



Contents lists available at ScienceDirect

## Pain Management Nursing

journal homepage: [www.painmanagementnursing.org](http://www.painmanagementnursing.org)

## Original Article

## Effect of Transcutaneous Electrical Nerve Stimulation on Postoperative Pain and Patient Satisfaction

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## ARTICLE INFO

## Article history:

Received 26 December 2017

Received in revised form

13 May 2018

Accepted 18 June 2018

## ABSTRACT

**Background and Aims:** This study was conducted to investigate the effect of transcutaneous electrical nerve stimulation on postoperative pain, changes in patients' vital signs, and patient satisfaction after inguinal herniorrhaphy.

**Design:** This study used a randomized controlled design.

**Setting:** A state hospital in the west of Turkey.

**Participants/Subjects:** The study was conducted on 52 patients who had inguinal herniorrhaphy between January and July 2015.

**Methods:** Patients were randomly divided into two groups (intervention and control). Intervention group patients received transcutaneous electrical nerve stimulation postoperatively five times for 30 minutes each. Electrodes in control group patients were placed, but the device was not started. At each transcutaneous electrical nerve stimulation session, the patients' vital signs and pain severity were recorded. A satisfaction scale was administered before discharge to assess patient satisfaction with nursing care.

**Results:** Pain scores of patients in the intervention group were lower than those in the control group ( $p < .05$ ). No differences were found in pre- and post-transcutaneous electrical nerve stimulation in the vital signs. Satisfaction scores were higher in the intervention group than control group ( $p < .05$ ).

**Conclusions:** After inguinal herniorrhaphy, transcutaneous electrical nerve stimulation reduced postoperative pain without a negative impact on vital signs and increased patient satisfaction with nursing care.

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Inguinal hernia accounts for 75% of all abdominal hernia cases. The lifetime risk is 27% for men and 3% for women (Fitzgibbons & Forse, 2015). Inguinal hernia repair constitutes 10%–15% of all surgical procedures and is globally performed more than 20 million times a year (Broadhurst & Wakefield, 2015).

Acute pain develops in 80% of patients after surgery, and 75% reported moderate or high levels of pain. Pain that is not adequately managed negatively affects quality of life and performance of daily

activities, increases postoperative complications, and extends healing time (Peng, Wijeyesundera, & Li, 2007). To manage postoperative pain, several pharmacologic agents are used, such as opioids, nonsteroidal anti-inflammatories, and analgesics, after the postoperative period (Peng et al., 2007; Pogatzki-Zahn, Segelcke, & Schug, 2017). These agents are often used in the management of postoperative pain only or in combination with other therapeutic drugs. A combination of agents from different classes may ensure additive analgesic effects with fewer side effects compared with a single therapeutic drug. A combination of drugs reduces pain through different mechanisms (Ong, Seymour, Lirk, & Merry, 2010).

In recent years, various nonpharmacologic methods, such as acupuncture, transcutaneous electrical nerve stimulation (TENS), physiotherapy, and hypnosis, have been used to decrease pain (Coutaux, 2017). TENS involves the application of different frequencies of electric currents through surface electrodes placed on the skin. The TENS works by multiple peripheral and central mechanisms. The analgesic effects of TENS can be explained by the

This study was accepted for the 2015 Master's Program of Celal Bayar University, Institute of Health Science, and Department of Surgical Nursing in Turkey. It was also presented at the 1st International Congress of Graduate Students held on May 12–14, 2016.

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<https://doi.org/10.1016/j.pmn.2018.06.003>

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gate control theory. In this theory, TENS selectively stimulates A- $\beta$  sensory fibers and prevents the transmission of impulses sent to the brain at the level of the spinal cord. In addition, TENS initiates the release of natural opioids in the body, thus reducing the perception of pain (Coutaux, 2017; Jones & Johnson, 2009). The TENS method is inexpensive, noninvasive, well tolerated, and easy to use (Jones & Johnson, 2009).

Transcutaneous electrical nerve stimulation is an adjunct to routine pharmacologic methods in the postoperative period. Most studies have indicated a significant decrease in pain intensity and additional analgesic requirement after surgery (Ahmed, 2010; Çelik et al., 2010; DeSantana et al., 2008; Tsang et al., 2011). The surgical operations included were herniorrhaphy (DeSantana et al., 2008), inguinal hernia repair (Ahmed, 2010), hysterectomy, (Çelik et al., 2010; Tsang et al., 2011), total knee replacement surgery (Rakel et al., 2014), abdominal surgery (Tokuda, Tabira, Masuda, Nishiwada, & Shomoto, 2014), liposuction (Da Silva, Liebano, Rodrigues, Abla, & Ferreira, 2015), and thoracotomy (Fiorelli et al., 2012). In all these studies TENS was used for postoperative pain relief. Rakel and Frantz (2003) noted the effectiveness of TENS in improving mobilization and movement and reducing pain in patients undergoing surgery. In the 2011 study by Amer-Cuenca et al., 2011 patients in the TENS group had significantly lower pain after colonoscopy compared with the control group. Karayurt et al. (2014) reported that TENS reduced pain in patients with chronic pain. Contrary to the studies of DeSantana et al. (2008) and Ahmed (2010), two reports reported no impact of TENS on postoperative pain after inguinal herniorrhaphy (Gilbert, Gledhill, Law, & George, 1986; Smedley, Taube, & Wastell, 1988).

There are few research studies about TENS for controlling the pain after inguinal herniorrhaphy. Results on the effectiveness of TENS are conflicting. The results of the present study will be used to provide new evidence and guide future studies. This study was conducted to determine the effect of TENS on postoperative pain, changes in patients' vital signs, and patient satisfaction with nursing care after inguinal herniorrhaphy.

## Research Question

Three research questions guided this study.

After inguinal herniorrhaphy, what is the effect of TENS on (1) reducing pain; (2) changes in patients' vital signs (systolic and diastolic blood pressure, pulse, respiratory rate and oxygen saturation); and (3) raising patient satisfaction with nursing care?

## Methods

### Study Design and Setting

This parallel-group randomized controlled trial (RCT) was conducted between January and July 2015 in a state hospital in the west of Turkey. The hospital had 315 beds, with 24 beds located in the general surgery clinic. The research protocol was developed using a multidisciplinary approach, including the perioperative team.

### Sample

The sample size was calculated using the visual analog scale (VAS) scores at postoperative second hour reported in DeSantana et al. (2008) as a reference. The minimum sample size was determined as 42 (21 intervention and 21 control) with a power of 80%,  $\alpha = .05$  error, and 95% confidence level. Initially, 70 patients were planned to ensure a comparative parametric analysis; however, patients did not fulfill research criteria or chose not to participate. Patients were divided into two groups using block randomization. A flow diagram (Fig. 1) provides attrition, including postoperative

period exclusions. The study was completed with 52 patients. Neither patients nor health care providers were blinded to treatment assignments.

The inclusion criteria for this study were patients who received inguinal herniorrhaphy with the Lichtenstein technique and had a physical status class I or II based on American Society of Anesthesiologists classification (I, patient is completely healthy and fit; II, patient has mild systemic disease). They had to be orientated, conscious, and able to answer questions, and they could not have hearing, sight, or speech disorders. Exclusion criteria were being younger than 18 or older than 80 years; having a pacemaker or electronic implant or liver, kidney, neurologic, or cardiovascular diseases; having disorders or diseases that impaired decision-making ability (e.g., dementia, psychological disorders); morbid obesity; being on antihypertensive, antidepressants, or opioid drugs or steroids; or having an allergic response to the electrodes, gel, or tape.

### Data Collection Tools

The data were collected using an information form, VAS, and the Newcastle Satisfaction with Nursing Care Scale (NSNCS).

### Information Form

This form included questions concerning sociodemographic characteristics, inguinal hernia risk factors, and the presence of other system diseases and duration of disease. The form was developed by researchers according to literature and contained 12 questions. Well-structured open-ended and multiple-choice questions were used.

### Observation Form

The second form was related to clinical data including vital signs (systolic and diastolic blood pressure, pulse, respiratory rate, and oxygen saturation); the pain intensity at 0, 2, 4, 8, and 24 postoperative hours; and the amount of analgesics used after operation. Vital signs, pain intensity, and amount of analgesic used were recorded on this form.

### Visual Analog Scale

The VAS measures the intensity of patients' pain. It is 10 cm in length with 0 being no pain and 10 indicating most severe pain. Reliability and validity of the scale was confirmed by Price et al. (Price, McGrath, Rafii, & Buckingham, 1983).

### The Newcastle Satisfaction with Nursing Care Scale

The NSNCS was developed by Thomas et al. in 1996 (Thomas, McColl, Priest, Bond, & Boys, 1996). Turkish reliability and validity of NSNCS has been determined (Uzun, 2003). It is a 5-point Likert scale containing 19 items on nursing care. Total score was obtained by summing the score of each item and converting the total to a standardized 0–100 point scale, where a score of 100 indicates highest satisfaction with nursing care (Thomas et al., 1996; Uzun, 2003).

### Intervention

Intervention group patients received five sessions of TENS at postoperative hours 0, 2, 4, 8, and 24, each lasting 30 minutes. The TENS device (Medisana 88310 TENS, Wembley, UK) had dual-channel capability with four electrodes. Researchers placed self-adhesive electrodes measuring 5 cm  $\times$  5 cm 2 cm apart, with the first channel being placed on one side of the inguinal incision site and the second on the other side. Throughout the TENS application, patients were not left alone and were closely observed.

The dual-channel TENS device was used in the conventional mode with asymmetric biphasic square wave impulses at 100 Hz

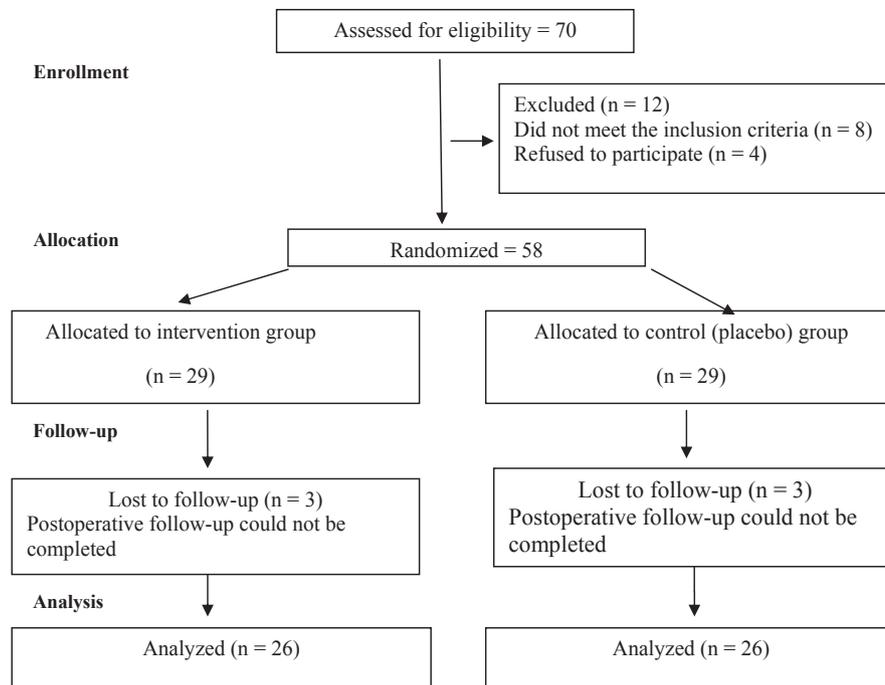


Figure 1. Flow diagram of the study.

frequency with 100  $\mu$ s pulse duration and at a current level that would not cause discomfort or muscle contraction after postoperative period.

Patients in the control group had the four TENS electrodes applied on the same sites, at the same hours, and for the same duration as the intervention group. The TENS device was switched on, and the red light was visible but no current was applied. Usual postoperative care included receiving diclofenac sodium (Voltaren, 75 mg) intramuscularly three times a day per physician orders. Patients with a VAS score of  $\geq 4$  received an additional dose of diclofenac sodium.

Pain intensity of patient was evaluated using VAS before and after each TENS session (at postoperative hours 0, 2, 4, 8, and 24). Vital signs were measured before and after each TENS session in the intervention group and same time in the control group and recorded using a noninvasive bedside monitor (Datex Ohmeda, GE Healthcare, Helsinki, Finland). The bedside monitor was calibrated before use. The NSNCS was used to evaluate their satisfaction with

nursing care before discharge (postoperative first day) in both groups' patients. Pain intensity, vital signs, the amount of analgesic consumption, and satisfaction with nursing care were evaluated and recorded by same researchers.

In a face-to-face interview in the patient's hospital room, the patients were asked to complete the information form and were clearly informed about the TENS application.

#### Data Analysis

Data were analyzed using SPSS 15.0 (SPSS, Chicago, IL, USA). The Shapiro-Wilk test was performed to determine whether data were normally distributed. Numerical variables were described as mean (standard deviation), and median (interquartile range). Categorical variables were described as number and percent. Between-groups comparisons included Student *t*, Mann-Whitney *U*, and  $\chi^2$  tests. Measurements of changes in the groups were obtained using the Wilcoxon signed rank test. Student *t* test and Mann-Whitney *U* test

Table 1  
Demographic Characteristics of the Patients

Characteristics	TENS Group (n = 26)	Control Group (n = 26)	<i>t</i> ,* $\chi^2$ ,† $\chi^2$ ‡	<i>p</i>
	Mean $\pm$ SD	Mean $\pm$ SD		
Age (y)	44.96 $\pm$ 14.48	50.04 $\pm$ 15.04	-1.240*	.221
BMI (kg/m <sup>2</sup> )	25.36 $\pm$ 2.52	24.97 $\pm$ 2.45	.573*	.569
Working time (y)	11.15 $\pm$ 7.10	15.50 $\pm$ 7.92	-1.715*	.096
Sex				
Female, n (%)	2 (66.7)	1 (33.3)	—†	1.000
Male, n (%)	24 (49.0)	25 (51.0)		
Education level				
Primary school, n (%)	18 (51.4)	17 (48.6)	.087‡	.768
Secondary school and higher, n (%)	8 (47.1)	9 (52.9)		
Occupation				
Retired, n (%)	6 (31.6)	13 (68.4)	4.064‡	.044
Worker/public servant, n (%)	20 (60.6)	13 (39.4)		

TENS = transcutaneous electrical nerve stimulation; SD = standard deviation; BMI = body mass index.

Data presented as mean  $\pm$  SD or number (percentage).

\* Student *t* test.

† Fisher's exact test.

‡  $\chi^2$  Test.

**Table 2**  
Comparison of Patient Satisfaction and VAS Scores of the Patients Obtained at Baseline and at Hours 0, 2, 4, 8, and 24

Times	TENS Group (n = 26)	Control Group (n = 26)	z, <sup>*</sup> t <sup>†</sup>	p
	Mean ± SD	Mean ± SD		
Preoperative VAS	2.96 ± 2.16	2.58 ± 1.92	0.678 <sup>†</sup>	.501
	Median (IQR)	Median (IQR)		
<b>Postoperative Period</b>				
0 h before TENS	1.00 (0.00–2.00)	1.00 (0.00–1.25)	-0.722 <sup>*</sup>	.470
0 h after TENS	1.00 (0.00–1.25)	2.00 (1.00–3.00)	-3.602 <sup>*</sup>	<b>.000</b>
2 h before TENS	3.00 (3.00–4.00)	4.00 (3.00–4.00)	-2.566 <sup>*</sup>	<b>.010</b>
2 h after TENS	2.00 (1.00–3.00)	3.00 (3.00–4.25)	-3.520 <sup>*</sup>	<b>.000</b>
4 h before TENS	3.00 (3.00–4.00)	4.00 (4.00–6.00)	-4.728 <sup>*</sup>	<b>.000</b>
4 h after TENS	2.00 (1.00–3.00)	5.00 (4.00–6.00)	-5.987 <sup>*</sup>	<b>.000</b>
8 h before TENS	3.00 (2.00–3.00)	5.00 (5.00–6.00)	-6.118 <sup>*</sup>	<b>.000</b>
8 h after TENS	2.00 (1.75–3.00)	5.00 (5.00–6.00)	-6.301 <sup>*</sup>	<b>.000</b>
24 h before TENS	1.00 (1.00–2.00)	3.00 (2.00–4.00)	-5.479 <sup>*</sup>	<b>.000</b>
24 h after TENS	1.00 (1.00–1.00)	4.00 (2.00–4.00)	-6.482 <sup>*</sup>	<b>.000</b>
Patient Satisfaction	87.89 (82.11–93.95)	79.47 (75.53–85.53)	-3.251 <sup>*</sup>	<b>.001</b>

VAS = visual analog scale; TENS = transcutaneous electrical nerve stimulation; SD = standard deviation; IQR = interquartile range.

Bold values indicate statistical significance.

\* Mann-Whitney U test.

† Student t test.

were used to compare VAS pain intensity scores between groups. Results were considered significant when  $p < .05$ .

**Ethics**

The study was conducted in accordance with the principles of the Helsinki Declaration. Before commencement of the study, the approval of the local ethics committee of the university was obtained (reference number: 14/12/2014/20478486-426). All participants provided written and verbal informed consent.

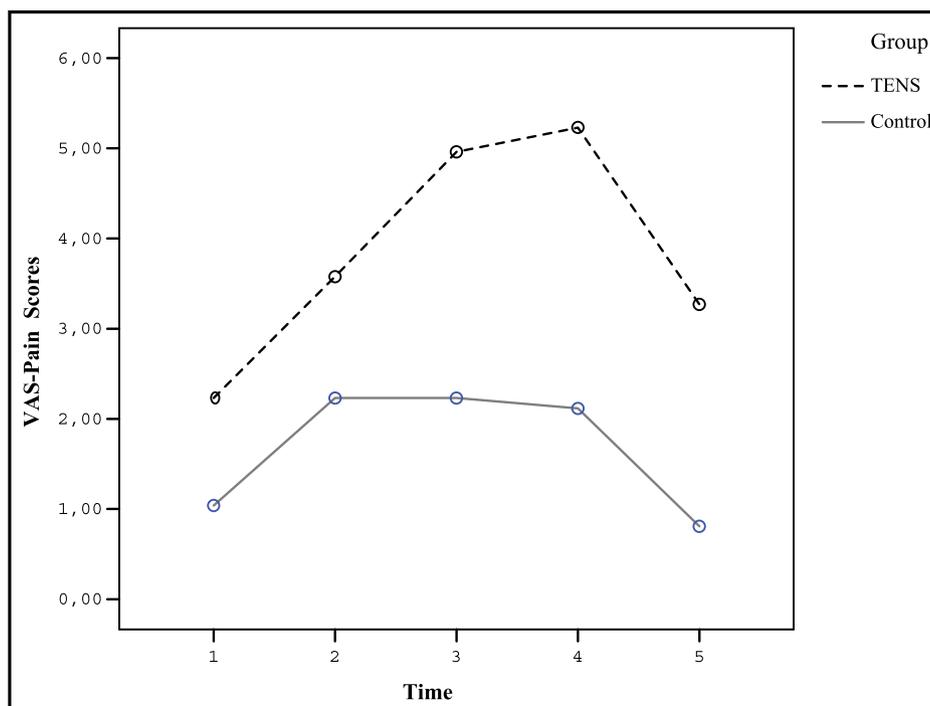
**Results**

In total, 52 patients completed all follow-up data collection and were included in analysis. Table 1 provides patient demographic

information. There were no differences in mean age, sex, body mass index, and mean working time between groups. Only one factor, occupation, varied by group. Control group patients were more likely to be retired, and TENS group patients were more likely to be employed (Table 1).

There was no difference between lengths of hospitalization in both groups. All patients were discharged on the first postoperative day.

Between-group VAS scores did not differ at baseline and hour 0 postoperatively. At postoperative assessment periods 2, 4, 8, and 24 hours, pain scores of the TENS group were lower than those of the control group at all measurement periods (Table 2 and Fig. 2). There was no change in vital signs of patients in the intervention and control groups before and after TENS application (all  $p > .05$ ). Patient satisfaction with nursing care was higher in the TENS group compared with the control group ( $z = -3.251, p = .001$ ).



**Figure 2.** Changes in pain intensity before and after transcutaneous electrical nerve stimulation (TENS) by measurement time.

**Table 3**  
Changes in VAS Scores Over Measurement Time

Times	TENS Group (n = 26)				Control Group (n = 26)			
	Before TENS	After TENS	z	p <sup>*</sup>	Before TENS	After TENS	z	p <sup>*</sup>
	Median (IQR)	Median (IQR)			Median (IQR)	Median (IQR)		
VAS								
0 h VAS	1.00 (0.00–2.00)	1.00 (0.00–1.25)	–1.997	<b>.046</b>	1.00 (0.00–1.25)	2.00 (1.00–3.00)	–3.581	<b>.000</b>
2 h VAS	3.00 (3.00–4.00)	2.00 (1.00–3.00)	–3.437	<b>.001</b>	4.00 (3.00–4.00)	3.00 (3.00–4.25)	–1.186	.236
4 h VAS	3.00 (3.00–4.00)	2.00 (1.00–3.00)	–3.581	<b>.000</b>	4.00 (4.00–6.00)	5.00 (4.00–6.00)	–2.309	<b>.021</b>
8 h VAS	3.00 (2.00–3.00)	2.00 (1.75–3.00)	–3.017	<b>.003</b>	5.00 (5.00–6.00)	5.00 (5.00–6.00)	–1.000	.371
24 h VAS	1.00 (1.00–2.00)	1.00 (1.00–1.00)	–2.919	<b>.004</b>	3.00 (2.00–4.00)	4.00 (2.00–4.00)	–1.518	.129

VAS = visual analog scale; TENS = transcutaneous electrical nerve stimulation; IQR = interquartile range.

Bold values indicate statistical significance.

\* Wilcoxon signed rank test.

When change in VAS scores within groups was compared at each assessment period, the TENS group had a decrease in VAS scores at all assessment periods; however, control group VAS scores increased after the placebo application compared with pre-placebo application at time 0 and at 4 hours (Table 3).

## Discussion

This study was carried out to examine the effect of TENS on postoperative pain, vital signs, and patient satisfaction with nursing care after inguinal herniorrhaphy. The results indicated that postoperative pain was significantly decreased in the TENS group compared with the control group after inguinal herniorrhaphy. The results were in agreement with two reports in the literature, one of which involved pain intensity for the first 5 days after inguinal hernia repair compared with usual care (Ahmed, 2010) and the second of which studied pain for the first postoperative 24-hour period (DeSantana et al., 2008). However, in two reports, TENS application after inguinal herniorrhaphy did not change pain intensity (Gilbert et al., 1986; Smedley et al., 1988). Contradicting study results may be associated with different techniques used in surgery. Similar to our study, authors of the positive studies used the Lichtenstein technique for inguinal hernia repair (Ahmed, 2010; DeSantana et al., 2008), whereas authors of the ineffective studies used the Shouldice method (Gilbert et al., 1986; Smedley et al., 1988). It was reported that patients who underwent herniorrhaphy with the Shouldice method experienced more pain than with the Lichtenstein technique (Sugunakara & Waddi, 2016). In recent years the Lichtenstein technique has become the gold standard for hernia repair (Kulacoglu, 2011).

In some studies TENS application was not found to be effective (Benedetti et al., 1997; Ferreira, Issy, & Sakata, 2011). Similar to our research, other studies reported that this method reduced analgesic consumption and pain intensity and duration (Ahmed, 2010; Çelik et al., 2011; DeSantana et al., 2008).

Transcutaneous electrical nerve stimulation is used as a non-pharmacologic method to control postoperative pain of various procedures. Freynet and Falcoz (2010) indicated that seven of nine RCTs found that TENS decreased analgesic consumption and improved the duration of recovery after thoracotomy. In another study (eight RCTs, 442 patients) TENS diminished the severity of pain and analgesic consumption for various surgical procedures (thoracotomy, inguinal herniorrhaphy, laparoscopic tubal ligation, laparoscopic cholecystectomy, spine surgery, and total hip arthroplasty) (Kerai, Saxena, Taneja, & Sehrawat, 2014). In these studies, frequency, intensity, and site of TENS were different. Also, sample size and methodology were insufficient. These parameters may be the cause of the different effects of TENS on postoperative pain.

Contact dermatitis and skin irritations under the electrodes can occur as complications of TENS (Johnson, 2007). However, we did

not observe any side effects or intolerance associated with TENS in our patients. Also, TENS application did not cause any negative changes in vital signs. This result indicates that TENS is easily applied, and its efficacy and safety could help in pain relief for inguinal herniorrhaphy.

In this study, although there was no difference between the two groups' length of hospitalization, the patient satisfaction with nursing care scores were found to be higher in the intervention group compared with the control group. To evaluate patient satisfaction with nursing care after TENS application, all patients were administered the NSNCS. There was no question about pain in NSNCS. Patient satisfaction with nursing care may increase as the pain of the patients decreases in the intervention group.

Currently, effective pain management is accepted as an indicator of patient satisfaction (Glowack, 2015). To our knowledge, no study has investigated patient satisfaction with nursing care after TENS application for herniorrhaphy. Patient satisfaction with nursing care was studied after TENS application in different populations. For example, patient satisfaction with care was higher after low-frequency and conventional TENS after abdominal hysterectomy (Çelik et al., 2011) and in patients with chronic pain (Karayurt et al., 2014). In studies investigating patient satisfaction scores without the TENS, patient satisfaction with nursing care has been reported to be high (Findik, Ünsar, & Sut, 2010). The results of this study are consistent with the literature.

Effective and adequate pain management ensures earlier mobilization and reduces postoperative complications such as pulmonary complications, urinary retention, and ileus (Glowack, 2015). Previous studies have found that further benefits of effective postoperative pain management provided earlier mobilization, diminished length of discharge time, lower readmission rates, earlier recovery, increased quality of life and patient satisfaction, and reduced hospital costs (Gupta et al., 2010; Kolettas et al., 2015). In present study there was no difference between the groups in duration of hospitalization. All patients were discharged on day 1 postoperatively, possibly because this surgery was minor. It was thought that this difference could be revealed in larger surgeries.

## Nursing Implications

Postoperative pain management is an important subject in surgical nursing practice. Surgical nurses are the members of the perioperative team who are with the patients the longest time, to apply care and interventions in the postoperative time. Therefore, they have an important role in the control of surgical pain. Inadequate pain management may increase morbidity and delayed recovery after operation. To manage postoperative pain, pharmacologic agents and nonpharmacologic methods are used. Nonpharmacologic methods such as TENS are used to decrease pain. Nurses can reduce postoperative complications using TENS

for effective pain management, and patients may recover more quickly. Side effects such as nausea and vomiting caused by analgesic drugs can be reduced by TENS application. The TENS application can improve patient outcomes and assist clinical nurses in connecting with patients more closely. Additionally, patient comfort and patient satisfaction with nursing care can be increased. TENS application, as a nursing intervention, is a noninvasive and safe treatment for pain relief. Nurses who can use TENS application as an intervention for patients who have had operative inguinal herniorrhaphy improve patient satisfaction. It is recommended that TENS application become a part of nursing care given to patients experiencing pain because TENS is a low-cost therapy that has no side effects.

### Limitations

The results of the study can only be generalized to patients with similar characteristics to the sample. A single center was used, and sample size was small. It is unknown whether findings would vary if multiple centers or centers in different environments and a larger sample size were used. This study was single blind. TENS was applied to patients in the control group, but the TENS device was not activated. Researchers performed TENS and collected data during face-to-face interviews, which could introduce bias (internal threat to validity). Patient satisfaction with nursing care was assessed before hospital discharge. Patients could have responded based on what they believed hospital personnel wanted to see, rather than providing true responses.

### Conclusions

TENS was a useful method to reduce postoperative pain, and patient satisfaction with nursing care increased without any negative effect on vital signs in patients undergoing herniorrhaphy. TENS should be used as an adjunct to pharmacologic methods to reduce postoperative pain. In-service training programs for TENS application should be organized for nurses.

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