodes to output low-frequency or high-frequency electrical pulses, stimulating local nerves to relieve pain, improve local blood circulation, or regulate nerve function. TENS is mainly used to treat acute and chronic joint pain, and can also reduce the dosage of opioid drugs [1]. The experiment confirmed that this therapy has a good therapeutic effect on knee osteoarthritis pain. In addition to joint pain, transcutaneous nerve electrical stimulation has also shown good efficacy in relieving postpartum pain in pregnant women and treating acute pain caused by idiopathic facial neuritis. Based on the pulse frequency, duration, and intensity they deliver, TENS therapeutic devices can be grouped into four types: normal TENS, acupuncture-like TENS, burst mode TENS, and brief intensity TENS. At present, the first two are widely applied in patients' physical therapy, whereas the latter two see much less use [2]. In earlier research, studies on TENS were largely rooted in the "gate control theory"—whereby the electrical stimulation generated by TENS closes the "gate" formed by glial cells in the dorsal horn of the spinal cord, thus dampening

pain. Yet recent investigations have uncovered that the release of endogenous analgesic substances, such as opioid peptides and enkephalins, also plays a role in the analgesic mechanism of TENS [3]. Transcutaneous electrical nerve stimulation (TENS) evolved from the "pain gate control theory". It applies specific electrical currents to the human skin, thereby achieving pain relief and disease treatment. In recent years, with the deepening of research, this therapy has been widely used not only for pain relief but also for restoring motor function and promoting nerve rehabilitation. Moreover, it has been combined with acupoints in traditional Chinese medicine acupuncture to form transcutaneous electrical acupoint stimulation (TEAS), which boasts the dual advantages of both acupuncture and electrical stimulation [3]. TENS devices used in medical facilities vary slightly depending on manufacturers and national standards. In China, TENS machines typically consist of a main unit and a manual control unit. These devices come in two types: wired and wireless. They deliver stimulation via electrodes, with electrode pads (both positive and negative) connecting the electrodes to painful areas or regions needing correction on the skin. The power can be adjusted according to the patient's needs. When combined with traditional Chinese medicine theory, the electrode pads can also be placed on acupoints for treatment—for instance, in managing labor pain [4]. To help rehabilitation medicine practitioners and medical scholars develop a clearer understanding of this therapeutic approach, further advance the medical technology, and identify a safe, non-invasive, and relatively flexible alternative to drug therapy for patients, this analysis explores transcutaneous electrical nerve stimulation (TENS) across five common conditions: knee osteoarthritis, post-total hip arthroplasty recovery, labor pain with postpartum low back pain, central facial paralysis, and stroke. It examines TENS in terms of its mechanisms of action, treatment modalities, therapeutic effects and the extent of its efficacy, aiming to deepen understanding of TENS.

2. Clinical efficacy and differential analysis of Transcutaneous Electrical Nerve Stimulation in various diseases

2.1. Application in the treatment of knee osteoarthritis

Knee osteoarthritis is a chronic joint disease characterized by degenerative changes in the knee cartilage and secondary osteophyte formation. It is one of the common joint diseases in middle-aged and elderly people, also known as degenerative knee arthritis, senile knee arthritis, etc. Its main clinical manifestations include knee joint pain, stiffness, swelling, and limited mobility. Transcutaneous nerve electrical stimulation is mainly aimed at joint pain symptoms, which are characterized by aggravated pain after activity and nighttime pain. In severe cases, it can lead to knee joint deformities, seriously affecting the patient's normal life and walking ability. This therapy achieves pain relief by releasing low-frequency or mid-frequency alternating current to stimulate the nerve distribution areas associated with pain.

Wang et al. evaluated the pain level of 124 patients with knee osteoarthritis after receiving TENS treatment, and the results showed that transcutaneous nerve electrical stimulation has a good therapeutic effect on knee osteoarthritis [5]. They conducted a two-month treatment and follow-up observation on the patients. Finally, they evaluated the knee joint function of the patients after the treatment and assessed the pain level of the patients using the Visual Analogue Scale (VAS). The results were compared with those obtained before the treatment, and data analysis was conducted using SPSS 23.0 statistical software, the conclusion was drawn: TENS can significantly improve the VAS score and knee joint function score of patients with knee osteoarthritis, and enhance the overall clinical effect.

2.2. Application in the treatment of total hip replacement surgery

Total Hip Arthroplasty is a surgical procedure that involves replacing the diseased or damaged part of the hip joint with an artificial prosthesis through an operation, in order to restore the normal function of the hip joint, relieve pain, and improve the quality of life of the patient. During the operation, the damaged femoral head and acetabulum will be removed. The artificial prosthesis used for implantation usually consists of two parts, namely the acetabular side and the femoral side. On the hip socket side, a "hip socket cup" made of metal or polymer materials is used to replace the original hip socket cavity. On the femoral side, it is composed of a metal stem and an artificial femoral head, replacing the damaged femoral head and the upper part of the femur. After total hip replacement surgery, the affected limb often experiences severe pain [6]. Poor control may lead to reduced joint mobility, muscle atrophy, and in severe cases, serious symptoms such as deep vein thrombosis and pulmonary embolism.

After the patient has undergone surgical treatment and received appropriate drug therapy (oral celecoxib 0.2g twice a day 48 hours before surgery, and the same dose 8 hours after surgery), TENS can be used to treat postoperative pain [1]. The specific method is as follows: Place four electrodes respectively at the upper, lower inner, upper outer and lower outer positions of the knee joint centered on the incision, and set the frequency to 80-120 HZ. During the treatment process, the patient may experience a tingling sensation, which is a normal phenomenon. If the patient experiences uncontrollable pain during the treatment (with a VAS score greater than 7), a temporary relief can be achieved by intramuscular injection of 100 mg of bromazepam.

The mechanism of action of TENS after total hip replacement surgery is to promote the enhancement of nerve fiber activity, activate glial cells, block the transmission of pain-related neurotransmitters, and thereby inhibit the transmission of pain signals [7]. At the same time, it also activates the endogenous analgesic system, causing the central nervous system to release morphine like neurotransmitters to the nerve endings. Low-frequency electrical stimulation can promote the release of endorphins and enkephalins in the central nervous system, high-frequency electrical stimulation can promote the release of enkephalins, and alternating high and low frequency stimulation can simultaneously release all three, producing local thermal effects and reducing sensory nerve excitability [8,9]. Transcutaneous electrical nerve stimulation, as an adjunctive therapy after total hip arthroplasty, can effectively inhibit patients' pain, reduce patients' VAS scores, improve patients' quality of life, accelerate patients' recovery, and promote the restoration of hip joint activity function.

2.3. Application in the treatment of pain during childbirth in pregnant women

Labor pain refers to the pain that pregnant women experience during the process of giving birth, often described as the most severe pain in a woman's life, and gradually intensifies with the progression of labor. This type of pain may trigger a series of reactions in the endocrine system, leading to uterine artery constriction and subsequently causing maternal and infant functional and metabolic disorders [10].

To alleviate pain in pregnant women and reduce complications, transcutaneous nerve electrical stimulation can be chosen for analgesia. When using TENS treatment, bilateral Hegu points, Sanyinjiao points, and Zusanli points are selected for pain relief. The initial current intensity is 15mA and gradually increases, so that the patient has no pain sensation [11]. By observing experiments, comparing the concentration of endorphins in postpartum women before and after treatment, examining the birth outcomes of newborns, and analyzing the incidence of postpartum

hemorrhage, the conclusion shows that this therapy is effective in relieving postpartum pain [12]. Some pregnant women may still experience lower back pain after childbirth, known as Postpartum Pregnancy Related Lower Back Pain (PPLBP), which refers to the lower back pain that occurs in women after childbirth and is directly related to the pregnancy process. Its core feature is that the pain can be traced back to physiological changes during pregnancy and persists or worsens after childbirth. The treatment method for this type of pain mainly involves selecting a stimulation frequency of 2-100Hz at the corresponding spinal segment of the lower back pain site, with a pulse form of bidirectional asymmetric waves and a recommended output current intensity of 8-12mA. Typically, the first long strip electrode is placed on both sides of the surface of the 7th to 10th thoracic vertebrae, and the second long strip electrode is placed on both sides of the surface of the 11th to 1st lumbar vertebrae [13]. A study compared the self-perceived pain levels of patients before and after treatment, and used the SCODI questionnaire to evaluate the differences in pain, walking, sleep, and other aspects compared to before treatment. The results showed that TENS has a good therapeutic effect on PPLBP.

2.4. Application in the treatment of facial paralysis

The incidence of Idiopathic Facial Palsy (IFP) is approximately 15 to 40 cases per 100,000 person-years. This condition can occur across all age groups and populations, with no significant gender predilection. Although IFP has a relatively high cure rate, it may still result in unfavorable prognostic outcomes for some patients, such as progression to chronic facial nerve palsy. Facial palsy can lead to low mood, fear of social interaction, and loss of confidence in affected individuals, which, if prolonged, may contribute to severe mental health disorders [14]. Ear herpes zoster is also one of the triggering factors of this disease, and patients with facial nerve paralysis caused by it usually have a poor prognosis [15].

The treatment measure is to place three anode electrodes with a diameter of 2.5 centimeters on the mandible, temporal region, and zygomatic bone, respectively, while a cathode electrode is positioned on the mastoid process. The current is gradually increased until the patient feels a sensation on the skin. The optimal frequency is 20Hz, and a monophasic or biphasic pulse should be adopted. The electric current was applied identically across the three channels [15].

Zhang et al. compared and analyzed the facial signs (such as nasolabial folds, bulging cheeks, forehead wrinkles, etc.), House Brackmann (H-B) facial nerve function grading evaluation, and R1 wave extraction rate of patients before and after treatment. The validity of the results was calculated using statistical methods, and the final conclusion was that transcutaneous nerve electrical stimulation has a therapeutic effect on the acute phase of idiopathic facial nerve paralysis [16].

2.5. Application in stroke treatment

Stroke refers to an acute cerebrovascular disease caused by the sudden rupture or occlusion of blood vessels in the brain, which can result in damage to or hypoxia of brain tissues. Also known as cerebrovascular accident (CVA), it is a clinical syndrome with a duration exceeding 24 hours or resulting in death. Stroke is a common disease endangering the health of middle-aged and elderly people, characterized by abrupt onset and high mortality, which deserves serious attention. According to statistics on the incidence rate of stroke in urban and rural areas of China, the annual incidence rate of this disease is recorded as 200 cases per 100,000 people, with the mortality rate reaching as high as 80-120 cases per 100,000 people. Among the survivors, over 70% of patients will have residual functional impairments of varying degrees; severe disability is documented at

40%, and the recurrence rate is also documented at 40%. The placement of electrodes varies depending on the treatment site, usually in the nerve running area, target muscle, or painful area. For example, to improve upper limb function (such as hands and wrists), electrodes can be placed in the flexor/extensor muscles of the forearm, the median nerve running area, etc., set as continuous waves with a frequency of 100Hz, and the output intensity should be based on the patient's maximum tolerance [17].

3. Conclusion

This paper elaborates on the types of five common diseases, explores the application methods of transcutaneous electrical nerve stimulation (TENS) in these five common diseases, and demonstrates the efficacy of this therapy by citing the experimental results of previous studies. Transcutaneous Electrical Nerve Stimulation (TENS), a non-invasive physical therapy technique, has demonstrated significant value in the treatment of five common conditions: knee osteoarthritis, post-total hip arthroplasty, labor pain and postpartum low back pain (PPLBP), idiopathic facial paralysis, and stroke. The findings of this study indicate that TENS can significantly improve VAS pain scores and knee joint function in patients with knee osteoarthritis, with clear clinical effects observed after two months of treatment and follow-up. In the context of post-total hip arthroplasty, TENS—when applied with specific electrode placement and frequency settings (80-120Hz)—effectively inhibits pain signal transmission, activates the endogenous analgesic system, reduces patients' VAS scores, and accelerates hip joint function recovery. For labor pain and PPLBP, TENS shows positive effects by stimulating acupoints such as Hegu and Sanyinjiao (for labor pain) and corresponding lumbar spinal segments (with frequencies ranging from 2-100Hz for PPLBP). It alleviates pain, improves outcomes for both mothers and newborns, and enhances pain levels, walking ability, and sleep quality in PPLBP patients. In the acute phase of idiopathic facial paralysis, TENS with a 20Hz frequency and specific electrode placement (anodes at the mandible, temporal region, and zygoma; cathode at the mastoid process) improves facial signs and facial nerve function. For stroke patients, placing electrodes along nerve pathways or on target muscles (using 100Hz continuous waves) helps improve upper limb function. This study systematically summarizes the mechanisms of action and application protocols of TENS in these five conditions, providing a non-pharmacological treatment option for clinical practice. It contributes to reducing drug dependence and side effects, advancing basic research in rehabilitation medicine, and lowering healthcare costs. However, existing studies have certain limitations: some have small sample sizes (e.g., 124 cases in knee osteoarthritis research), long-term efficacy data are insufficient, standardized protocols for TENS parameters (such as frequency and intensity) across different diseases have not yet been unified, and the impact of individual differences on efficacy requires further exploration. Future research should expand sample sizes through multi-center studies, optimize TENS treatment parameters for different diseases, deepen investigations into mechanisms of action by integrating approaches like traditional Chinese medicine acupoint stimulation, and explore its application in more conditions to enhance treatment precision and effectiveness.

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