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Control of Acute Postoperative Pain by Transcutaneous Electrical Nerve Stimulation after Open Cardiac Operations: A Randomized Placebo-Controlled Prospective Study

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ABSTRACT

Objective: We investigated the effectiveness of transcutaneous electrical nerve stimulation (TENS) therapy on pain during the first 24 hours after a cardiac surgical procedure.

Methods: A total of 60 patients who had undergone median sternotomy (MS) for coronary artery bypass graft (n = 55) or valve repair surgery (n = 5) were randomized to receive TENS and pharmacologic analgesia, placebo TENS and pharmacologic analgesia, or pharmacologic analgesia alone (control group). For each group we recorded severity of pain, analgesic intake, and pulmonary complications. Pethidine HCL and metamizol sodium were administered for postsurgical analgesia.

Results: Pain after MS was measured on a 10-point visual analogue scale (VAS). Mean scores in the TENS, placebo TENS, and control groups, respectively, were 5.70 ± 1.78, 5.75 ± 1.83, and 5.95 ± 1.63 before treatment ($P > .05$); 2.40 ± 1.18, 3.90 ± 1.48, and 3.55 ± 1.60 on the 12th hour of the intervention ($P < .05$); and 1.25 ± 0.91, 2.30 ± 1.34, and 2.15 ± 1.13 on the 24th hour of the intervention ($P < .05$). The mean VAS scores decreased within each group ($P < .05$). However, the mean VAS scores decreased much more significantly in the TENS group ($P < .05$). Metamizol sodium intake was 1.05 ± 0.39 g, 2.30 ± 1.08 g, and 2.90 ± 1.20 g and pethidine HCL intake was 17 ± 16.25 mg, 57 ± 21.54 mg, and 51.50 ± 18.99 mg, respectively, in the TENS, placebo TENS, and control groups. Metamizol sodium and pethidine HCL intake was least in the TENS group ($P < .05$). Postoperative complications were observed in 6 (10%) of patients. The most frequent complication was atelectasia.

Conclusions: TENS was more effective than placebo TENS or control treatments in decreasing pain and limiting opioid and nonopioid medication intake during the first 24-hour period following MS.

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INTRODUCTION

Patients who have undergone median sternotomy (MS) report considerable early postoperative chest pain [Donald 1976; Fitzpatrick 1988]. Pain may inhibit effective coughing and deep breathing, and restrict early postoperative mobilization [Chulay 1982; Jansen 1986]. Pulmonary exercises are important in decreasing pulmonary complications after open-heart surgery, so pain that limits pulmonary exercises should be decreased. Otherwise lung ventilation and independence in self-care may not be optimal, and there may be an increased risk of lung infection [Jenkins 1989].

Opioid medication use in MS patients has been described in the literature [Forster 1994]. Determining the minimum effective analgesic concentration is a difficult task, however. Although opioid medications relieve pain, they may also lead to cough suppression, drowsiness, nausea, and vomiting and limit effective expectoration. Sedation, urinary retention, and constipation are also well-known side effects of opioids [Solak 2007]. For these reasons, adjunctive means of pain control that may help limit opioid medication intake and reduce opiate side effects are of considerable interest [Solak 2007].

The aim of the present study was to examine the efficacy of transcutaneous electric nerve stimulation (TENS) in relieving pain during the first 24-hour period following MS.

METHODS

The study included 60 patients who had undergone MS for coronary artery bypass graft (CABG) or valve repair surgery. We used a table of random numbers to randomize patients to receive TENS and pharmacologic analgesia, placebo TENS and pharmacologic analgesia, or pharmacologic analgesia alone (control group) to relieve postoperative pain during the first 24 hours following MS. A Biomed Plus (BioMedical Life Systems, Vista, CA, USA) TENS unit was used. The TENS unit provided an asymmetric square biphasic waveform at a frequency of 100 pulses/s and a pulse width of 200 microseconds. The placebo TENS unit was identical to the treatment unit but did not provide current. Two sterile electrodes (first unit channel) were placed on one side of the incision and 2 other electrodes (second unit channel) on the other side. The electrodes (5 × 5 cm) were

positioned 1 cm away from the suture line. The patients in the TENS group adjusted the stimulus intensity until a strong but comfortable tingling sensation was felt, whereas the patients in the placebo TENS group were told that the electrical stimulation produced no sensation. Approximately 1 hour after extubation, electrical stimulation or placebo stimulation was instituted for 1 hour in patients who received no analgesics. A 1-hour rest interval followed to prevent accommodation of nerve fibers. Then 1-hour stimulation or placebo stimulation was performed again.

Patients could request further analgesia if necessary during the first 24 hours after surgery, and the drugs were administered at each request (pethidine HCL 0.2 mg/kg intravenously and metamizol sodium, 1 g intravenously). Pethidine HCL was administered to patients whose pain could not be controlled with metamizol sodium.

The intensity of pain was assessed by means of a visual analogue scale (VAS) of scores ranging from 0 (no pain) to 10 (unbearable pain) before treatment (VAS0) and on the 12th hour (VAS12) and 24th hour of treatment (VAS24) [Chapman 2001].

During the first 24 hours after MS we recorded patients' intensity of pain, analgesic intake, pulse rate/min, arterial tension, body temperature, and pulmonary complications.

We performed statistical calculations with SPSS 11.5 (SPSS, Chicago, IL, USA). We used the Kruskal-Wallis test for intergroup analysis and the paired sample test was used for intragroup evaluations of therapeutic effectiveness. We used the χ^2 test to evaluate postoperative complications. *P* values less than .05 were considered significant.

RESULTS

Patient demographic data are presented in Table 1. In the TENS, placebo TENS, and control groups, respectively, the mean VAS0 scores were 5.70 ± 1.78, 5.75 ± 1.83, and 5.95 ± 1.63 ($P > .05$); the mean VAS12 scores were 2.40 ± 1.18, 3.90 ± 1.48, and 3.55 ± 1.60; and the mean VAS24 scores were 1.25 ± 0.91, 2.30 ± 1.34, and 2.15 ± 1.13 (Figure 1). The mean VAS scores decreased within each group. However, the mean VAS12 and VAS24 scores decreased much more significantly in the TENS group than in the placebo TENS and control groups ($P < .05$).

The mean metamizol sodium doses administered during the 24-hour postoperative period were 1.05 ± 0.39 g, 2.30 ± 1.08 g, and 2.90 ± 1.20 g in the TENS, placebo TENS, and control groups, respectively ($P < .05$) (Figure 2). The mean pethidine HCL doses during the 24-hour postoperative period were 17 ± 16.25 mg, 57 ± 21.54 mg, and 51.50 ± 18.99 mg in the TENS, placebo TENS, and control groups, respectively ($P < .05$) (Figure 3). Metamizol sodium and pethidine HCL intake was lowest in the TENS group ($P < .05$).

No significant changes were observed in systolic tension, diastolic tension, or pulse rate (Table 2).

Postoperative complication (atelectesia) was observed in a total of 6 patients (10%); 1 (5%) in the TENS group, 1 (5%) in the placebo TENS group, and 4 (20%) in the control group (Table 1). Airway clearing was performed by bronchoscopy in patients with atelectasia because excess pulmonary secretion was observed.

Table 1. Patient Data*

Variable	TENS (n = 20)	Placebo TENS (n = 20)	Control (n = 20)	*P*
Age, y	59.3 ± 10.0	63.9 ± 8.9	61.2 ± 10.1	>.05
Sex (F/M)	4/16	6/14	8/12	>.05
Weight, kg	74.8 ± 13.9	75.7 ± 14.3	73.4 ± 13.4	>.05
Systemic diseases				
Diabetes mellitus	3 (15%)	4 (20%)	4 (20%)	
Hypertension	1 (5%)	3 (15%)	2 (10%)	>.05
Type of surgery				
CABG	20 (100%)	0	18 (90%)	
Valve repair	2 (10%)	17 (85%)	3 (15%)	>.05
Extubation time, h	8.5 ± 3.2	8.0 ± 3.7	8.5 ± 2.5	>.05
Detubation time, h	24 ± 12.3	22.5 ± 13.9	25.4 ± 3.6	>.05
Complications	1 (5%)	1 (5%)	4 (20%)	>.05

*Data are expressed as n, n (%), or mean ± SD. TENS indicates transcutaneous electrical nerve stimulation; CABG, coronary artery bypass graft.

DISCUSSION

TENS can be used for pain relief after median sternotomy [Richardson 1994]. TENS is applied to appropriate dermatomes connected to the posterolateral incision area and delivers a low-voltage current that stimulates large myelinated A nerve fibers. The proposed mechanism of action is the modulation of the nociceptive input (via small unmyelinated C fibers) in the dorsal horn of the spinal cord by peripheral

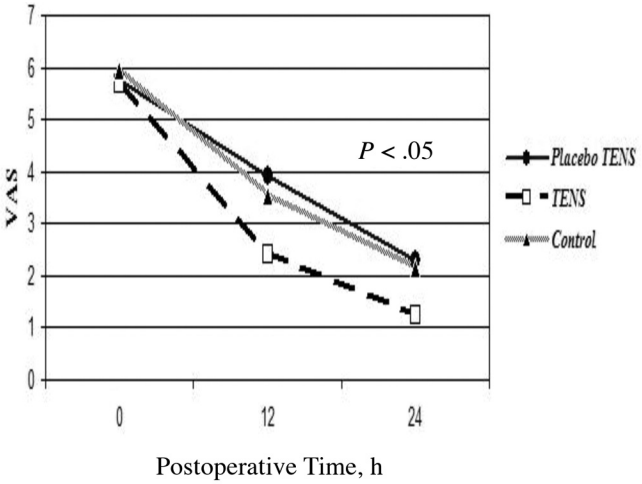

Figure 1. Mean visual analogue scale (VAS) scores at the 24th hour of postsurgical pain treatment. TENS indicates transcutaneous electrical nerve stimulation.

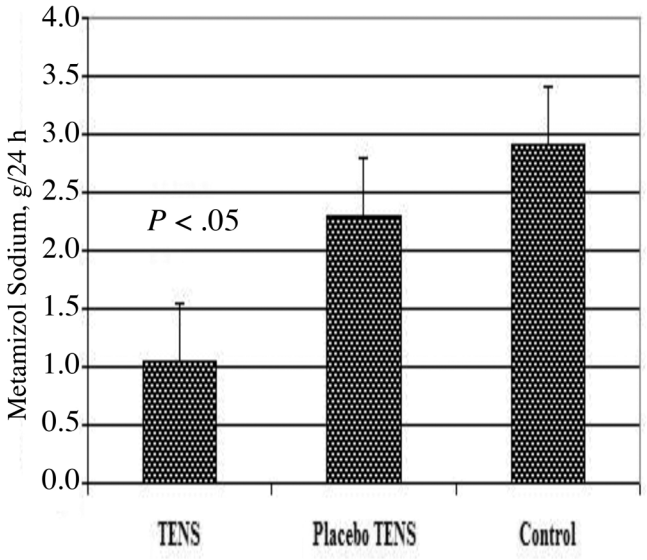

Figure 2. Mean metamizol sodium doses. TENS indicates transcutaneous electrical nerve stimulation.

stimulation of the larger sensory afferent A nerve fibers. Alternatively, afferent peripheral nerve stimulation may cause the release of endogenous opioids and nonopioid substances that have an analgesic effect [Brown 1998].

TENS has been reported to be an effective adjunct to traditional pain medications in patients after cardiac surgery [Klin 1984; Navarathnam 1984; Bayindir 1991]. In a descriptive study, Klin et al [1984] used TENS as an adjunct to opioids on days 3 and 4 after cardiac surgery. Pain levels, medication amounts, and statistical analyses were not reported, however. Navarathnam et al [1984] used TENS for 72 hours after CABG, valve repair, and other cardiac procedures. Their study included treatment and placebo groups, and the investigators recorded medications and pulmonary function test results daily. Bayindir et al [1991] used TENS for 180 minutes, starting at 4 ± 1.5 hours after surgery in patients who underwent cardiac valve repair or CABG that did not use the internal thoracic artery. Their study also included treatment and placebo groups. Both Navarathnam et al [1984] and Bayindir et al [1991] used TENS as the initial therapy for postoperative pain, with pain

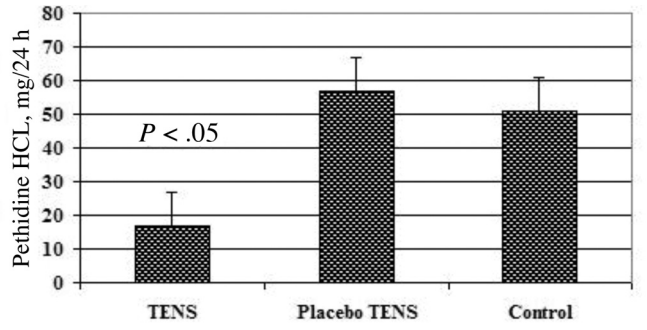

Figure 3. Mean pethidine HCL doses. TENS indicates transcutaneous electrical nerve stimulation.

Table 2. Mean Pulse and Arterial Tension Measurements*

Variable	TENS (n = 20)	Placebo TENS (n = 20)	Control (n = 20)	*P*
Pulse rate/min	89.95 ± 11.70	92.10 ± 11.57	88.30 ± 13.69	>.05
Arterial tension, mm Hg				
Systolic	115.40 ± 16.50	62.30 ± 7.85	118.80 ± 16.35	
Diastolic	67.05 ± 11.55	119.55 ± 16.47	63.45 ± 10.50	>.05

*Data are expressed as mean ± SD. TENS indicates transcutaneous electrical nerve stimulation.

medication provided if TENS was ineffective. Forster et al [1994] reported that TENS was no more effective than placebo TENS or control treatments in decreasing pain at rest and with cough, limiting opioid medication intake, or preventing decreases in forced vital capacity, forced expiratory volume in 1 second, and peak expiratory flow rate. As a result, high-frequency, continuous TENS did not appear advantageous as a means of controlling pain or improving pulmonary function during the 24- to 72-hour period following CABG involving the internal thoracic artery.

Contrary to the study by Forster et al [1994], our prospective, randomized placebo-controlled study demonstrated that TENS provided more analgesic effect than placebo TENS and control group pain treatments during the 24-hour period following MS, and patients who received TENS had decreased intakes of opioids and other analgesics.

Opioid medication use in MS patients has been described in the literature [Forster 1994; Solak 2007]. Determining the minimum effective analgesic concentration is a difficult task, however. Although opioid medications relieve pain, they may also lead to cough suppression, drowsiness, nausea, and vomiting and limit effective expectoration. Sedation, urinary retention, and constipation are also well-known side effects of opioids [Forster 1994; Hamza 1999; Solak 2007]. Another alternative to opiods are nonsteroidal antiinflammatory drugs (NSAIDs), but these do not provide an analgesic effect comparable to that of opioids [Dahl 1991]. Nevertheless, NSAIDs were shown to reduce morphine requirements by up to 60% [Dellemijin 1999]. However, their side effects include platelet dysfunction and gastric mucosal ulceration [Richardson 1994]. Epidural analgesia has been successfully used for MS pain. Adverse side effects include hypotension and motor neuron blockade, however, and the treatment necessitates multiple injections [Richardson 1995]. In addition, because these patients are heparinized, the risk of bleeding and hematoma during epidural anesthesia is increased.

Our study results showed that TENS provided significant pain relief in patients who underwent MS, and TENS decreased opioid and nonopioid analgesic intake by up to 3 times. It is plausible to surmise that TENS could be a viable alternative to pharmacologic analgesics for the treatment of MS patients. TENS was more effective than placebo TENS or control treatments in decreasing pain and limiting opioid and nonopioid medications intake during the 24-hour postoperative period following MS.

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