Special Article

Role of transcutaneous electrical nerve stimulation in post-operative analgesia

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ABSTRACT

The use of transcutaneous electrical nerve stimulation (TENS) as non-pharmacological therapeutic modality is increasing. The types of TENS used clinically are conventional TENS, acupuncture TENS and intense TENS. Their working is believed to be based on gate control theory of pain and activation of endogenous opioids. TENS has been used in anaesthesia for treatment of post-operative analgesia, post-operative nausea vomiting and labour analgesia. Evidence to support analgesic efficacy of TENS is ambiguous. A systematic search of literature on PubMed and Cochrane Library from July 2012 to January 2014 identified a total of eight clinical trials investigating post-operative analgesic effects of TENS including a total of 442 patients. Most of the studies have demonstrated clinically significant reduction in pain intensity and supplemental analgesic requirement. However, these trials vary in TENS parameters used that is, duration, intensity, frequency of stimulation and location of electrodes. Further studies with adequate sample size and good methodological design are warranted to establish general recommendation for use of TENS for post-operative pain.

Key words: Anaesthesia, post-operative analgesia, transcutaneous electrical nerve stimulation

INTRODUCTION

Transcutaneous electrical nerve stimulation (TENS) is a technique in which a special device transmits low voltage electrical impulses through electrodes on the skin to the area of the body that is in pain. It is widely used to relieve a range of painful conditions, including malignancy related pain and non-malignant acute[1] and chronic pain.[2]

Transcutaneous electrical nerve stimulation is cheaper, non-invasive and safe with no side-effects compared with pharmacological analgesic modalities. This review presents a brief summary of the technical aspects of TENS, mechanism of action and its uses in anaesthesia. Clinical studies on the role of TENS on post-operative pain were systematically searched and reviewed with the aim to determine its role in post-operative analgesia and factors affecting analgesic efficacy.

TECHNICAL ASPECTS

A TENS unit consists of electrical signal generator, battery and a set of electrodes. The TENS unit is small and programmable and the generator can deliver stimuli with variable current strengths, pulse rates and pulse width. The waveform in TENS machine can be monophasic or biphasic.

The usual settings for the stimulus parameters used clinically are the following:

- Amplitude-TENS units intensity ranges from 1 to 100 mA
- Pulse width-40-250 μs
- Pulse rate-1 or 2 Hz to 200-250 Hz.

There are a number of TENS devices available in the market, the main types being conventional TENS acupuncture TENS and intense TENS [Table 1].

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Table 1: Different types of TENS techniques

Conventional TENS	Acupuncture TENS	Intense TENSE
Selectively activates large diameter Aβ fibres Produces segmental analgesia with rapid onset and rapid offset which is localised to the dermatomes Uses high frequency, low intensity current in continuous stimulation pattern	Selectively activates small diameter fibres arising from muscles Induces forceful but non-painful phasic muscle contraction over the myotomes causing pain and producing extrasegmental analgesia Using low frequency, high intensity currents	Selectively activates small diameter Aδ fibres Using high intensity and high frequency current just tolerable to the patient

TENS – Transcutaneous electrical nerve stimulation

MECHANISM OF ACTION

The mechanism of pain relief by TENS has been explained by various theories. According to the gate control theory by Melzack and Wall[3] when an electrical current is applied to a painful area, transmission of the perception of pain through small diameter fibres to the brain is inhibited by the activity of the large diameter, fast-conducting highly myelinated, proprioceptive sensory nerve fibres, closing the gate to the pain perception to the brain. Another mechanism proposed is activation of descending inhibitory pathway, through release of endogenous opioids.[4] The areas involved in descending inhibition include nucleus raphe magnus in rostral ventral medulla (RVM) and the periaqueductal gray (PAG). The PAG sends projections to the RVM, which in turn send projections to the spinal dorsal horn. The stimulation of PAG or the RVM produces inhibition of dorsal horn nucleus including spinothalamic tract cells. Specific and different opioid receptors are activated through release of endogenous opioids by different frequencies of TENS. Application of low frequency TENS causes activation of δ-opioid receptors and high frequency TENS activates μ-opioid receptors. These opioid receptors in turn activate the PAG-RVM pathway.

Uses of transcutaneous electrical nerve stimulation in anaesthesia

Transcutaneous electrical nerve stimulation is currently being used in anaesthesia for post-operative analgesia, labour analgesia and for treatment of post-operative nausea/vomiting. We reviewed the clinical studies using TENS for postoperative pain.

METHODS

We searched for randomised controlled trials (RCTs) of patients who underwent elective surgery and were treated in perioperative period with either TENS versus placebo; TENS/pharmacological analgesia or TENS with adjuvant analgesia versus placebo TENS with pharmacological analgesia/pharmacological analgesia alone.

The outcomes included were decrease in post-operative pain intensity and/or decrease in requirement of pharmacological analgesia. The RCTs which were non-randomised and non-blinded, published before year 2000, with incomplete data and unavailable in English language were excluded. RCTs of TENS for post-operative analgesia were systematically searched using PubMed database and Cochrane Library without language restriction. We used free combination of terms-TENS, post-operative analgesia or post-operative pain. The last search was performed in January 2014.

RESULTS

The initial search identified 377 studies. Based on title and summary 29 studies were retrieved for review out of which one study was with incomplete data, four studies were not available in English language and full text of six studies was not available and hence excluded. The methodological quality of remaining 18 RCTs was evaluated by Oxford five-point scoring system by two investigators independently and found to vary from 0 to 5. The RCTs with score of 3 or above were included for review [Table 2]. Eight RCTs[5-12] with a total of 442 patients met the required criteria [Table 3].

The surgical procedures included were thoracotomies,[5,6] inguinal hernia repair,[7] laparoscopic tubal ligation,[8] laparoscopic cholecystectomy,[9] spine surgery[10,11] and total hip arthroplasty.[12] In all these studies TENS was used as a part of multimodal post-operative analgesia. The evidence for efficacy of TENS as sole agent for acute pain is insufficient.[1] TENS was started in post-operative period in six studies, whereas in remaining two studies[10,12] it was given before surgical incision and continued post-operatively.

The duration for which TENS was used in post-operative period was found to be variable. Erdogan *et al*.[5] used TENS continuously for 48 h and at 3 h interval for subsequent 3 days. Lan *et al*.[12] utilised TENS for 48 h at various time intervals and Silva *et al*.[9] used for 24 h. In two studies,[7,11] it was applied twice in immediate post-operative period, while in three studies[6,8,10] it was used once. At each time interval when TENS was

Table 2: Oxford quality score of trials

Study, year	Type of surgery	Randomisation	Double blinding	Withdrawals/drop-outs	Total score
Erdogan *et al.*	Thoracotomy	1	1+1	0	3/5
Ferreira *et al.*	Thoracotomy	1+1	0	1	3/5
DeSantana *et al.*	Hernia repair	1+1	1+1	1	5/5
DeSantana *et al.*	Laproscopic tubal ligation	1+1	1+1	1	5/5
Silva *et al.*	Laproscopic cholecystectomy	1+1	0	1	3/5
Unterrainer *et al.*	Major spinal surgeries	1+1	0	1	3/5
Kara *et al.*	Open lumbar discectomy	1+1	0	1	3/5
Lan *et al.*	Total hip arthroplasty	1+1	0	1	3/5

activated, it was applied for duration of 20-30 min in most of the studies.

Transcutaneous electrical nerve stimulation parameters

Lan *et al*.[12] placed electrodes at six acupoints, while in remaining seven studies two pairs of electrodes were placed around the surgical incision. The amplitude of current used was high and described as being strong, but adjusted to comfort of patient. High frequency was used in five studies whereas dense and disperse mode[11,12] was employed in two studies. DeSantana *et al*. compared high and low frequency of stimulation to placebo TENS.[8]

The effectiveness of TENS on post-operative pain was evaluated in terms of decrease in pain intensity and reduction in consumption of analgesics. In five studies[6-9,11] the intensity of post-operative pain was measured as primary outcome and TENS was found to be effective in producing statistically significant analgesia. In three studies both post-operative pain intensity[5,10,12] and consumption of analgesics were studied. TENS was found to produce statistically significant decrease in the intensity of pain in one study[5] while in a second study[10] it decreased the intensity of pain on activity only and in other study[12] it was found to be ineffective. The reduction in analgesic consumption was statistically significant in all three studies.

DISCUSSION

For post-operative analgesia the role of TENS is inconclusive.[1] There is limited systemic review on efficacy of TENS for post-operative analgesia. An initial systemic review[13] on TENS concluded TENS to be ineffective; however, the trials included in these reviews did not take into consideration the effective parameters of TENS and the outcome measures were not standardised. Bennet *et al*.[14] found that low fidelity in studies may be responsible for inconclusive findings. They found many areas of concern such as lack of information given to patients on the sensations they might experience, lack of instruction on how to self-administer TENS devices and assessment of compliance, poor reporting of the pattern and duration of TENS use, and failure to standardise or report concurrent analgesia and to assess comparability between groups. However, the main area of concern was the adequacy of the TENS intervention and poor assessment of outcomes.

Treatment protocols vary among studies included in this review. Different timings and duration of TENS application was followed. In two studies[10,12] TENS was started before surgical incision and continued post-operatively while in rest six studies it was started in post-operative period. Electroacupuncture which is quiet similar to TENS has been shown be to ineffective for pre-emptive analgesia.[15] The proposed mechanism is that pre-incisional stimulation yields specific effect on the pain producing substance and conductance of painful stimuli through k-receptors.

Erdogan *et al*. used TENS continuously for 48 h[5] while in other studies it was employed intermittently at various time intervals. Solak *et al*.[16] compared continuous TENS (CTENS) with intermittent TENS (ITENS) and found both to be equal in reducing pain; however, CTENS led to greater reduction in consumption of analgesics compared to ITENS.

However the appropriate duration of treatment with TENS to produce analgesia and duration of analgesic effect from one session of TENS is not known and needs further studies.

The meta-analysis by Bjordal *et al*.[17] advocated that selection of optimal TENS parameters is important for it to be effective. The effective current intensity, site of electrodes and the frequency of stimulation are the common investigated parameters. Trials reporting strong, subnoxious electrical stimulation with adequate frequency showed significant reduction in in need for rescue analgesic drugs.

Table 3: Use of TENS for post-operative analgesia

Study	Type of surgery	Timing of TENS	TENS parameters	Results
Erdogan *et al.*	Posterolateral thoracotomy (group TENS=60; group placebo=56)	Post-operatively for 48 h continuously Later for 20 min at 3 h interval for 3 days	Intensity: Patient's comfort Frequency: 100 Hz Pulse width: 100 μs Location: 2 pairs of electrodes 2 cm above and 2 cm below the thoracotomy incision	VAS score in TENS group was significantly less after second post-operative hour at rest and while coughing (P=0.009 and 0.008 respectively) Decrease in opioids consumption during the 5-day post-operative period (P=0.013) The FEV1, FVC and PaO_2 were high and $PaCO_2$ was low in TENS group. All these results are statistically significant (P=0.012, P=0.01, P=0.024 and P=0.02 respectively)
Ferreira *et al.*	Thoracotomy (group G1; with TENS=15, G2; without TENS=15)	On second post-operative day for 1 h	Intensity: According to patient's perception Frequency: 100 Hz Pulse width: 100 μs Location: Parallel to incision	Pain severity is significantly less in TENS group at rest immediately after TENS application (P=0.0380) and with elevation of limb at 1 h after TENS (P=0.05) No difference in pain severity while coughing and changing decubitus
DeSantana *et al.*	Unilateral inguinal herniorraphy (active TEN=20, placebo TENS=20)	At 2 and 4 h post-operatively for both with duration of 30 min	Intensity:Strong but comfortable Frequency=100 Hz Pulse duration: 100 μs Position of electrodes=4 electrodes around incision	Decreased pain intensity at 2, 4, 8 and 24 h (P=0.028, 0.022, 0.006, 0.001) Decreased analgesic consumption (P=0.001)
DeSantana *et al.*	Laproscopic tubal ligation (n=64) (high frequency TENS=23, low frequency TENS=20, placebo TENS=21)	Immediately after recovery from anaesthesia for 20 min	Intensity: Individually titrated, with a sensory intensity to maximal tolerance without muscle contraction Frequency: 100 Hz for high frequency TENS group and 4 Hz for low frequency TENS group Pulse duration: 100 μs Location: Around surgical incision	Pain intensity was significantly lower in low and high TENS groups when compared with placebo TENS group and also in the time before administration of TENS using numerical rating scale (P=0.001), pain rating index (P=0.001) and number of words chosen (P=0.001)
Silva *et al.*	Laproscopic cholecystectomy (active TENS=21, placebo TENS=21)	First 24 h after the operation, in those patients who complained of pain or discomfort at the incision or drainage sites after surgical intervention for 30 min	Intensity; maximum tolerable without causing pain, discomfort or muscle contraction Frequency: 75 Hz Pulse width: 150 μs Location: Around incision	Active TENS significantly reduced post-operative pain compared to placebo (P<0.016)
Unterrainer *et al.*	Major spinal surgeries (group A; PCA+TENS=13, group B; PCA+Sham TENS=12, group C; control=11)	30 min before skin incision, for 8 h after skin closure and 30 min on the first post-operative day	Intensity: 10-20 mA (i.e., the highest tolerated amplitude of electrical stimulation) Frequency: 100 Hz Pulse width: 0.25 m Location: Peri-incisional	Post-operative demand of pharmacological analgesia differed significantly A versus B (P<0.05), A versus C (P<0.05) and B versus C (P<0.05)
Kara *et al.*	Spinal surgeries (control group=29, PCA+TENS=25)	TENS was administered when patient arrived in post-surgical ward twice for 30-40 min each time with a 3-4 h rest interval	Intensity: Increased until patient received a strong paraesthesia without muscle contraction (0-30 mA) Frequency: Dense and disperse modes, with alternating electrical stimulation at 50 Hz and 100 Hz Pulse width: 20-60 ms Location: Around skin incision	Statistically significant difference in analgesic consumption of the TENS group, number of button presses and additional need of analgesic compared to control group (P<0.05) Significant difference in VAS score in 1st and 2nd post-operative day during activity and rest (P<0.001)
Lan *et al.*	Total hip arthroplasty (group PCA+TENS=30, group PCA+Sham TENS=30)	30 min before incision and at various time points in 2 days after surgery, i.e., 2, 4, 20 and 44 h	Intensity: 9-20 mA (depending on patient's ability to tolerate the patient) Frequency: 2/100 Hz in standard dense and disperse mode Location: On six acupoints bilateral P6 and L14, ST36, GB 31	Group PCA+TENS required 37% and 31% less analgesic at 24 and 48 h after surgery No difference in pain intensity between groups

TENS – Transcutaneous electrical nerve stimulation; VAS – Visual analogue scale; FEV1 – Forced expiratory volume in 1 second; FVC – Forced vital capacity; PCA – Patient controlled analgesia

Consistent with these findings most studies in our review reported the intensity of TENS used to be 'strong' but comfortable to patients.

The studies with both peri-incisional placement of electrodes and acupoint stimulation reported TENS to be effective in reducing pain and additional analgesics requirement. We found different types of frequencies used by investigators for post-operative analgesia. There is controversy regarding optimal frequency of TENS in literature. The high frequency, low frequency and alternating frequencies of 2 Hz and 100 Hz have been found to be effective for analgesia. DeSantana *et al*.[8] compared analgesic efficacy of high and low frequency of stimulation and found that pain intensity was significantly lower in low and high TENS groups when compared with placebo TENS group.

The stimulation with alternating high and low frequencies is found to release different neurotransmitters, which has synergistic effect with exogenously administered opioids. Furthermore, the modulating high and low frequency TENS has advantage of delaying development of opioid tolerance by approximately 5 days compared to either low or high frequency.[18]

This review included trials involving surgeries with variable post-operative pain profile; from thoracotomy which is known to be most painful procedures to laparoscopic surgeries causing relatively less pain. Seven of 8 trials evaluating effectiveness of TENS in decreasing post-operative pain intensity reported positive outcomes. Three studies additionally demonstrated significant reduction in consumption of analgesic medications.

Lan *et al*.[12] did not find any significant difference in intensity of pain and Unterrainer *et al*. found only pain on activity to be reduced by application of TENS. This result can be attributed to the fact that in both of these studies TENS was compared to patient controlled analgesia (PCA) with opioids. The best parameter for evaluating efficacy of TENS in these studies is decrease in total analgesic consumption. In both studies the analgesic consumption was reduced significantly.

The two studies[1-4] assessing TENS as complementary post-operative analgesic modality after thoracotomies included in this review demonstrated positive results. This is in contrast to result of Benedetti *et al*.[19] who found TENS is useful after thoracic surgical procedures only when post-operative pain is mild to moderate; it is ineffective for severe pain. The difference reported by Benedetti *et al*. can be due to different analgesic medications used in their study groups. TENS can not be used as the first or only pain control system, but as an adjunct to post-operative analgesics. Solak *et al*.[20] also reported first 3 days post-thoracotomy TENS as equivalent to PCA and afterwards it had significantly more analgesic efficacy.

There are several limitations to present study. First, it included heterogeneous surgical patient population. Second, treatment protocols and selected TENS parameters were variable among studies. Third, the nature, dose and route of administration of pharmacological analgesic used in addition to TENS were different. Fourth, the methodological quality of all included trials was not high.

CONCLUSION

This review concludes that TENS is effective in reducing post-operative pain following various surgeries as a part of multimodal analgesia. The success with use of TENS depends on appropriate selection of parameters and understanding the principles of application. The intensity of current for effective post-operative analgesia should be strong, but comfortable for the patient. The electrodes should be positioned around the surgical incision or corresponding acupoints. The alternating low and high frequency seems more beneficial to either high frequency or low frequency but needs validation in future studies. Due to low methodological quality and small sample sizes within included studies, future studies on TENS need to be well-designed, and need to ensure adequate implementation and standardisation of outcome parameters with ample sample size. The efficacy of TENS as sole agent and its comparison with other modalities for post-operative analgesia requires further clinical investigations.

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