

Short-Duration Transcutaneous Electrical Nerve Stimulation in the Postoperative Period of Cardiac Surgery

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Abstract

Background: Respiratory muscle strength has been related to the postoperative outcome of cardiac surgeries. The main documented therapeutic purpose of transcutaneous electrical nerve stimulation (TENS) is the reduction of pain, which could bring secondary benefits to the respiratory muscles and, consequently, to lung capacities and volumes.

Objectives: The objective of the present study was to evaluate the effectiveness of short-duration transcutaneous electrical nerve stimulation (TENS) in the reduction of pain and its possible influence on respiratory muscle strength and lung capacity and volumes of patients in the postoperative period of cardiac surgery.

Methods: Twenty five patients with mean age of 59.9 ± 10.3 years, of whom 72% were men, and homogeneous as regards weight and height, were randomly assigned to two groups. One group received therapeutic TENS ($n = 13$) and the other, placebo TENS ($n = 12$), for four hours on the third postoperative day of cardiac surgery. Pain was analyzed by means of a visual analogue scale, and of respiratory muscle strength as measured by maximum respiratory pressures and lung capacity and volumes before and after application of TENS.

Results: Short-duration TENS significantly reduced pain of patients in the postoperative period ($p < 0.001$). Respiratory muscle strength ($p < 0.001$), tidal volume ($p < 0.001$) and vital capacity ($p < 0.05$) significantly improved after therapeutic TENS, unlike in the placebo group.

Conclusion: Short-duration TENS proved effective for the reduction of pain and improvement of respiratory muscle strength, as well as of lung volumes and capacity. (Arq Bras Cardiol 2010; 94(3):325-331)

Key words: Transcutaneous electrical nerve stimulation; cardiac surgery; pain; lung volume measurements.

Introduction

Pain is a physiological response to different body injuries and is significant in patients in the postoperative period of cardiac surgery. Despite the therapeutic advances achieved, the use of adjuvant resources may contribute to a favorable outcome. Transcutaneous electrical nerve stimulation (TENS) has proven an efficient alternative adjuvant therapy. However, its secondary effects are not frequently described in the scientific literature.

Pain in the postoperative period of cardiac surgery is an actual, fact and may contribute to worsening of the respiratory muscle strength and decrease of lung volumes and capacity, thus reducing the number of deep breaths and effectiveness of cough, which is indispensable in the postoperative period of cardiac surgery. The pain stimulus

can make physical therapy even slower due to the lack of cooperation^{1,2}. The surgical wound pain restricts lung expansion to a certain extent, thus favoring respiratory complications. Pulmonary complications are the major causes of morbidity in the postoperative period of cardiac surgery, and can contribute to the reduction of respiratory muscle strength, lung volumes and capacity; atelectasis is one of the most common of them, affecting approximately 64% of patients undergoing surgery³⁻⁶.

TENS is a modality of low-frequency electric current with the therapeutic purpose of reducing pain stimuli. It is considered an efficient, easy-to-use, noninvasive, non-toxic and relatively low-cost procedure which, however, is poorly corroborated by non-controlled randomized studies⁷⁻⁹. Few studies report the secondary effects of the use of TENS, and most of them are not related to cardiac surgery.

The objective of the present study was to use TENS in the postoperative period of cardiac surgery for a short period of four hours and also to evaluate its effects on pain, respiratory muscle strength, and lung volumes and capacity.

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Methods

This is a prospective randomized clinical trial. The individuals were assigned so as to have equal chances of belonging to the therapeutic TENS or placebo groups. Randomization was made with the use of a sealed box.

The inclusion criteria were patients aged between 35-80 years who had undergone elective cardiac surgery via longitudinal median sternotomy. The exclusion criteria were patients with pacemaker; pregnant women; cognitive or intellectual impairment; absence of pain in the postoperative period; sensitivity disorders; and patients undergoing any type of analgesia in the eight-hour period preceding the beginning of the protocol.

Clinical and functional assessment

In the preoperative period, one day before surgery, the patients underwent a clinical assessment as defined by a protocol. Their respiratory muscle strength as well as their lung volumes and capacities were also evaluated in the preoperative period.

On the third postoperative day, when the patients returned to the hospital ward, they underwent a pre-TENS clinical reassessment according to a protocol. In this reassessment, pain intensity was verified with the use of a visual analogue scale (VAS); respiratory muscle strength as well as lung volumes and capacity were assessed with the use of a compound gauge and a ventilometer. Then, TENS was applied for four hours according to the randomized groups. By the end of the intervention, the patients were reassessed as regards pain, respiratory muscle strength, and lung volumes and capacity.

The following vital signs were monitored during the pre-TENS and post-TENS phases: respiratory rate (RR, rpm), heart rate (HR, bpm), and blood pressure (BP, mmHg).

Transcutaneous electrical nerve stimulation

Therapeutic and placebo TENS were applied with the use of a portable device for transcutaneous electrical nerve stimulation (TENS) (TENS Device™, KLD, Amparo, São Paulo, Brazil). The electric current was delivered by two pairs of adhesive electrodes (10 x 3.5 cm) positioned one on each side of the surgical wound in the subclavian region, approximately two to three centimeters. The parameters for therapeutic TENS were pulse rate of 80 Hz (hertz), pulse width of 150 μ s (microseconds) and dose in milliamperes (mA) adjusted at a sensitive threshold. The placebo TENS device underwent modifications in its internal programming: the control capacitor of the time constant was changed and the active time between pulses was modified from 330 milliseconds to 33 seconds, in order to prevent an analgesic effect.

The patients adjusted the intensity of stimulation at the point at which they felt a "strong", although yet comfortable, prickling sensation, and were told to reduce the intensity if they felt uncomfortable.

The treatment and placebo groups were given the same instructions. Even though they were not sure whether or not

they were receiving electric current after some time of use, the device could deliver both continuous and intermittent current.

Maximal respiratory pressure test

Respiratory muscle strength was measured according to Neder et al's protocol¹⁰ in order to obtain the maximal inspiratory ($P_{i\text{-max}}$) and expiratory pressures ($P_{e\text{-max}}$).

$P_{i\text{-max}}$ was measured with the use of a tube with an open distal tip through which the individual initially breathed normally and was further asked to make a maximal expiration until reaching the residual volume. Next, the therapist would set the spinning valve so as to occlude the orifice of the compound gauge (GerarMed, model MVD300, Gerar®, Brazil), with the patient wearing an occlusive nose clip. Then, the individual would make a maximal inspiratory effort against the occluded airway. During the test, standard verbal prompts were given: "Please exhale, inhale. Let the air out, now inhale deeply".

For the $P_{e\text{-max}}$ test, the same tube with an open distal extremity was used, through which the individual was once again asked to breathe normally; then, they were told to perform a maximal inspiration until reaching the total lung capacity. The therapist would set the spinning valve so as to occlude the orifice of the compound gauge, with the occlusive nose clip kept in position. Then, the individual would make a maximal expiratory effort against the occluded airway, according to the standardized verbal prompt "Please inhale, exhale. Please fill your lung with air and now force it out".

The tests were repeated five times at most, and the best result of each one of the three tests whose variation was lower than 10% was chosen. A two-minute rest was allowed between one test and the next.

Assessment of lung volumes and capacity

The assessment was made with the use of a ventilometry test (Wright ventilometer, model Mark 8, nSpire Health Inc., Longmont, RU) to obtain measurements of minute volume (MV, L/min), tidal volume (TV, mL) and vital capacity (VC, L). The patient was duly positioned, with the back supported at approximately 90°, and their nasal airway was occluded by a clip; the equipment was fit to the mouth by means of a disposable mouthpiece. In order to measure the VC, the patient was asked to perform a maximal inspiration followed by a slow maximum expiration, close to the residual volume. For MV measurement, the patient was asked to breathe normally, with effortless inspiratory and expiratory movements for one minute, after a two-minute adaptation. TV measurement was obtained from the ratio between the MV and respiratory rate (RR, rpm).

Pain assessment

Pain was assessed with the use of a numerical visual analogue scale¹¹ (VAS). The patients were told to mark the point that best represented their pain at rest and with cough with a cross-sectional line. The assessment was made before and after TENS application.

Analysis of results

Continuous and semi-continuous variables were analyzed in the normal curve and defined as non-parametric with the use of the K-S (Kolmogorov-Smirnov) distance. Parametric data were expressed as mean and standard deviation, and non-parametric data as median and quartiles. Categorical data were expressed as absolute (n) and relative (%) frequency.

Results

Twenty five individuals admitted in the ward of the University Hospital of *Unifesp*, with mean age of 59.9 ± 10.3 years, of whom 18 (72%) were males were selected for the sample. The surgeries included in the study were: 18 myocardial revascularizations, including grafts; 15 saphenous veins and 16 internal thoracic arteries; two aortic valve replacements; one correction of the ascending aorta; two mitral valve replacements; one myxoma; and one correction of ASD. The procedure was performed off-pump in eight patients. For those undergoing extracorporeal circulation, the operative time was 72.2 ± 17.01 minutes. Analysis of data regarding the sample pattern revealed that the groups were homogeneous in relation to age, weight and height (Table 1).

Results regarding maximal respiratory pressures, lung capacity and volumes, and the cardiovascular response in the preoperative, pre-TENS, and post-TENS periods were observed.

In relation to pain, there was improvement of 40% at rest and 42.9% with cough (Figure 1) in the treatment group in relation to the placebo group. In the placebo group, no statistical difference was found (Table 2).

As regards lung capacity and volumes (Figure 2), the comparison between groups showed that the TV improved by 16.28% in relation to baseline values when TENS was performed, whereas the values of the placebo group worsened by 7.36%, with a difference of 23.64% between the groups. In relation to the VC, there was an 18.18% improvement in the treatment group, and only 3.13% in the placebo group, with a difference of 15.05% between the groups. The MV showed a tendency of improvement in the treatment group (11.48%) in comparison to the placebo group (1.04%), with a difference of 10.44% between the groups, whereas the respiratory rate was similar in the two groups. Between the pre and post-TENS periods, the VC after the application of TENS increased in the treatment group (Figure 3) in comparison to the placebo group.

The comparison between groups regarding the $P_{i_{max}}$ and $P_{e_{-max}}$ variables showed improvement by 23.08% of $P_{i_{max}}$ in the treatment group and worsening by 9.72% in the placebo group, with a 32.80% difference between groups. Improvement by 25% was observed in $P_{e_{-max}}$ of the treatment group, with no change in the median of the placebo group (Figure 4). Maximal respiratory pressures after the use of TENS (Figure 5) increased significantly in comparison to the placebo group.

Discussion

The effects of transcutaneous electrical nerve stimulation (TENS) on acute and chronic pain have been studied since

the 1970's. Further studies also analyzed the benefits of TENS in pain processes occurring in the postoperative period. This prospective randomized study evaluated the effect of TENS on the reduction of pain in the postoperative period of cardiac surgery. We not only found a positive effect of TENS on pain relief, but also improvement of respiratory muscle strength and lung capacity and volumes.

Corroborating our findings, preliminary studies also showed that TENS is effective in the control of mild to moderate pain in the postoperative period, and could also be useful in cases of severe pain^{12,13}.

Klin et al⁷, Bayindir et al¹², Erdogan et al¹³ and Benedetti et al¹⁴ studies evaluated the benefit of TENS and verified that electrostimulation reduced the level of pain in the postoperative period and decreased the amount of analgesic drugs used in comparison to the placebo or control group.

Bjordal et al¹⁵ published a meta-analysis with studies using TENS as an analgesic resource in the postoperative period

Table 1 – Baseline characteristics of patients selected for elective cardiac surgery (n=25)

	Mean	±	SD	CV (%)
Age	59.9	±	10.3	17.9
Height	1.66	±	0.08	5.18
Weight	71.68	±	11.63	16.23
	Nº		(%)	
Gender				
Male	18		72	
Female	7		28	

SD - standard deviation; CV - coefficient of variation.
Statistical method used: Continuous parametric data expressed as mean ± standard deviation; categorical or continuous data expressed as Nº, Number of patients (% of the total)

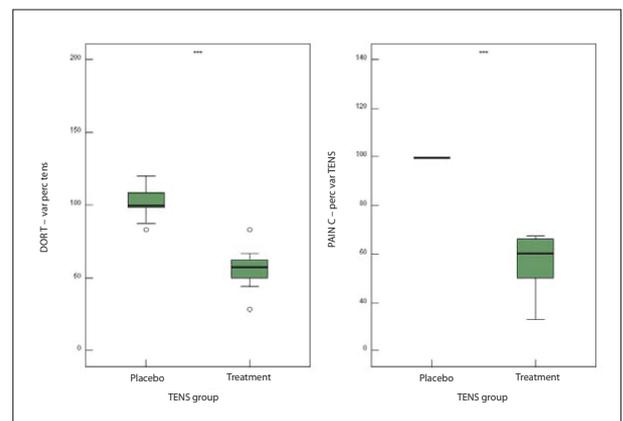


Fig. 1 - Comparison of percentage variation of pain with cough and at rest in the treatment versus placebo groups.
PAIN C - pain with cough; PAIN R - pain at rest. Statistical method used: non-parametric data expressed as median and quartiles. ***p<0.001.

Table 2 – Overall analysis of pain, respiratory muscle strength, lung volumes and capacity, and cardiovascular response in the preoperative, pre-TENS, and post-TENS periods of patients in the postoperative period of cardiac surgery

	Preoperative			Pre-TENS			Post-TENS		
	Mean	±	SD	Mean	±	SD	Mean	±	SD
Pain									
Pain R	0	±	0	3.4	±	1	2.6	±	1
Pain C	0	±	0	6.2	±	1.5	4.8	±	1.4
Respiratory muscle strength									
Pi _{-max} (cmH ₂ O)	-64.8	±	27.7	-51.3	±	23.9	-54.6	±	22.5
Pi _{-max} (% expected)	100.74	±	16.5	83	±	28	90	±	35
Pe _{-max} (cmH ₂ O)	62.6	±	22.6	43.8	±	19	48.5	±	17
Pe _{-max} (% expected)	106.2	±	21	75	±	26	86	±	28
Lung volumes and capacity									
TV (ml)	494.7	±	104.5	435.7	±	81.2	466.4	±	84.4
RR (bpm)	16.7	±	2.4	19.3	±	2.9	18.8	±	2.9
VC (L)	2.5	±	0.7	1.5	±	0.5	1.7	±	0.4
MV (L/min)	8.1	±	2.3	8.3	±	2.1	8.8	±	1.9
Cardiovascular response									
HR (bpm)	86	±	16.1	87.8	±	12.3	89	±	10.1
SBP (mmHg)	120.8	±	18.6	127.2	±	7.3	125.2	±	6.5
DBP (mmHg)	75.5	±	8.4	73.2	±	8.5	73.2	±	8

HR - heart rate; SBP - systolic blood pressure; DBP - diastolic blood pressure; PAIN R - pain at rest; PAIN C - pain with cough; TV - tidal volume; RR - respiratory rate; VC - vital capacity; MV - minute volume; Pi_{-max} - maximal inspiratory pressure; Pe_{-max} - maximal expiratory pressure.
Statistical method used: continuous data expressed as mean ± standard deviation.

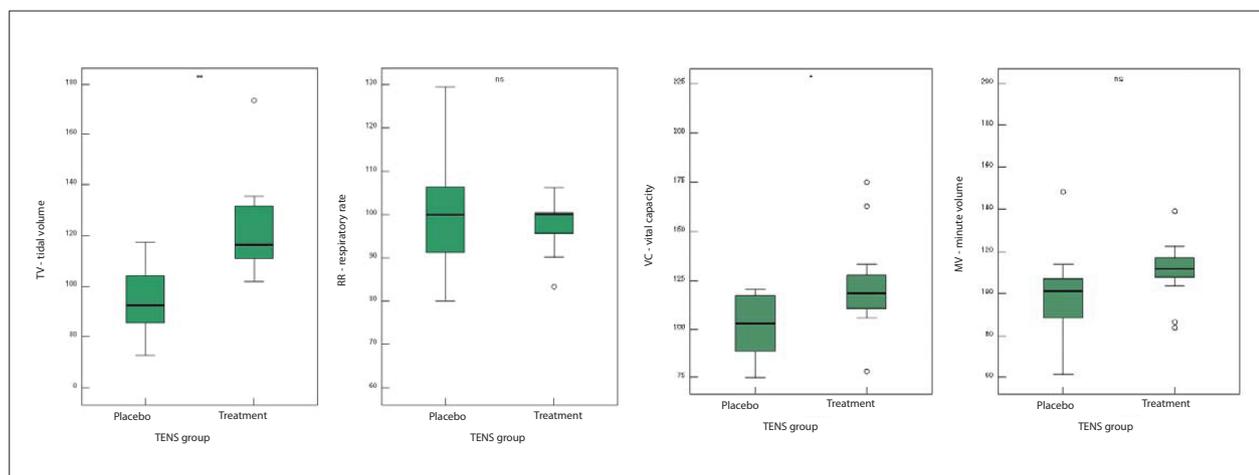


Fig. 2 – Comparison of percentage variation of lung volumes and capacity of the treatment versus placebo groups after TENS application in the postoperative period of cardiac surgery.

TV - tidal volume; RR - respiratory rate; VC - vital capacity; MV - minute volume; Pi_{-max} - maximal inspiratory pressure; Pe_{-max} - maximal expiratory pressure; Statistical method used: non-parametric data expressed as median and quartiles; * p<0.05; ** p<0.01; *** p<0.001; ns, non significant.

between 1966 and 2001. In that meta-analysis they showed that TENS reduced the use of analgesic medication during the first three postoperative days, thus decreasing the side effects of the medications, one of which is depression of the respiratory center. They also demonstrated an important difference in pain assessment in patients undergoing placebo versus therapeutic TENS.

In the analysis of respiratory muscle strength, we observed that the maximal expiratory pressure increased after the use of TENS, thus facilitating the process of pulmonary toilet, mucus clearance, and efficacy of cough. The maximal inspiratory pressure also improved and this could be related to pain reduction, thus providing increased pulmonary ventilation and reducing the incidence of atelectasis, which is one of the major causes of respiratory complications in the postoperative period of cardiac surgeries¹⁶.

In our bibliographic survey, no studies correlating the use of TENS with respiratory muscle strength were found. Johnson et al study¹⁷ included 138 patients undergoing cardiac surgery, who had their maximal inspiratory and expiratory pressures and pulmonary function assessed in two periods: at the day of hospital discharge, which occurred on the fifth postoperative day, on average, and on the eighth postoperative week. In the first analysis, pain, as assessed subjectively, was described as mild to moderate. The authors believed that pain could have been the limiting factor for the patients to perform maximum effort. On the eighth week, the patients still presented reduced respiratory pressures and pulmonary function in comparison to baseline levels, and the authors presumed that these findings could be related to muscle weakness in the postoperative period.

Lock et al¹⁸ and Belle et al¹⁹ evaluated the respiratory pressures and pulmonary function in the first, sixth and eighth postoperative weeks of cardiac surgery, and they also found a significant reduction in respiratory pressures in the first week. However, Belle et al¹⁹ studied patients in the sixth week and found that pressure levels had returned to baseline levels, but the pulmonary function was still reduced. Lock et al¹⁸, in turn, demonstrated that respiratory pressures and pulmonary function remained reduced even in the second analysis carried

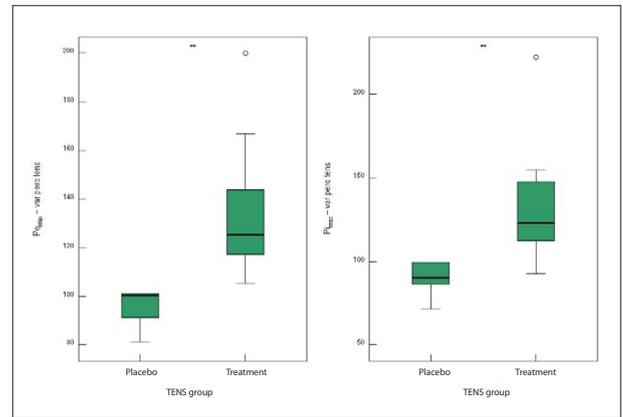


Fig. 3 – Comparison of percentage variation of respiratory muscle strength of the treatment versus placebo groups after TENS application in the postoperative period of cardiac surgery. VC - vital capacity; L - liter; Statistical method used: non-parametric data expressed as median and quartiles; * p<0.05

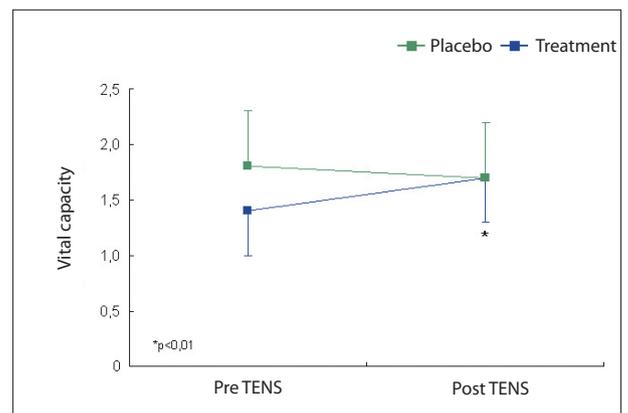


Fig. 4 - Comparison of vital capacity (VC) pre and post TENS application TV - tidal volume; RR - respiratory rate; VC - vital capacity; MV - minute volume; $P_{i,max}$ - maximal inspiratory pressure; $P_{e,max}$ - maximal expiratory pressure; Statistical method used: non-paired Student's t test

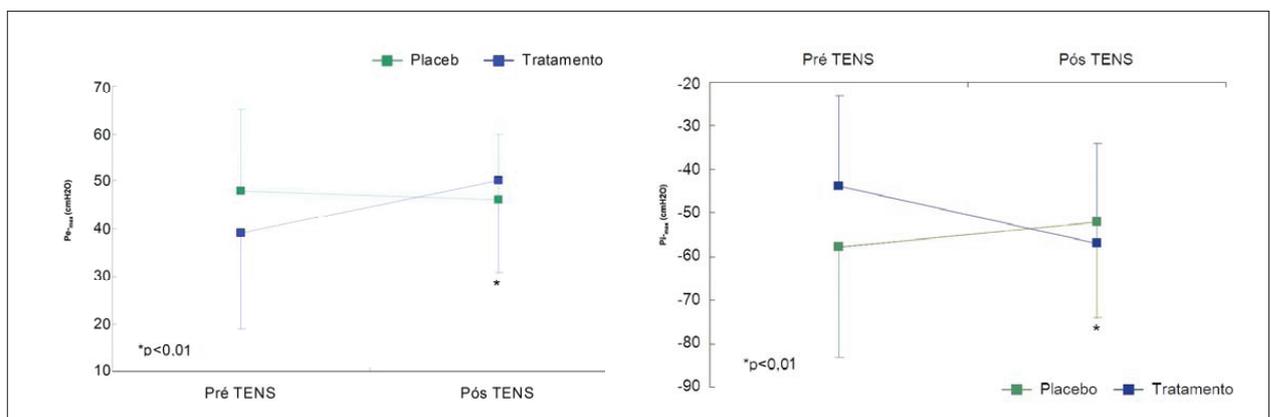


Fig. 5 – Comparison of maximal respiratory pressures ($P_{i,max}$ and $P_{e,max}$) pre and post TENS application $P_{i,max}$ - maximal inspiratory pressure; $P_{e,max}$ - maximal expiratory pressure; p<0.001 Statistical method used: non-paired Student's t test

out in the eighth postoperative week. The authors consider the possible occurrence of trauma to the costovertebral joints, thus producing reflex inhibition of intercostal muscle contraction, causing the rib cage to be unable to resist the inward force of diaphragmatic contraction.

Changes in lung volumes and capacity of patients undergoing cardiac surgery account, to a great extent, for the morbidity of these patients⁶. Atelectases are the most frequent complications^{4,20,21}, resulting from decreased functional residual capacity that leads to hypercapnia and hypoxia^{5,22}, from rib cage changes¹⁷, and from the cephalad displacement of the diaphragm. Changes in the respiratory mechanics²³ may also occur due to increased airway resistance, postoperative pain²⁴, paresis of the phrenic nerve²⁵, and others.

In this study, we sought to study the relationship between pain and lung capacity and volumes in the postoperative period of cardiac surgery. We could observe that, after the use of TENS for four hours, the patients presented improvement of pain, so that they could perform deeper inspiratory movements, thus obtaining improved vital capacity in comparison to the placebo group. Also, the tidal volume increased by 23% in comparison to the placebo group, whereas the respiratory rate (RR) tended to decrease after the use of TENS, thus resulting in a slight improvement of the minute volume. These data corroborate those of other studies such as Ali et al³, which reported improved VC after the use of TENS; Stratton and Smith²⁶, which also found improved forced vital capacity (FVC) after the use of TENS; and Cipriano²⁷, which demonstrated the positive effects of TENS on pulmonary and musculoskeletal functions of patients in the postoperative period of cardiac surgery. Erdogan et al¹³ conducted a controlled prospective randomized double-blind study evaluating the efficacy of TENS in thoracic surgery, and demonstrated beneficial effects of electrostimulation in their patients, so that they needed less opioid analgesics and their cough effort was increased during physical therapy.

There can be, however, important limitations to the present study: the sample was relatively small due to the

difficulty of including patients undergoing the surgical procedure with the same medical team and using the same anesthetic protocol; the fixed and reduced time of utilization of the current in order to be more adequate to reality; and the hospital routine. Another limitation refers to the cross-sectional design chosen for the analysis of the third postoperative day, since the correct evaluation of TENS application depended on the patients not being receiving intravenous analgesics and being already cognitively able to answer a questionnaire. Also, one other limitation was the fact that our sample included several types of cardiac surgeries homogenized as to the type of surgical incision (longitudinal median sternotomy).

We believe that our findings will encourage and disseminate the use of low-cost adjuvant therapies in the postoperative period of cardiovascular surgery, thus positively contributing to a better clinical and functional outcome.

Conclusions

Short-duration transcutaneous electrical nerve stimulation is useful in the control of pain in the postoperative period of cardiac surgery. It also provides improved respiratory muscle strength and increased lung capacity and volumes.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

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