Treatment of Knee Osteoarthritis with Transcutaneous Electrical Nerve Stimulation

Wenxuan Duan *

First hospital, Shanxi medical University, Taiyuan, China

* Corresponding Author Email: duanwenxuan@sxmu.edu.cn

Abstract. In China, the majority of osteoarthritis patients have the disease in the knee. Clinically, knee osteoarthritis (KOA) often has joint swelling, pain, stiffness, dysfunction and other symptoms, which reduce the patients' quality of life. There is a trend that osteoarthritis affects more and more young people in China, so it is much more important to treat KOA. Being a cheap and non-surgical option, the transcutaneous electrical nerve stimulation (TENS) has unique advantages in dealing with the pain caused by KOA. This article presents the pathogenesis and pain mechanism of KOA, describes the mechanism of TENS in KOA treatment, discusses the advantages and disadvantages, and proposes some combined treatment methods. Some studies have shown that the pathogenesis of KOA is related to the theory of unequal settlement of knee joints, and the pain comes from cartilage, subchondral bone and synovial membrane lesions. The gate control theory, endogenous opioid peptide release theory and diffuse noxious inhibitory controls theory are considered as the theoretical basis for TENS to inhibit pain. Its effectiveness, adaptability and incidence of adverse reactions are better than using drugs, but it cannot improve walking ability and the range of motion of the joints. Combination therapies of TENS are currently effective for treating KOA, including TENS combined with ultrasound, sodium hyaluronate, massage, functional training and other treatment options.

Keywords: Knee Osteoarthritis, Transcutaneous Electrical Nerve Stimulation, Pathogenesis, Pain Mechanism, Mechanism of TENS.

1. Introduction

In worldwide, the osteoarthritis (OA) is one of the most common musculoskeletal disorders, among which knee osteoarthritis (KOA) is more common in China and the European Union, with the rate of Disability Adjusted of Life Years (DALYs) registered 1.89% and 1.56%, respectively. While in the United States, it is mainly hand osteoarthritis (HOA), where the rate of DALYs is 1.36% for KOA and 1.68% for HOA [1]. Clinically, KOA often has joint swelling, pain, stiffness, dysfunction and other symptoms, which reduce the quality of life of patients. In the recent 30 years, the relevant data have revealed that the incidence of KOA increased rapidly in people aged 40-44 years old and reached the peak in people aged 50-54 years old in China. Compared with other population groups, people over 70 years old have the highest prevalence [1-2]. Therefore, the treatment of KOA is more important to the extended life expectancy and the development of aging society.

The commonly used methods for treating KOA include medication, surgery and physiotherapy. While the contraindications and side effects are factors to be considered for drug treatment, surgical treatment has such disadvantages as greater trauma and high cost. Therefore, TENS is applied in clinical practice as a kind of physiotherapy for it has the advantages of fewer side effects and low cost.It does not need to implant device. It is highly effective and convenient to use, so it is used as the primary treatment in clinical disease diagnosis and treatment process. However, in practical application, there is some controversy about the use of TENS. Currently, there are some problems, such as few statistical samples and different statistical standards in the relevant studies and statistics of TENS in treating KOA. Therefore, it is essential to summarize the current situation and continue the research. This article presents the pathogenesis and pain mechanism of KOA, describes the mechanism of TENS in the treatment of KOA, discusses the advantages and disadvantages, and proposes some combined treatment methods.

2. Pathogenesis and pain mechanism of KOA

2.1. Pathogenesis of KOA

One reason for KOA might be the force line deviation caused by the unequal settlement of the tibial plateau. With the aggravation of osteoporosis, the tibial plateau subsidence occurs. The lateral tibial plateau is supported by fibula while the medial tibial plateau has no bony support, resulting in greater pressure on the medial tibial plateau. It is shown by the difference in the descendant degree of the medial and lateral tibial plateau, which leads to the internal shift of the force line of the lower extremity, and then results in KOA [3-5]. The proximal fibular osteotomy（PFO）based on this theory balanced the pressure on the medial and lateral tibial plateau. An animal model experiment showed that PFO can reduce the progression of knee osteophyte formation and subchondral bone sclerosis, while also inhibiting the development of cartilage damage in osteoarthritis. In addition, PFO can also inhibit the progression of osteoarthritis by delaying the change of the force line in the lower limbs [6]. Compared with the conventional surgical method such as high tibial osteotomy, the PFO has advantages in four aspects: the intraoperative bleeding, the incidence of postoperative complications, length of hospital stay and mean operation time [7].

The Osteoporosis is another factor leading to KOA, and KOA can aggravate osteoporosis. They often occur in the state of comorbidity. The incidence of KOA combined with osteoporosis in China is up to 30%, and there is a complex mechanism and interaction between KOA and osteoporosis [8].

In addition, estrogen deficiency is closely related to the incidence of KOA in women. With the decrease of estrogen in postmenopausal women, the incidence of osteoarthritis such as KOA and osteoporosis increases significantly [9].

2.2. KOA pain mechanism

The pain mechanisms of KOA include cartilage lesions, subchondral bone lesions, and synovial lesions.

2.2.1 Cartilage lesions

In KOA, the cartilage is the first site of the lesion. The cartilage lesions are manifested as cartilage wear and fibroid degeneration. It is believed that stress stimulus such as stretch and pressure caused by these lesions could impact the surrounding synovial tissue and cause pathological changes, resulting in joint swelling and pain and it is also believed that focal cartilage surface softening often appears in the early stage of KOA, and the diseased cartilage would gradually lose its normal elasticity and dissociate in the joint cavity in the form of small pieces, which can aggravate the pain and wear of the joint during joint moving [10]. Some studies tend to believe that KOA pain is caused by the imbalance of the normal metabolic cycle of cartilage tissue, and the activity of some cells is enhanced, and sensory nerves grow in cartilage tissue, so that cartilage can feel the pain stimulus [11].

2.2.2 Subchondral bone lesions

The stimulation coming from sensory nerves in the subchondral bone is another pain mechanism of KOA. In contrast to cartilage, the subchondral bone has more nerves and vessels. When cartilage lesions lead to incomplete cartilage and exposed subchondral bone, the mediator of inflammation existing in the articular cavity can stimulate sensory nerves in the subchondral bone. It is believed that increased subchondral bone load after cartilage defects could promote subchondral bone remodeling. In this process, osteoclasts are stimulated to secrete Netrin-1 protein, promoting subchondral bone to grow the sensory nerve axons, making exposed subchondral bone more sensitive to stimulation [12].

2.2.3 Synovitis

Synovitis is a common feature of osteoarthritis, and the development of synovitis can lead to KOA pain. Cartilage pieces that fall off the diseased cartilage stimulate the synovium of the joint and joint capsule, causing their congestion, edema, hyperplasia and hypertrophy, and result in synovitis [10].

Some clinical cases showed that the synovitis in the medial knee of most patients was more serious than that in the lateral knee [13]. A total of 184 KOA patients with 257 knee joints were selected for the statistics of pain sites and obvious synovitis sites under arthroscopy, and the results showed that 70% of the patients' pain occurred in the anteromedial knee space. 10% of the patients had pain in the lateral knee and the posterolateral popliteal space. 80% of the patients had synovitis located in the medial patellofemoral sulcus, and 30% in the lateral patellofemoral sulcus [14].

3. Application of TENS in the treatment of KOA

3.1. Mechanism of TENS

The mechanism of TENS is not completely clear, and the main theories are gate-control theory, endogenous opioid peptide release theory and diffuse noxious inhibitory controls theory.

3.1.1 Gate-Control theory(GCT)

The theory is that the excitation of Aβ-fibers, which conduct peripheral tactile and pressure sensations, inhibits the transmission of excitation signals by C-fibers, which conduct pain and temperature sensations [15]. TENS suppresses pain signal uploading by selective activation of certain fibers. Normal TENS is high frequency and low intensity electrical stimulation, activating Aβ-fibers, acupuncture-like TENS is low frequency and high intensity electric stimulation, activating Aδ and C-fibers and brief intense TENS is high frequency and high intensity electric stimulation, activating Aδ fibers [16-17].

3.1.2 Endogeneous opioid peptide(EOP) release theory

Some studies believe that TENS can activate endogenous morphotinergic neurons in the brain, causing endogenous morphine-like peptides to produce analgesic effect. Different electrical stimulation frequencies can lead to the release of different kinds of peptides to produce different degrees of analgesic effect, The study proposed that 2Hz can cause the release of enkephalin (Enk), endorphin (End) and endomorphin (EM), and 100Hz can cause the enkephalin (Dyn) release [18].

3.1.3 Diffuse noxious inhibitory controls theory

High intensity electrical stimulation may cause intense pain in some body parts while reducing pain in other parts [19].

3.2. Principle of the treatment process

In treating KOA, TENS mainly use electrical stimulation to reduce the excitability of nociceptive neurons in the dorsal horn of the spinal cord, and curbed the transmission of pain signals from small diameter nociceptive fibers. In the same time, it leads to the central nervous system to release endogenous opioids to control the pain.

3.3. Advantages and problems of TENS in the treatment of KOA

3.3.1 Advantages

There are many cautions for using conventional drugs to treat KOA. For example, although the first-line drugs for osteoarthritis are non-steroidal anti-inflammatory drugs, gastrointestinal and cardiovascular adverse events still need to be prevented. The Long-term and repeated intra-articular injection of glucocorticoids could increase the risk of the accelerated loss of articular cartilage and the blood glucose rise in a short time. The weak opioid drug tramadol can significantly increase the incidence of all-cause mortality, myocardial infarction and hip fracture in patients with osteoarthritis [20]. As the population with a high incidence of KOA, middle-aged and elderly people often suffer from other common diseases of the elderly and metabolic diseases, such as obesity, hypertension, osteoporosis, and cardiovascular diseases. Therefore, these diseases easily limit their use of drugs.

The main advantage of TENS in treating KOA is demonstrated in suppressing the pain. Generally, TENS has a long analgesic effect. After TENS treatment, its analgesic effect is evident for 4 weeks [21].

TENS is more effective and better tolerated than some drugs. A study of TENS therapy based on wearable devices showed that, Comparing with weak opioids, wearable TENS(W-TENS) has better performance in effectiveness and tolerability in treating KOA pain. In the average eight-day pain intensity index, The W-TENS and WO(weak opioids) groups were 3.87 (2.12) and 4.66 (2.37), respectively. Among the treatment-related adverse events, seven patients were reported in the W-TENS group versus 36 patients in the WO group, this shows that W-TENS is obviously better than WO in treating KOA pain [22].

3.3.2 Existing problems

The most important problem for TENS therapy is that it cannot fundamentally treat KOA pain. At present, TENS mainly uses GCT and EOP release mechanisms to inhibit pain, which cannot remove the small pieces of diseased cartilage in the joint space. There is no sufficient evidence to show that TENS can repair the damaged cartilage tissue, and it has no obvious improvement for synovitis. This is backed up by some studies, including one that showed no difference between TENS and placebo TENS (put electrodes but no electricity) [23].

Another meta-statistical result showed that TENS could not improve joint range of motion and lower limb walking ability [21].

3.4. Combination therapies based on TENS

A meta-analysis was conducted to evaluate the overall clinical efficiency before and after treatment. The control group was treated with massage, drug therapy (sodium hyaluronate) and functional therapy respectively, while the experimental group was additionally treated with TENS or transcutaneous electrical acupoint stimulation. According to the sample statistics, after combined treatment, the effective rate of treatment can reach 90% [24].

There is another clinical observation of ultrasound combined with TENS in the treatment of KOA, the VAS (3.33±1.75 in the control group, 2.47±1.50 in the experimental group after treatment) and the 6min walking distance (405.57 ±30.22m in the control group, 423.07m±31.56m in the experimental group after treatment) and WOMAC of knee joint (105.10±25.51 in the control group, 84.50±29.87 in the experimental group after treatment) showed significant advantages in comparison with those of ultrasound alone) [25].

4. Conclusion

This article presents the pathogenesis and pain mechanism of KOA, describes the mechanism of TENS in the treatment of KOA, discusses the advantages and disadvantages, and proposes some combination treatments.

The pathogenesis of KOA includes the theory of unequal settlement of the knee joint. The uneven subsidence of the tibial plateau leads to the imbalance of the force line of the lower extremity, which leads to KOA. At the same time, statistics show that the pathogenesis of KOA is closely related to osteoporosis, and the incidence of KOA in the female population is also associated with estrogen. The pain results from cartilage damage, exposure to subchondral bone, and synovial inflammation.

In KOA treatment, TENS follows the gate control theory, endogenous opioid peptide release theory and diffuse noxious inhibitory controls theory to curb the pain caused by KOA and has advantages over drug therapy in terms of efficacy, adaptability and incidence of adverse reactions. Its disadvantages are that it does not significantly improve the range of motion and lower limb walking ability of patients with KOA. Besides, the statistical results of analgesic efficacy are often conflicting.

Combined treatments mainly include TENS combined with ultrasound therapy, TENS or TEAS (derived treatment from TENS) combined with massage, function training and sodium hyaluronate injection, which can improve the efficacy compared with a single treatment.

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