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Effect of Transcutaneous Electrical Nerve Stimulation on Postoperative Pain after Inguinal Hernia Repair: A Randomized Placebo-Controlled Trial

Transkutanöz Elektriksel Sinir Uyarımının İnguinal Herni Onarımı Sonrasında Postoperatif Ağrı Üzerindeki Etkisi: Randomize Plasebo Kontrollü Çalışma

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Summary

Objective: Transcutaneous electrical nerve stimulation (TENS) is widely used for pain management in various clinical conditions. In this prospective, randomized, double-blind, placebo-controlled study, we investigated the effect of TENS on postoperative pain, analgesic requirements and serum cortisol level (SCL) after inguinal hernia repair.

Materials and Methods: Sixty-seven patients, who underwent a standard surgical hernia repair using the Lichtenstein principles with a wound infiltration anesthetic technique, were randomly chosen to receive either active TENS (conventional TENS at 100 Hz, with a pulse width of 120 microseconds and a perceptible tingling sensation) or placebo TENS treatment. Both active and placebo TENS treatments were applied for 30 minutes, twice daily for 5 consecutive days using two electrodes placed parallel to the incision. Pain intensity was assessed using the visual analogue scale (VAS) and SCL measured on 5 consecutive postoperative days (PODs), respectively. Follow-up assessment of pain intensity was performed at 30 days postoperatively.

Results: Baseline parameters were similar between the groups. Pain intensity in the active TENS group significantly decreased at POD1 ($p<0.04$), POD2 ($p<0.027$), POD3 ($p<0.026$), POD4 ($p<0.0006$), and POD5 ($p<0.0006$), and after one month compared with the placebo group. Postoperative SCL was decreased in the active TENS group compared with placebo TENS ($p<0.05$).

Conclusion: Our results indicate that TENS is beneficial for postoperative pain relief following inguinal hernia repair. No side effects were observed, and its pain-reducing effect lasted for one month postoperatively. Consequently, the routine use of TENS after inguinal hernia repair is recommended for its short-and long-term effectiveness for decreasing pain, analgesic requirement and SCL. *Turk J Phys Med Rehab 2010;56:170-6.*

Key Words: Postoperative pain, inguinal hernia repair, transcutaneous electrical nerve stimulation

Özet

Amaç: Transkutanöz elektriksel sinir uyarımı (TENS) çeşitli klinik durumlarda ağrı tedavisi amacıyla sıklıkla kullanılmaktadır. Bu prospektif, randomize, çift kör, plasebo kontrollü çalışmada, TENS'in inguinal herni onarımı sonrası postoperatif ağrı, analjezik gereksinimleri ve serum kortizol seviyeleri üzerindeki etkisini araştırdık.

Gereç ve Yöntem: Lichtenstein metodu kullanılarak, infiltrasyon anestezisi tekniği ile inguinal herni onarımı uygulanan 67 hastaya randomize olarak aktif TENS (100 Hz, 120 mikro saniye atım genişliği ve algılanabilir karıncalanma hissi ile konvansiyonal TENS) veya plasebo TENS tedavisi uygulandı. Hem aktif hem de plasebo TENS tedavisi, insizyona paralel iki elektrot yerleştirilmesi suretiyle, arka arkaya 5 ardışık gün, günde iki kez 30 dakikalık seanslar halinde yapıldı. Operasyon sonrası 5 gün ağrı yoğunluğu görsel ağrı skalası ve serum kortizol düzeyi kullanılarak ölçüldü. Cerrahi sonrası 30. günde ağrı tekrar değerlendirildi.

Bulgular: Grupların başlangıç parametreleri aynı idi. Ağrı birinci ($p=0,04$), ikinci ($p=0,027$), üçüncü (0,026), dördüncü (0,0006) ve beşinci ($p=0,0006$) günlerde ve birinci ayda aktif TENS grubunda plasebo grubuna oranla önemli ölçüde azaldı. Aktif TENS grubunda cerrahi sonrası serum kortizol seviyeleri, plasebo TENS grubuna kıyasla düşük bulundu.

Sonuç: Elde ettiğimiz sonuçlar inguinal herni onarımı sonrası TENS'in postoperatif ağrı giderilmesinde yararlı olduğunu göstermektedir. Yan etki görülmemiştir ve etkisi cerrahi sonrası bir ay boyunca sürmüştür. Sonuç olarak, inguinal herni onarımı sonrası ağrı, analjezik gereksinimi ve kortizol seviyesinin azaltılmasındaki kısa ve uzun süreli etkisi nedeniyle TENS'in rutin kullanımı önerilir. *Türk Fiz Tıp Rehab Derg 2010;56:170-6.*

Anahtar Kelimeler: Cerrahi sonrası ağrı, inguinal herni onarımı, transkutanöz elektriksel sinir stimulasyonu

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Introduction

The natural history of postherniorrhaphy pain, including its prevalence, aetiology, duration, and associated disabilities, is unknown. This pain remains a significant problem in the first postoperative weeks and can persist, causing limitations in daily function activity and an extension of the convalescent period from one to several weeks (1-3). Postherniorrhaphy pain can also lead to missed work, limitations in activity, patient dissatisfaction, and unnecessary use of medical resources (4).

Transcutaneous electrical nerve stimulation (TENS) is a non-pharmacological intervention that reduces pain. It is noninvasive, inexpensive, safe, and easy to operate. Stimulation is delivered to peripheral sensory nerves through surface electrodes to elicit analgesia by both peripheral and central nervous system mechanism (5). The results of TENS studies for postoperative pain, however, have been inconsistent (6). Some investigators have reported that TENS relieves postoperative pain, decreases narcotic requirements, shortens the stay in recovery room, increases postoperative mobility and physical activity, and reduces the postoperative side effects of pulmonary complications (7,8). On the other hand, some researchers have failed to confirm any significant benefits (9,10).

Although previous studies (6,11-13) have used different methods to assess pain, such as the visual analogue scale (VAS), numerical rating scale (NRS), narcotic requirements, and patient-controlled analgesia, a few (14-16) have used serum cortisol level (SCL) as an index of pain relief. The SCL tends to be higher in the postoperative period with regard to the surgical stress affecting the metabolic activities and psychological effects of pain following surgery (17,18).

No study, however, has yet demonstrated the benefits of TENS in treating postoperative pain following inguinal herniorrhaphy using SCL as an outcome measure. Therefore, the objective of this prospective, randomized, double-blind, placebo-controlled trial was to evaluate the effects of TENS on postoperative pain and SCL following unilateral inguinal hernia repair.

Materials and Methods

Subjects

This study was a prospective, randomized, double-blind, placebo-controlled trial. Male subjects were recruited from the General Surgery Department at EL-Mataria Teaching Hospital, Cairo, Egypt. After obtaining written informed consent during preoperative visit, 67 male subjects with a physical status I–II (Physical Status I means a normal healthy patient with no organic, physiological and psychiatric disturbance, while physical Status II means a patient with mild systemic disease without functional limitation) according to the American Society of Anesthesiology (ASA), who underwent an elective inguinal hernia repair, were randomly assigned to either the active TENS group (n=34) or placebo TENS group (n=33), using a computer-generated randomization sequence.

The randomization occurred in the order, in which the patients were enrolled in the study according to the computer-generated randomization schedule prepared before commencement of the study. An estimation of the required sample size for dependent groups was determined based on pain intensity scores for the first 15 study subjects. On the basis of an effect sizes 0.22 for active TENS versus placebo TENS, with a=3, α=0.05, and power=0.8, a sample size of 60 subjects was required for both groups (12,19). This number was increased to 67 to account for possible dropout.

The inclusion criteria were as follows: (1) a primary unilateral direct or indirect inguinal hernia (20); (2) use of the Lichtenstein surgical technique (21); (3) use of the infiltration anesthetic technique (22); (4) male gender and age between 25 and 45 years; (5) a physical status I - II, using ASA criteria (8); (6) no hearing, visual, or speaking impairments; (7) no cognitive disturbances; and (8) pain score of 5 or greater on VAS.

The exclusion criteria were: (1) a recurrent hernia, as this type of hernia is more painful and requires more extensive dissection (23); (2) morbid obesity (BMI >35 kg/cm^2); (3) poor liver (serum bilirubin >2.0 mg/dL) or kkidneys function (serum creatinine >1.5 mg/dL.) (24); (4) neurological or pulmonary diseases; (5) cardiac conditions such as cardiac arrhythmia, angina pectoris, congestive heart failure, or uncontrolled hypertension, (6) wound infection, and (7) chronic use of opioids (24).

Surgical Procedure

The surgical and therapeutic procedures were explained thoroughly to the patients by a physical therapist, leading to an excellent therapist-patient rapport. The patients were admitted to the hospital on the day of the planned surgery, and all operations were performed by the author using the wound infiltration technique, first described by Amid et al. (22). All patients underwent a standard surgical procedure according to the Lichtenstein principles (21). The inguinal canal was opened by ample separation of the external oblique muscle from the rectus sheath. Then, the spermatic cord, including the ilioinguinal nerve and genital nerve, was lifted out of the inguinal canal, hernia was identified therein and the sac was excised. The posterior wall of the inguinal canal was then flattened. The repair was completed using onlay sutured tension-free monofilament polypropylene mesh, which covered the entire posterior wall of the inguinal canal and overlapped the conjoint tendon and rectus sheath by 1-1.5 cm. The medial end was sutured to the anterior rectus sheath above the pubic bone with prolene suture avoiding the periosteum of the bone. These sutures were continued with no more than three or four passes to attach the lower edge of the mesh to the inguinal ligament, just lateral to the internal ring. A new internal ring was fashioned by splitting the lateral portion of the mesh, creating two tails that surrounded the cord to form a snug opening ensuring the nerve integrity. The upper edge of the mesh was sutured in place with two interrupted absorbable sutures, one to the rectus sheath and the other to the internal oblique aponeurosis. The external oblique aponeurosis and subcutaneous tissues were closed routinely using absorbable sutures, and layered closure of wounds and adhesive dressing were performed similarly in all patients. All nurses and attending surgeons were blind to the study groups.

Outcome Measures

Postoperative Pain Assessment

Two physiotherapists (PT) were involved in this study and were trained to standardize treatment and measurements. The PT1 was responsible for gauging pain intensity at rest and

collecting blood samples over the 5 postoperative days and at follow-up. PT2 applied either active or placebo TENS therapy to the patients. Only PT2 knew whether a subject received active or placebo TENS therapy. Thus, PT1 and the subject were blinded to the type of TENS therapy. The patients were informed that 2 types of TENS treatment were being tested–one, in which a strong but comfortable tingling sensation would be felt and the other, in which a little or no sensation would be generated. The placebo TENS group received no electrical stimulation, but the unit displayed an active indicator light, suggesting to the patient that the unit was active.

The assessment of postoperative pain using visual analogue scale (VAS) on postoperative da-1 (POD), POD2, POD3, POD4, and POD5 was performed after 15 minutes of TENS application. Follow-up VAS assessment of pain was conducted again at 30 days postoperatively (POD30). The patients were instructed on how to use 10-cm VAS endpoints that were labeled in Arabic; "no pain" on the right side and "the worst possible pain" on the left side.

Assessment of Serum Cortizol Level (SCL)

Venous blood samples of (8cc) were drawn through an indwelling catheter inserted into the antecubital vein and collected in pre-chilled tubes containing proline, ethylenediamine tetraacetate (EDTA). After centrifugation at 40 C, the separated plasma samples were stored at -200 C until assayed (27). The blood samples were collected after 30 minutes of TENS treatment at 8:00 am and at 8:00 pm during the study period (25).

Intervention

All interventions were performed in the inpatient ward of the general surgery department and physical therapy department of Mataria Teaching hospital. For all subjects, the physical therapist applied active or placebo TENS using a dual-channel WELL-TENS device (WELL-Life Healthcare Limited, Taiwan) with a pulse frequency range of 0–160 Hz and an intensity of 0–100mA. Each subject received 30 minutes of TENS treatment twice daily at 7 am and 7 pm for five consecutive days. Two 15cm sterile adhesive electrodes were removed from their sterile protective coverings, placed longitudinally on either side of the incision and connected to pin connectors. The mode of conventional TENS therapy was adjusted to frequency of 100 Hz and pulse width of 120 μsec. The intensity of amplitude was adjusted individually based on patient tolerance between 10–30 mA generating a perceptible tingling sensation without significant muscle contraction.

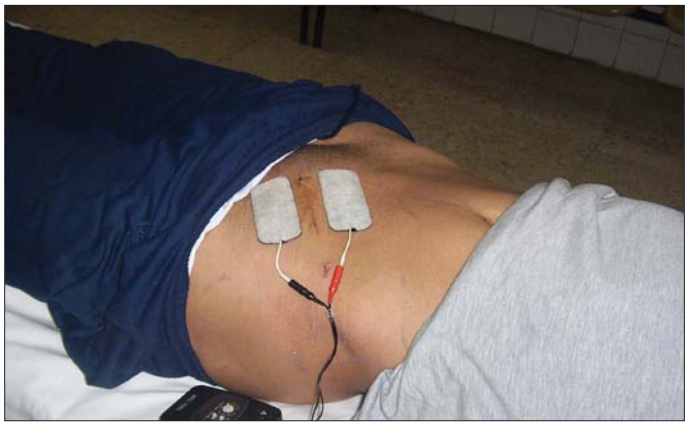

Figure 1. Electrodes placement and TENS unit application.

For the placebo TENS group, there was no perceptible sensation, as the TENS unit was turned on to display an active indicator light, but the current intensity (5-10mA) was below the level of perception of the patients, without any electrical stimulation. Figure 1 shows the application of the TENS unit. All subjects received a pain killer (500 mg of paracetamol) every 8 hours and diclofenac (50 mg, twice daily) as requested to control pain after surgery.

Statistical Analysis

The data were expressed as mean and standard deviation (Mean±SD). For normally distributed data, unpaired Student's t-test was used to identify the differences between the 2 groups. In addition, the frequency and percentage of improvement were calculated. The alpha level of significance was set at less than 0.05.

Results

Subject Characteristics

Table 1 shows the demographic and operative characteristics of the groups. Sixty-seven men who underwent inguinal hernia repair were enrolled in the study. Seven patients were excluded due to postoperative complications: wound infection (n=4) and wound dehiscence (n=3). Figure 2 depicts a CONSORT flowchart of the trial. There were no statistically significant differences between the active and placebo TENS groups in mean age, body mass index, occupation, types of hernia, ASA physical status, and duration of surgical procedures defined by the time from the skin incision to the placement of the last suture. The amount of time subjects waited after the surgery before beginning of TENS stimulation ranged from 20 to 24 hours and did not differ between the active and placebo TENS groups.

Pain Outcomes (VAS)

The data for pain intensity are shown in Table 2. The mean pain intensity did not differ between the groups on POD1, before

Table 1. Demographic and operative characteristic of patients.

Variables	Active TENS (n=30) Mean±SD	Placebo TENS (n=30) Mean±SD	p-value
Age Age (years)	36.06±8.18	34.3±6.18	0.67*
BMI (Kg/m^2)	25.39±3.21	25.47±2.87	0.9*
Occupation			
Heavy manual	18 (60%)	16 (53.3%)	0.77*
Light manual	7 (23.3%)	8 (26.7%)	-
Retired	5 (16.7%)	6 (20%)	-
Type of hernias			
Direct	21 (70%)	19 (63.3%)	0.3*
Indirect	9 (30%)	11 (36.7%)	-
Physical status			
I	21 (70%)	19 (63.3%)	0.3*
II	9 (30%)	11 (36.7%)	-
Duration of surgical procedures (minutes)	35.15±8.56	38.2›±7.3	0. 2*

*Non-significance (p›0.05), BMI, body mass index.

the application of TENS, 7.2±1.06 for the active TENS group versus 7.6±0.97 for the placebo TENS group. Following the assigned treatment, the mean score on the VAS in the active TENS group decreased significantly after TENS application compared to placebo group on POD1 ($p<0.04$), POD2 ($p<0.027$), POD3 ($p<0.026$), POD4 ($p<0.006$) and POD5 ($p<0.006$).

The percentage of pain intensity declined significantly from pretreatment on POD2 (43.75% vs. 23.28%), POD3 (70.14% vs. 52.46%), POD4 (75.69% vs. 54.65%), and POD5 (80.83% vs. 52.46%) in the active TENS group versus the placebo TENS group, respectively. At follow-up assessment (POD30), the number of patients who reported no pain increased significantly in the active TENS group compared to the placebo TENS group, [24 (80%) vs. 16 (53.3%)], and mild and moderate pain decreased [4 (13.3%) vs. 8 (26.7%)] and [2 (6.7%) vs. 6 (20%)], respectively as shown in Table 3.

Change SCL

The data related to SCL are shown in Table 4. There was no significant difference in the mean SCL (μgm/dl) between the active TENS and placebo TENS groups at POD1 before application of TENS. Subsequently, SCL fell significantly ($p<0.05$) during the assessment in the active TENS group compared to the placebo TENS group on POD1, POD2, POD3, POD4 and POD5.

Request for Pharmacological Analgesia

There were significant differences between the groups in the total amount of analgesic intake. The patients in the active TENS group requested less analgesic medication over the first three postoperative days than those in the placebo TENS group ($p<0.01$). Fourteen patients (11 in the active TENS group and 3 in the placebo TENS group, $p=0.01$) required no additional analgesic medication during the 5-day study period and returned the unopened package of analgesic drugs. Only 12 patients started with a regular paracetamol dose at approximately 6-hour intervals (5 in the active TENS group and 7 in the placebo TENS group), and only 6 patients used diclofenac (2 in the active TENS group and 4 in the placebo TENS group). Eight patients used a regular dose of paracetamol and diclofenac (two in the active TENS group and six in the placebo TENS group). Figure 3 shows that there were significant differences between the two groups in the total amount of analgesic intake. The patients in the active TENS group requested less analgesic medication than those in the placebo TENS group ($p<0.01$). On average, the subjects in the active TENS and placebo TENS groups consumed 0.6 and 2.9 doses of pain killer, respectively.

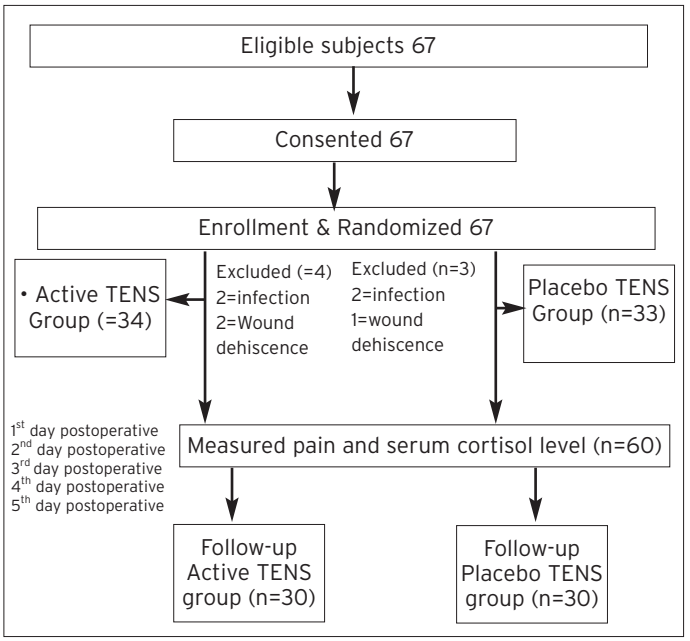

Figure 2. Eligibility and enrollment of subjects.

Discussion

The aim of this study was to investigate the effects of high-frequency TENS after unilateral inguinal repair. To this end, the effects of 100-Hz TENS were investigated over the first 5 postoperative days. Active TENS significantly reduced pain intensity, analgesic requirements and SCL when compared to

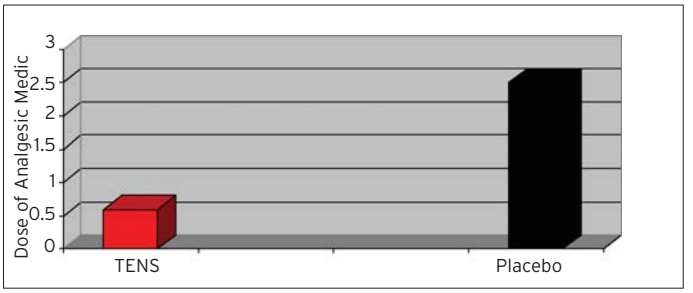

Figure 3. Mean number of doses of analgesic medicine for transcutaneous electrical nerve stimulation (TENS) and placebo TENS.

Table 2. Mean pain scores for active and placebo TENS groups.

Postoperative period	Active TENS (n=30) Mean±SD	Placebo TENS (n=30) Mean±SD	p-value
POD1 before TENS	7.2±›0.48	7.3±0.63	0.13*
POD1 after TENS	4.93±0.7	6.61±0.69	0.04**
POD2 after TENS	4.05±0.57 (43.75)	5.6±0.54 (23.28)	0.027**
POD3 after TENS	2.15±0.55 (70.14)	3.47±0.65 (52.46)	0.026**
POD4 after TENS	1.75±0.5 (75.69)	3.31±0.56 (54.65)	0.006**
POD5 after TENS	1.38±0.97 (80.83)	3.47±0.65 (52.46)	0.006**

POD=postoperative day, **significance ($p<0.05$), *non-significance ($p>0.05$)
The number in ( ) is percentage of changes in pain intensity.

placebo TENS. To our knowledge, this is the first study to show the effectiveness of TENS in reducing postoperative pain, analgesic requirements and SCL after inguinal hernia repair.

Our findings are supported by the work of Wang et al. (6) who compared the effects of high-frequency (100 Hz) and low-frequency (2 Hz) TENS in 101 gynecological patients after lower abdominal procedures. This study showed that 100 Hz TENS decreased the hydromorphone requirement by 65% (sham by 23%) and reduced the duration of patient-controlled analgesia (PCA) therapy along with the incidence of nausea, dizziness, and pruritus. Moreover, our results mirror those of De Santana et al. (12) who found significant reductions in pain intensity and total analgesic intake after application of high-frequency TENS during the first 24 hours following surgery.

Our findings are also supported by the work of Chen et al. (7), who noted a significant reduction in pain intensity, analgesia requirements, and opioid-related side effects after TENS application. Despite, there are differences in the methods of application and parameters of treatment, as we used stimulation at dermatomal levels corresponding to the skin incision with a consistent frequency, while Chen et al. (7) used acupoint stimulation and an alternating frequency of 2/100 Hz.

Tverskoy et al. (24) concluded that postoperative pain after inguinal herniorrhaphy decreases significantly if the surgery is performed with local infiltration anesthesia or spinal anesthesia instead of general anesthesia, perhaps because neural blockade prevents nociceptive impulses from entering the central nervous system during and immediately after surgery and, thus, suppresses the development of the sustained hyperexcitable state in the central nervous system that is responsible for postoperative pain. Moreover, the wound infiltration with a local anesthetic blocks the initiation of painful impulse and the transmission of nerve signals from the wound and also inhibits the cellular activities that regulate the inflammatory response (27).

Table 3. Assessment of pain at 30 days postoperatively.

	Active TENS N=30 N (%)	Placebo TENS N=30 N (%)	p-value
No Pain	24 (80%)	16 (53.3%)	0.02**
Mild pain	4 (13.3%)	8 (26.7%)	0.19*
Moderate pain	2 (6.7%)	6 (20%)	0.12*
**significance (p<0.05), *non-significance (p>0.05)			

In contrast to the current study, both Gilbert et al. (28) and Smedley et al. (29) showed no effect of TENS on postoperative pain or analgesic intake among patients who had undergone unilateral inguinal herniorrhaphy. These two studies used 70 Hz TENS delivered with 180↔sec pulse duration and sensory intensity similar to the current study. The surgical procedures used by Gilbert et al. (28) and Smedley et al. (29) however, were different from the current study, which used the Lichtenstein technique, while the other two studies used the Shouldice method. It is likely that the Shouldice method produces greater postoperative pain than the Lichtenstein technique.

Aytaç et al. (30) compared the outcomes of surgical treatment for unilateral inguinal hernias between the Lichtenstein open mesh repair and Shouldice repair. In the Lichtenstein group compared to Shouldice group, the need for analgesic medication after mesh repair was lower and the time to return to work was shorter. According to Nordin et al.(31), the Lichtenstein technique has become the gold standard due to its highly favourable properties: simple technique, moderate postoperative pain, recurrence rate below 1%, short hospital stay, very low complication rate, and early return to physical activity.

Nevertheless, Vrijland et al. (32) concluded that there were no significant differences in postoperative pain at 1 week or 1 month up to 36 months between non-mesh and mesh repair of primary inguinal hernia. Moreover, Callesen et al. (1) found that the cumulative pain scoring or use of analgesic did not differ significantly between different surgical techniques (extirpation of hernial sac, annulorrhaphy, or modification of Lichtenstein tension-free mesh repair).

We observed a significant reduction in SCL to normal levels following active TENS, which is in contrast to Rodriguez et al. (15) who reported statistically insignificant (p>0.05) reduction in the mean post-treatment cortisol and prolactin levels in women with post-operative pain following hysterectomy. Christensen et al. (33) studied metabolic stress and responses to 320 msec of 100-Hz TENS applied for 20 minutes during the early postoperative period and concluded that there were no significant differences between the experimental and control groups in postoperative SCL or thyroid-stimulating hormone.

These inconsistent results of TENS therapy might be related to several factors, including the stimulation site, frequency, intensity and pulse duration, duration of electrical stimulation, the type of surgical procedures, and patient's psychological profiles (34).

Table 4. Mean values of serum cortisol level (μgm/dl) for active and placebo TENS groups.

Postoperative period	Active TENS (n=30) Mean±SD	Placebo TENS (n=30) Mean±SD	p-value
POD1 before TENS	37.2±2.59	37.6±2.66	0.58*
POD1 after TENS	32.2±2.08	35.46±2.75	0.04**
POD2 after TENS	27.6±2. 91	31.23±2.31	0.03**
POD3 after TENS	24.21±3.92	27.82±1.98	0.04**
POD4 after TENS	21.4±0.94	23.25±1.44	0.03**
POD5 after TENS	19.4±0.94	23.3±1.31	0.02**
POD=postoperative day, **significance (p<0.05), *non-significance (p>0.05)			

Although, the precise mechanisms of TENS are not understood, it appears that it exerts beneficial effects through several pathways. The classical gate theory of pain control suggests that the stimulation of large-diameter myelinated A-β nerve fibers, which have a low threshold for stimulation by electrical current, alters pain recognition in the substantia gelatinosa, thus, "closing the gate" and decreasing the transmission of painful stimuli through the small-diameter A-δ and C fibers (35). Furthermore, there is also evidence that TENS directly decreases the conduction and amplitude of painful stimuli through the A-δ fibers (36). An endogenous opioid-dependent mechanism involving the release of endorphins, enkephalins, and dynorphins in the central nervous system has been proposed (37,38).

The ability of high-frequency TENS to achieve a reduction in pain can be attributed to its effects on the opioid-modulating analgesia system (OMAS). The application of TENS stimulates the release of endogenous opioid (e.g. β-endorphin), which have analgesic effects (39). In addition to modulating pain, β-endorphin is associated with cortisol and prolactin level (40,41) and shares a precursor with ACTH, which regulates cortisol secretion (41). β-endorphin has been implicated in the analgesic response to TENS treatment. The anterior pituitary gland is a source of β-endorphin along with ACTH that is derived from the prohormone proopiomelanocortin (POMC). Subsequently, ACTH stimulates the synthesis and release of cortisol from the adrenal cortex (42). These suggest that the anterior pituitary is not a source of β-endorphin in TENS-induced analgesia.

A possible limitation of our study was a body mass index (BMI) <35 kg/cm^2, as obesity contributes to a copious secretion of cortisol, therefore, these patients were excluded from the study to ensure that SCL was related to surgical stress not to high BMI. Pain intensity was not evaluated during movement and functional tasks in this study, but should be included in future investigations. Due to the specific and limited nature of this type of surgical procedure with local anesthesia, our results might not be generalized to all postsurgical patients or post-hernia repair patients who have undergone a more extensive surgical repair. Nevertheless, we show that active TENS has a greater effect than placebo. We were unable to determine the extent of the placebo effect, because we did not include a "no TENS" control group.

In conclusion, this double-blind, randomized, placebo-controlled study shows that high-frequency TENS reduces postoperative pain intensity and SCL after an inguinal hernia repair that elicits mild to moderate pain. Due to the absence of complications and adverse effects of TENS compared to conventional opioids and non-opioid analgesics, we suggest that TENS is a safe and reliable therapeutic procedure that can be used as a part of postoperative care following inguinal hernia repair.

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