

Role of Transcutaneous Electrical Nerve Stimulation in Pain Management after Cardiac Surgery

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ABSTRACT

Background and aims: Transcutaneous electrical nerve stimulation (TENS) has become a popular non-invasive treatment modality in management of chronic pain and postoperative pain after a variety of surgical procedures. The aim of this study was to evaluate the efficacy of TENS on pain modulation, analgesic requirements and pulmonary functions after valvular surgeries. *Methods and Results:* Fifty five adult patients (27 males and 28 females) undergoing elective valvular surgery were randomly assigned postoperatively into four groups. One was control group (10 patients) received Sham TENS, the other three groups received TENS session every 8hrs for 10 days. They assigned according to the type of applied TENS into Conventional TENS group (15 patients), Low TENS group (15 patients) and Both frequencies TENS group (15 patients). Pain scores in all groups were assessed daily by visual analogue scale (VAS); the analgesic consumption was reported and the pulmonary function test was done at the 10th day. The perceived pain in the studied groups was less than placebo, with concomitant greater reduction in analgesic consumption. Also, recovery of pulmonary function was pronounced. *Conclusion:* TENS application is efficient modality and must be considered in management of pain after cardiac surgery.

INTRODUCTION

Postoperative pain for the adult cardiac surgery patient has many facets; pain can be caused by incisions, intraoperative tissue retraction and dissection, multiple intravascular cannulations, chest tubes left after surgery, and multiple invasive procedures that patients undergo as part of their therapeutic regimen¹³. So, acute pain after cardiac surgery is inevitable because of the associated trauma to many pain – sensitive structures. An inflammatory response to this trauma triggers the release of numerous chemical mediators in the periphery. These mediators lower the nociceptor threshold, making the receptors more responsive to painful stimuli (i.e. chronic pain). The dorsal horn receives these peripheral impulses and

transmits them via central pathways to the brain¹⁷.

Pain is more than just a physical process, it is a complex, subjective phenomenon. Pain can impair the hematologic, immune, hormonal, cardiac and respiratory systems. Pain also can limit mobility, interfere with sleep and rest, and contribute to agitation, psychosis, aggressive behavior and delirium^{12,15}.

The American Association of Critical Care Nurses has ranked pain management after cardiac surgery as a high priority. Inadequate postoperative analgesia has been recognized as a universal problem and is considered unacceptable. Currently opioids remain the mainstay of postoperative pain management after major surgery. Although the use of opioids can provide excellent analgesia, the doses necessary to provide effective pain relief may lead to undesirable side effects such as

respiratory depression, sedation and nausea. Non-steroidal anti-inflammatory drugs (NSAIDs) are potent analgesics, but are inadequate for postoperative analgesia after major surgery when used alone¹⁸. Moreover, the NSAIDs can cause gastrointestinal distress, renal, hepatic and hematologic dysfunction¹⁷. However, NSAIDs in conjunction with opioids for postoperative analgesia have been shown to improve pain scores and reduce opioid consumption. This combination of drugs has been termed balanced analgesia¹⁵.

Transcutaneous electrical nerve stimulation (TENS) is a useful device to relieve pain in a variety of conditions. The TENS is the application of an electric current through the skin to the peripheral nerves, for control of episodes of acute pain. TENS has become a popular non-invasive treatment modality for postoperative pain after abdominal and thoracic surgery^{2,16,28}.

So, the present study was conducted to investigate the efficacy of TENS application as an adjunct tool for management of patients after valvular surgery. That is; its effect on pain modulation, analgesic requirement and pulmonary functions recovery. As well, compare the efficacy of different modes of TENS application, in order to determine the optimum one.

SUBJECTS MATERIALS AND METHODS

Fifty five patients (27 males and 28 females), underwent elective valvular surgery, at National Heart Institute, were enrolled in this trial. Their age ranged from 25 to 35 years with a mean values 29.6 ± 2.7 years.

Pre operatively, all patients were instructed on reporting of pain on a visual analogue scale (VAS) and localize the pain site on schematic diagram. A standard 10-cm

VAS was used, where one end of the scale represented no pain (0 cm). and the other end represented the most severe pain imaginable (10cm), the distance in centimeters being taken as the pain score. Also, they were instructed about the application of TENS. All subjects were subjected to spirometry test using Morgan-Trans flow apparatus (made in UK). The maneuver of the flow volume loop (FVL) were run for each subject according to the criteria of the American Thoracic Society¹¹.

All the patients underwent standard procedures with membrane oxygenation and moderate hypothermia during the anesthesia, patients routinely received between 25 and 50 $\mu\text{g}/\text{kg}$ of fentanyl²⁴. The arms were positioned along the body on the operating table. The sternum was closed with five peristernal wires, mediastinal and thoracic drains were passed through the rectus abdominis muscle just below the xiphoid area.

All subjects fulfilled selection criteria chosen to minimize heterogeneity of the sample and to ensure proper data collection. These criteria included extubation before the first postoperative morning and the absence of alterations in cognitive functioning at any time during the hospital stay. As well as, showed the necessary cooperation which needed to acquire data. Also all patients were non-diabetics and non-smokers or quitted at least six months ago. Moreover, patients were excluded if they require a pacemakers or develop a renal failure or pleural effusion during the first 24h. The basic analgesic regimen included IV morphin sulfate at a dose of 1mg/g. from the first postoperative day (POD) until the removal of the drain (POD 2 or 3), 500 mg paracetamol was given IV. and 5 to 10 mg morphine was injected subcutaneously as required, alternating with tramadol.

Patients were divided randomly into matching three studied groups (each one 15 patients) and one control group (10 patients). they assigned as the type of applied TENS, that is, patients received TENS with frequency 100 Hz for 20 minutes as Conventional TENS group, patients received 10 Hz applied for 30 minutes as Low TENS group and patients who received Both frequencies (100 Hz first for 20 minutes then 10Hz for 30 minutes) as both frequencies TENS group. In addition to 10 patients received Sham TENS (the output cable was discontinuous) as Sham TENS group.

The TENS application started at the 2 or 3 POD, at least 6 hours after removal the drain tube. Two channels stimulator were used, with sterile adhesive electrodes fixed paravertebral at T2 and T10. The intensity of the stimulation adjusted according to patient sensation, while subjects in Sham TENS group, instructed that indicator lamp must be flashed during the session. The TENS session were conducted 3 times daily, for 10 days postoperatively, in addition to routinely physical therapy program.

All the pain data were collected daily on a separate sheet. The pain intensity, score of VAS, represented the average of different pain sites. Each recorded sheet included a drawing diagram to localize the site of pain. The amount of requested analgesic were reported. Also, the spirometry test (FVC, FEV₁/ FVC%) was redone at the 10th day of the study.

Statistics

Data were expressed as mean \pm SD. Mean values were compared using t-test, or ANOVA for repetitive measurement where appropriate values were considered to differ significantly if $p < 0.05$.

RESULTS

The patients' characteristics and the surgical indications are shown on table (1), the data collection started after, at least 6 hrs of removal of drain tubes, nearly at 2nd or 3rd postoperative day, and continues throughout 10 days.

Table (1): Patients' characteristics.

	Group -1 Conventional TENS	Group -2 Low Tens	Group -3 Both Frequency	Group -4 Sham TENS
Age (yrs)	29.6 \pm 2.7	29.9 \pm 2.8	28.1 \pm 2	29.3 \pm 3.1
Male / Female(n)	7/8	8/7	7/8	5/5
Height (cm)	168.1 \pm 13.2	163.7 \pm 4.6	165.1 \pm 4.8	161 \pm 5.1
Weight (kg.)	69.9 \pm 13.1	69.9 \pm 10.5	63.7 \pm 10.6	54.6 \pm 10.7
Type of Surgery				
MVR (n)	5	7	5	4
* Alone (n)	4	5	5	4
* With TVR(n)	1	2	-	-
AVR (n)	6	5	7	3
A& MVR(n)	4	5	3	3

Yrs = years
AVR= aortic valve replacement
n= number

MVR= mitral valve replacement
A & MVR = aortic and mitral valves replacement
TVR = Tricuspid valvoplasty

The percentage of patients involved with pain in the different areas, which reported daily throughout the entire course of the study,

were depicted in figure (1). Almost all patients had pain at the incisional site. Some of them had pain free at the end of the study. Also,

most subjects complained of pain referred to shoulder and dorsal areas, however some of patients felt pain at arms and axilla.

According the reported score of VAS (cm), arbitrarily, the perceived pain sensation was classified into mild (<3), moderate (4 to 7) and severe (> 7 to < 10). The reported value was the mean of severity of pain perceived at more than one area.

As shown in table (2), the pain severity were moderate in all groups. The pain sensation was gradually reduced, at the 5th day it became mild in the three studied groups, but in control (Sham TENS) group, it remained moderate with tiny reduction. At the 10th day, the pain sensation disappeared at most subjects in the studied groups.

Table (2): Daily records of pain score (VAS) for all groups.

	Conventional frequency	Low frequency	Both frequencies	Sham TENS
1 st day	5.1 ± 1.3	5.6 ± 0.1	5.1 ± 1.6	6.6 ± 1.9
2 nd day	4.5 ± 0.7	4.4 ± 2.1	4.2 ± 0.5	6.5 ± 0.5
3 rd day	3.9 ± 1.3	3.8 ± 1.8	4.6 ± 1.4	6.9 ± 1.4
4 th day	3.6 ± 0.7	2.7 ± 1.2	3.2 ± 1.3	6.0 ± 0.8
5 th day	2.4 ± 0.8	2.2 ± 0.5	2.3 ± 1.0	6.2 ± 1.2
6 th day	2.2 ± 1.1	2.5 ± 0.6	1.5 ± 0.4	5.9 ± 1.7
7 th day	1.6 ± 0.7	1.8 ± 0.6	1.1 ± 0.5	5.0 ± 1.5
8 th day	1.2 ± 0.6	1.4 ± 0.8	0.6 ± 0.4	5.1 ± 2.4
9 th day	1 ± 0.6	0.4 ± 0.2	0.3 ± 0.2	4.4 ± 1.9
10 th day	0.5 ± 0.2	0.3 ± 0.1	0.2 ± 1.0	4.1 ± 2.3

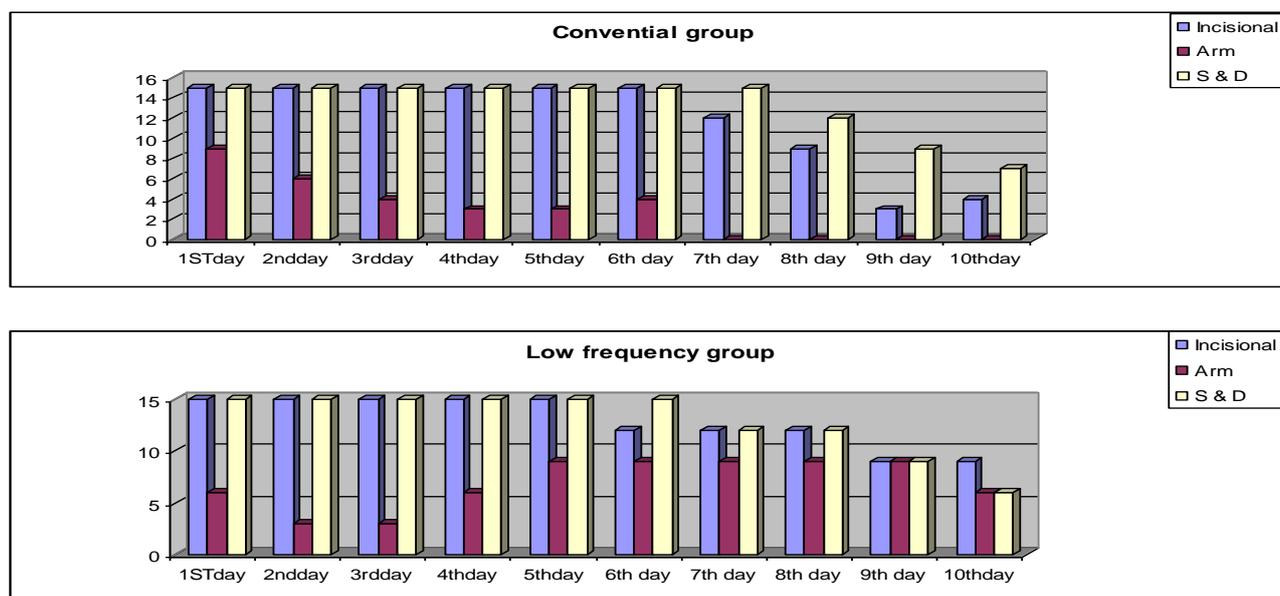
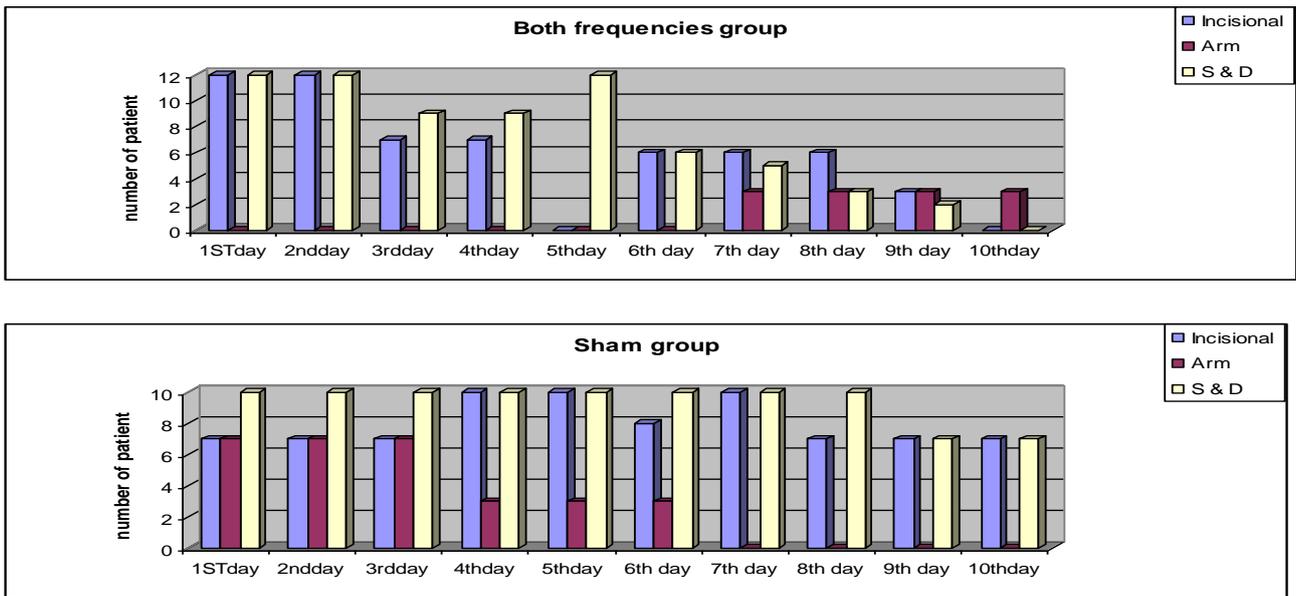


Fig. (1):



Key: S & D: shoulder and back dorsal areas

Fig. (1): the number of patients who complained of the 4 different pain sites throughout the study in all groups.

The applied policy for management of postoperative pain was the reactive approach, where the drugs were given as needed. Table (3) shows the percentage of patients involved with pain, requested analgesic drugs. It was

noticed that, the number of patients seek for analgesic medication were decreased greater in studied groups, in comparison with control (Sham TENS) group.

Table (3): pain relief medication (NSAIDs) requirement throughout the treatment days.

Day of treatment	Conventional group				Low frequency group				Both frequency group				Sham TENS group			
	Analgesic		NIAD		Analgesic		NIAD		Analgesic		NIAD		Analgesic		NIAD	
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
1 st day	15	100%	6	40%	15	100%	6	40%	15	100%	6	100%	10	100%	10	100%
2 nd day	12	80%	6	40%	15	100%	6	40%	12	80%	6	80%	10	100%	10	100%
3 rd day	15	100%	6	40%	13	86.6%	3	20%	9	60%	3	60%	10	100%	10	100%
4 th day	6	40%	6	40%	12	80%	2	13.3%	6	40%	3	40%	9	90%	7	70%
5 th day	2	13.3%	3	20%	9	60%	1	6.6%	5	33.3%	2	33.3%	8	80%	7	70%
6 th day	00	00%	3	20%	3	20%	1	6.6%	3	20%	0	20%	7	70%	5	50%
7 th day	00	00%	00	0%	00	00%	00	0%	00	00%	0	00%	8	80%	9	90%
8 th day	1	6.6%	00	0%	00	00%	00	0%	00	00%	0	00%	7	70%	6	60%
9 th day	00	00%	00	0%	00	00%	00	0%	00	00%	0	00%	5	50%	2	20%
10 th day	00	00%	00	0%	00	00%	00	0%	00	00%	0	00%	3	30%	0	00%

NSAIDs = non – steroidal anti – inflammatory drugs

Table (4) shows that respiratory parameters were reduced significantly due to surgical

intervention the ratios of changes were reduced by TENS application.

Table (4): values of pulmonary function pre-operatively and after TENS application (10 days) postoperative.

Group	Variable	Pre	Post	Relative change	P value
Group-1	FVC	4.1 ± 0.7	2.9 ± 0.4	↓ 27.3%	<0.001
Conventional	FEV ₁ /FVC(%)	85.5 ± 5.4	90.7 ± 4.4	↑ 6.5%	<0.001
Group-2	FVC	2.8 ± 0.3	2.3 ± 0.5	↓ 17.7%	<0.001
Low TENS	FEV ₁ /FVC(%)	88.9 ± 6.8	91.4 ± 4.4	↑ 3.02%	<0.001
Group-3	FVC	3.6 ± 0.9	2.6 ± 0.6	↓ 27.5%	<0.001
Both frequency	FEV ₁ /FVC(%)	86 ± 5.2	88.4 ± 6.7	↑ 3.2%	<0.001
Group-4	FVC	3.1 ± 0.7	1.5 ± 0.5	↓ 53.02%	<0.001
Sham TENS	FEV ₁ /FVC(%)	87.1 ± 4.9	94.9 ± 3.7	↑ 9.3%	<0.001

DISCUSSION

This study was conducted to investigate the potential influence of TENS application on postoperative pain in patients who had been operated upon for heart valvular surgeries as well to compare between the application of low frequency TENS, conventional TENS and combination of two types. The pain severity and localization were determined in this study by many parameters; visual analogue scale (VAS), schematic diagram and the registration of analgesics requirement; in addition, its effect on spirometric parameters (FVC and FEV₁/FVC) were investigated. The results of the current study revealed that TENS application ameliorate the postoperative pain, where all studied groups showed reduction in VAS scores and a decrease in the requirement of analgesic medications was found on comparison with the control group. The severity of pain in the studied three groups (which received TENS) was reduced to the mild intensity on the fifth day of the study maximally where this pain severity was tolerated with little or no need of analgesic medications. On the other hand, in the control group the pain severity rarely reach to the tolerable intensity at the end of the study (10 days). On comparison between the different frequencies of TENS current, it was found

that the application of both conventional and low frequency TENS at the same session had the superior influence when compared with sole low TENS application; while there was no difference between the application of sole conventional TENS application versus low TENS application or both TENS application.

Literature showed that lung volumes were reduced after median sternotomy and the resolve of this affection take at least three months¹⁹, in the present study, it was found that TENS applications three times daily postoperatively accelerate the recovery of lung volumes towards the preoperative values of pulmonary functions.

The reduction of lung volumes reported in the current study may be attributed to pain, where pain may induce a tonic contraction of abdominal muscles and intercostal muscles, causing upward displacement of the diaphragm into the chest, thus compressing the lower lobes and so reducing pulmonary volumes, this would result in decreasing diaphragmatic contribution to quiet tidal breathing^{20,28}. Also fear of coughing and deep breathing lay a considerable part in the reduction of voluntary pulmonary capacity. Therefore the depressed pulmonary functions were ascribed to the restrictive effects of pain related symptoms¹⁸.

In the control group, the postoperative FVC readings (after ten days of Sham TENS application) showed severe reduction with percentage 53.02% when it compared with the preoperative readings, while in Conventional TENS group, Both TENS group and Low TENS group (low frequency), there was less reduction in FVC postoperatively (after ten days of TENS application) with percentage 27.3%, 27.5%, and 17.7% respectively when they are compared to their preoperative readings with respect to the control group, and that show the superiority of low frequency TENS group in improvement of FVC.

In the current study the reported relative changes of FEV₁/FVC were increased postoperatively in the control group with percentage 9.3% when compared to its preoperative values. On comparison between FEV₁/FVC relative changes of studied TENS groups, the superiority improvement was shown in Low TENS group, where its relative changes were improved with percentage 3.02% and this improvement reached to the significant level. It was also noticed there was an improvement of FEV₁/FVC in both TENS group with percentage 3.2% but that improvement did not reach to significant level statistically when compared with the other two TENS groups. In Conventional TENS group, there was less improvement than the other two TENS groups with percentage 6.5%. So the control of post operative pain is assumed to allow a proper cough to take place, it will also inhibit muscle spasm, that permits the frequent deep diaphragmatic and segmental breathing exercises to provide an inflated lung^{13,16}.

With respect to the localization of postoperative pain, it was found that post median-sternotomy, the dominant sites of pain were the incisional pain, the arm pain, and the shoulder with upper dorsal region (back pain). The daily follow up of the studied groups

revealed that the incisional pain, the shoulder and the upper dorsal region persisted for almost 10 days of the study after the operation, while the arm pain (medial aspect and axilla) were fluctuated throughout the period of the study.

Scanty available studies investigate the role of TENS application for management of postoperative pain in cardiac patients especially the valvular surgeries. Some of these literatures confirm the findings of the present study. Klin et al.,¹² applied TENS after open heart surgery on two groups, one of them immediately after the surgery and the other one received TENS after eight weeks of the surgery with no control group. He found subjective reduction of pain and a decrease of analgesics requirement with less pulmonary complications. So he suggested that TENS should be used more frequently in patients after open heart surgery especially in older patients and in patients with chronic lung disease. Also Navarathnam et al.,¹⁴ found TENS application for 72 hours following cardiac surgeries is effective in reducing pain and analgesics requirement especially on the second postoperative day. Moreover, the findings of the present study were supported by the study of Bayindir et al.,¹ who suggested that TENS application is effective in reducing early postoperative pain and the analgesics requirement after cardiac surgeries in spite of the appearance of some placebo improvement in the control group. But they did not measure the pulmonary functions and their relation to pain.

On the other hand Benedetti et al.,² found sole TENS application without any analgesics is ineffective in relieving the post median-sternotomy pain if it is applied in the first 12 hours postoperatively. He suggested that TENS application can be used as an adjunct tool with the analgesics in relieving

the post median sternotomy pain; as it was applied in the current study. Also, Forster et al.,⁹ claimed that, there was no benefit of using TENS after cardiac surgeries. It was assumed that their negative findings may be attributed to accommodation phenomena where the TENS was applied continuously for 72 hours while in the present study the TENS was applied every 8 hours as it was proposed as the optimal time of achieving the analgesia of the different frequencies and to avoid the accommodation phenomena. The discrepancy between the present study and Forster et al.,⁹ results may be also attributed to the differences in the study populations where they chose the patients who undergone coronary artery bypass graft (CABG) surgeries with left internal mammary artery grafts (LIMA), while in this study the patients with valvular surgeries were investigated.

Later, Domaille and Reeves⁶, stated that after their application of TENS (100Hz) for one hour on CABG patients, they claimed that TENS application was ineffective. These negative findings may be attributed to the difference in population of the study or the persistence of the pain after CABG surgeries which may be continued for 5 months⁸.

The role of TENS in management of postoperative pain was investigated in non-cardiac as abdominal, thoracotomies and cholecystectomies. Stratton and Erdek et al.,^{7,23} found subjective reduction in pain and objective improvement of pulmonary functions following different thoracotomies with excluding the cardiac patients. Other investigators stated that, TENS application is effective in decreasing analgesic requirements and relieving pain perception after different types of the abdominal surgeries^{4,27}.

Also Chen et al.,³ found TTENS application is effective in reducing the postoperative pain and the analgesics

requirement especially if it is applied on dermatomal level or acupoint. On the other hand, Sim²¹, who measured the pulmonary functions in addition to the pain sensation and the analgesics requirement in the cases of cholecystectomies, he found no significant improvement in all parameters.

Most of the patients exhibited nearly similar fashion of pain behavior throughout the course of this study, where the severity of pain and the request of analgesics were reduced gradually throughout the postoperative ten days, however some patients need to increase the analgesics dose to overcome pain sensation. In the Conventional TENS group there was one patient returned to need the analgesics on the 8th day of the study after his pain relief. In the Low TENS group, one patient returned to request the analgesics on the 10th day of the study. In the control group, there were at least 5 patients who returned to order the analgesic medications on the 7th day of the study after their pain relief. This may be attributed to upper limb mobilization or excessive muscle contraction which may cause strain of the site of incision¹³.

The results of the control group in the current study showed some reduction in VAS and requirement of analgesic medications. This may be attributed to the placebo effect and / or normal healing process.

The pain relief following TENS application may be attributed to different theories. The most famous one is the gate control theory which directed an attention to the active role of the dorsal horn of the spinal cord in modulating sensory transmission²¹. So, TENS was efficacious when the stimulation was applied to the corresponding spinal segments as well as to the source or the actual site of pain. Another inhibiting system employs the release of endogenous opioids peptides, where the endorphins and

enkephalins release detect the time of analgesia would be gained after TENS application which can be related to the applied frequencies²⁵. There is another theory, the descending inhibitory system which suggest the descending pathway from the higher center to modulate the pain sensation²⁶.

It was found that the response to TENS application, three times daily in post valvular surgical patients depends on the frequency of the current where the influence of both frequencies application was the superior in relieving the pain severity. While in improving the pulmonary functions, the application of low frequency TENS has the superior influence. Theoretically, the reduction of the post median-sternotomy pain will enhance the lung volumes¹⁴, these conflicting findings may be attributed to subjective selection (i.e. inconsistency) or to specification of the response to TENS application.

The discrepancy between the effects of high frequency TENS and low frequency TENS which is reported in this study, can be explained as the following, the high frequencies stimulate the large diameter afferents fibers which will cause inhibition to the input from the small diameter afferent fibers in substantia gelatinosa of the spinal cord. This was thought to be a segmental inhibition and does not involve the descending inhibitory pathways²². There is also a commonly held theory that the mechanism of action of low frequency is the activation of endogenous opioid pathway²².

The postoperative pain is due to the injury itself which generates an acute mechanical stimuli and a barrage of small afferent input. This barrage evokes activity in dorsal horn neurons that eventually projects supraspinally, as long as the mechanical distortion persists the barrage will continue. In addition, the injury itself leads to formation of

active tissue factors that serve to both stimulate and sensitize the peripheral nerve endings²⁹, which may explain why the location of pain recorded in this study was consistent with the findings of Mueller et al¹³, who found in open heart surgeries, there is no significant difference of the pain location between the first day postoperatively and the seventh day postoperatively for the incisional pain and shoulder with upper dorsal region pain.

Finally in this study there was a benefit in the application of the different frequencies of TENS in relieving pain especially after the second day of the study (3rd day postoperatively) but before that the analgesics can not be prevented and that appeared through reduction in VAS score or analgesic requirements and there was more benefit when the high and low frequencies of TENS applied together in the same session.

Also in this study there was enhancing in the recovery of pulmonary functions after ten days of TENS application, which may take 3 months for recovery and returning to baseline or to the preoperative values^{5,8,10}.

Traditionally, postoperative pain has been managed either reactively with drugs given as needed or proactively with continuous infusion of analgesics. Evidence suggests that reactive pain management is ineffective. With a reactive approach, analgesics are administered at the discretion of clinical staff and only on as needed basis. Consequently, treatment takes place after pain occurs, causing some patients to experience severe pain. In contrast, proactive pain management improves effectiveness, because treatment is given before pain occurs. With a proactive approach, analgesics are often administered via a continuous peripheral or epidural infusion. However, because this approach may entail added risk, is short-term, high technique equipment dependent, and often self-

administered, the reactive approach was applied in the current study. So, it is recommended to investigate the role of TENS with proactive approach in management of pain after cardiac surgery.

Conclusion

TENS application is efficient modality and must be considered in management of pain after valvular surgery. The perceived pain was reduced with TENS application, inspite of decreased analgesic medications. Also, TENS application resulted in acceleration of pulmonary functions recovery after cardiac surgery.

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الملخص العربي

دور التنبيه العصبى الكهربائى خلال الجلد فى علاج الألم عقب جراحة صمامات القلب

يهدف هذا العمل لدراسة قدرة تطبيق التنبيه العصبى الكهربائى عبر الجلد على تعديل الألم والوظائف الرئوية بعد جراحات الصمامات. لقد طبق جهاز التنس على 15 مريض بموجة تردد 100 هرتز و 15 مريض تعرضوا للتنس بتردد 10 هرتز و 15 مريض تعرضوا للتنس بالتردد (10 & 100) وطبق التنس المموه على 10 مرضى. أدى تطبيق التنس (الثلاثة مجموعات) لخفض شدة الألم مقارنة بمجموعة التحكم وذلك بالرغم من انخفاض المسكنات المستخدمة وأدى أيضاً إلى تحسن ملحوظ فى الوظائف الرئوية.