The Role of Transcutaneous Electrical Nerve Stimulation (TENS) in Postoperative Analgesia

Essay

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بسم الله الرحمن الرحيم

قالوا

سبحانك لا علم لنا إلا ما علمتنا إنك أنت العليم الحكيم

صدق الله العظيم

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List of Abbreviations

Abb.	Full term
AAN	Academy of Neurology
AL-TENS	Acupuncture-like TENS
ASA	American Society of Anesthesiologists
CBT	Cognitive behavioral therapy
CLBP	Chronic low back pain
COPD	Chronic obstructive pulmonary disease
DC	Direct current
EDA	Electronic Dental Anaesthesia
ENF	Electro-neuro-feedback
ES	Electric stimulation
FS-TENS	Fixed-site high-frequency transcutaneous electrical nerve stimulation
IASP	International Association for the Study of Pain
ICDs	Implantable cardioverter defibrillators
NICE	National Institute of Clinical Excellence
NSTs	Nerve stimulation therapies
OAB	Overactive bladder
PAG	Periaqueductal gray
PPS	pulse per second
PVD	Provoked vestibulodynia
QALY	Quality-adjusted life year
RVM	Rostroventral medial medulla
SP	Substance P
TENS	Transcutaneous electrical nerve stimulation
WMSDs	Work-related msculoskeletal disorders

Introduction

Pain is an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of damage ***(The international Association for the Study of Pain (IASP), 2017).***

Although Pain sensation is associated with stimuli that have the ability to damage tissue, it may also exist in the absence of actual or potential tissue damage. The sensory-discriminative dimensions of pain include the intensity, location, and quality of the pain, subserved by the nociceptive system. Pain evokes emotions such as unpleasantness and fear generating affective emotional-motivational dimensions of pain, subserved by the reticular and limbic systems of the brain. Pain also evokes thoughts such as consideration of the appropriate action to take in response to pain generating cognitive-evaluative dimensions of pain, subserved by the frontal lobe of the brain ***(Johnson, 2014).***

Pain is the most common presenting symptom in medicine. It can occur in any part of the body and affect any system. It can be acute or chronic, episodic or continuous, and occurring regularly or irregularly. It is required to classify pain states to provide an understanding of pain disorders, initiate standards for diagnosis and description, and allow modification of standardized information. Pain is generally classified as nociceptive, neuropathic, idiopathic, psychogenic, and mixed ***(Cheng, 2018).***

A conceptual model for how sensory nerve stimulation leads to pain relief was proposed by Melzack and Wall in 1965. Their ‘pain gate theory’ stipulates that activation of large diameter sensory nerves (Aβ fibers) closes a “pain gate” in the spinal cord that inhibits the transmission of pain signals carried by nociceptive afferents (C and Aδ fibers) to the brain ***(Kong and Gozani, 2018)***.

In the past 20 years, anatomic pathways and molecular mechanisms that may underlie the pain gate have been identified. Sensory nerve stimulation activates the descending pain inhibition system, primarily the periaqueductal gray (PAG) and rostroventral medial medulla (RVM) located in the midbrain and medulla sections of the brainstem, respectively. The PAG has neural projections to the RVM, which in turn has diffuse bilateral projections into the spinal cord dorsal horn that inhibit ascending pain signal transmission. Enhanced central pain inhibition may also account for the benefits of sensory nerve stimulation in chronic pain of central nervous system origin ***(Kong and Gozani, 2018).***

Electrical currents are known to excite tissues of the body including nervous system tissue and therefore electricity can be used to produce local stimulation of the body for therapeutic purposes (electrotherapy) and the relief of pain (electroanalgesia). Stimulating nerves close to the surface of the body is relatively easy to achieve by delivering electrical currents across the intact surface of the skin (i.e. transcutaneous). The electrical currents can be generated by a battery-powered, portable, stimulating device and can be administered through the skin using conducting pads called electrodes. This technique is called transcutaneous electrical nerve stimulation (TENS) ***(Johnson, 2017).***

Pharmacological therapies for pain and inflammation are recognized and accepted by international medical guidelines as the first line of treatment. However, due to intolerable side effects (e.g., gastritis, nausea, and vomiting) or the ineffectiveness of these interventions in some individuals, analgesic and nonpharmacological treatments with minimal side effects are necessary ***(Sharma et al., 2017).*** In this case, transcutaneous electrical nerve stimulation (TENS) is a physiotherapeutic resource that has been increasingly studied as an alternative therapy ***(Igwea et al., 2016).*** TENS has been used since 1970 as adjunctive therapy for acute and chronic pain management in various medical and surgical conditions ***(Vance et al., 2014).***

Transcutaneous electrical nerve stimulation (TENS) is an intervention that activates a complex neuronal network to reduce pain by activating descending inhibitory systems in the central nervous system to reduce hyperalgesia. Population-specific systemic reviews and meta-analyses are emerging, indicating both High frequency and Low frequency TENS being shown to provide analgesia, specifically when applied at a strong, nonpainful intensity. The parameters of pulse frequency, and pulse intensity are adjustable and linked to TENS efficacy ***(Vance et al., 2014).***

TENS is popular with patients and practitioners because it is non-invasive, easy to administer, and has few side effects or drug interactions. Patients can administer TENS themselves at home and can titrate the dosage as required as there appears to be no potential for toxicity or overdose. The pain-relieving effects of TENS are immediate for most patients and some patients report prolonged effects after treatment. TENS treatment is relatively inexpensive when compared with long-term drug therapy ***(Johnson, 2014).***

With respect to the effectiveness of TENS in analgesia, studies show a reduction in pain intensity when compared to control groups in a variety of diseases ***(Vance et al., 2014; Johnson et al., 2015; Igwea et al., 2016; Jauregui et al., 2016; Sharma et al., 2017).*** TENS has been shown to be effective in controlling pain in several pathologies or after several surgical procedures ***(Vance et al., 2014).*** Recent studies have noted that in addition to analgesic effect of TENS, it may have an effect on the circulatory ***(Campos et al., 2016; Kamali et al., 2017)***, healing ***(Wang et al., 2016)***, and inflammatory systems ***(Fiorelli et al., 2016).***

Aim of the Study

The purpose of this study is to overview the principles, technical aspects, mechanism of action of TENS and its uses in analgesia.

HISTORICAL PERSPECTIVE OF TENS

Using electricity to relieve pain is an age-old technique that pre-dates the discovery of electricity. Stone carvings which date from the Egyptian Fifth Dynasty (c2500 BC) suggest that electric catfish (Malapterurus electricus) **(Figure 1a),** and electric rays (Torpedo marmorata) **(Figure 1b),** which are capable of generating 300-400 V were used to treat a variety of painful ailments. Over 2000 years later, Hippocrates (400 BC) referred to the use of electric fish to treat headache and arthritis, although it was Scribonius Largus (AD 46), a Roman physician, who is often credited with the first written report of the medical use of electric fish in Compositiones Medicae ***(Johnson, 2014).***

A B

Figure (1): A) Malapterurus electricus and B)Torpedo marmorata

The development of electrostatic generators in the eighteenth century increased the use of medical electricity, although its popularity declined in the nineteenth and early twentieth century due to variable clinical results and the development of alternative treatments ***(Johnson, 2014).***

Serious interest in the use of transcutaneous electrical stimulation for pain relief was rekindled in Europe and the USA by the publication of Pain mechanisms: a new theory by Melzack & Wall in 1965. The 'new theory' became known as the gate control theory of pain providing a physiological explanation of how stimulating the skin using electricity could relieve pain ***(Banerjee and Johnson, 2013).***

In 1967 Wall and Sweet stimulated large peripheral nerve fibres using needles inserted through the skin to deliver high-frequency (50-100 pps), non-painful electrical currents percutaneously, and found that patients reported relief from their chronic neurogenic pain ***(Banerjee and Johnson, 2013).***

In 1967 Shealy and colleagues implanted electrodes into spinal cord and administered electrical currents to stimulate nerves in the dorsal columns and found that this relieved chronic pain ***(Banerjee and Johnson, 2013).***

In 1969, Reynolds demonstrated that surgical anaesthesia could be achieved in rats by electrically stimulating the periaqueductal grey (PAG) region of the midbrain which acts as a relay station on the descending pain inhibitory pathways . This led to the development of deep brain stimulation techniques to relieve pain in humans ***(Banerjee and Johnson 2013).***

In the early 1970s TENS was being used to predict whether individuals would respond to dorsal column stimulation implants until it was realized that TENS could be used successfully on its own for various types of pain, including neuropathic pain, postoperative pain, and cancer pain ***(Banerjee and Johnson, 2013).***

Low-intensity, high-frequency pulsed electrical currents were delivered through the skin via electrodes attached to the intact surface of the body to stimulate nerve fibres with low thresholds of activation, and patients experienced a non-painful TENS sensation (i.e. electrical paraesthesiae). Nowadays this technique is termed (conventional TENS) ***(Watson, 2016).***

In 1977 Sjolund and colleagues found that electroacupuncture via surface electrodes increased levels of endorphins in the cerebrospinal fluid, although these muscle contractions generated by low-frequency high-intensity TENS using single pulsed current were found to be unpleasant for pain patients. Sjolund and colleagues found that muscle contractions generated by low-frequency bursts of high-frequency trains of pulses (burst mode TENS) were better tolerated by patients and they introduced the term (acupuncture-like TENS) to describe the technique ***(Kerai et al., 2014).***

In the 1980s research began to focus on the search for optimal electrical settings for TENS by evaluating effects on experimental pain in healthy humans. It was believed that the specific current amplitudes, frequencies, waveforms, durations, and patterns were optimal for certain types of pain, although study findings were inconsistent ***(Johnson et al., 2016).***

In the last decade, research conducted by Sluka and colleagues provided insights into the complexity of the physiology and pharmacology of TENS ***(Sluka et al., 2013).***

In 2009, NICE in the UK recommended that tens should not be offered for persistent non-specific low back pain, and in 2010 the therapeutics and technology assessment subcommittee of the American Academy of Neurology (AAN) published similar recommendations ***(National Institute of Clinical Excellence (NICE), 2009; Dubinsky and Miyasaki, 2010).***

However, in the same year an updated report by The American Society of Anesthesiologists (ASA) and the American society of Regional Anesthesia and Pain Medicine recommended that TENS should be used as part of multimodal approach to pain management for patients with chronic back pain and may be used for other pain conditions (e.g. neck pain and phantom limb pain) ***(The American Society of Anesthesiologists, 2010).***

For a full understanding of the role of TENS as a stand alone treatment for mild pain conditions and as adjunct