Postoperative and Preincisional Electrical Nerve Stimulation TENS Reduce Postoperative Opioid Requirement After Major Spinal Surgery

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Background and Objective: Preincisional and postoperative transcutaneous electrical nerve stimulation (TENS) administration reduces postoperative opioid demand in abdominal surgery. Aim of this study was to find out whether a comparable effect of TENS applies in major spinal surgery.

Methods: Thirty-eight patients of both sex scheduled for lumbar interbody fusion were enrolled and divided randomly into 3 groups. Group A received TENS preincisional and postoperative, group B received this treatment postoperative only, and group C was the sham controlled. The postoperative demand on piritramid to achieve a visual anlog scale pain score < 3 was delivered either by nurse or by a patient-controlled analgesia pump, when the patients were alert. The setting of the patient-controlled analgesia pump, bolus of piritramid 2 mg intravenously (IV), lockout time of 20 minutes, and maximum dose of piritramid 15 mg within 4 hours, the coanalgesic therapy diclofenac 75 mg IV, and the rescue medication metamizol 1 g IV was identical for all patients. The total amount of piritramid administered over the first 24 hours after surgery and an optional rescue medication were recorded.

Results: All groups were compared by pairs. The postoperative demand on piritramid differed significantly A versus B ($P < 0.05$), A versus C ($P < 0.05$), and B versus C ($P < 0.05$). Neither sex, body mass index, current, duration, and type of operation nor the occurrence of hypotensive phases showed any significant association with postoperative piritramid demand. The necessity of rescue medication was significantly higher in group C than in group A.

Conclusions: Postoperative TENS as well as the combination of preincisional and postoperative TENS therapy reduce the postoperative demand of piritramid in major spinal surgery in a safe and simple way free of systemic side effects.

Key Words: transcutaneous electrical nerve stimulation, preincisional, major spinal surgery, piritramid, postoperative analgesia

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OBJECTIVES

Transcutaneous electrical nerve stimulation (TENS) has been reported to significantly decrease the postoperative opioid requirements in abdominal and shoulder surgery.[1–3] In contrast, TENS has been shown ineffective in postoperative pain treatment after total knee arthroplasty.[4]

Preincisional administration of analgesics systemically, epidurally, and wound infiltration of local anesthetics[5] and ketamine has been proven as efficient.[6] Preemptive use of TENS in major spinal surgery has not yet been studied.

The aim of this study was to investigate the influence of preincisional and postoperative TENS on opioid demand within 24 hours postoperative in major spinal surgery. A visual analog scale (VAS) score of pain of 3 or less was regarded as satisfactory.

PATIENTS, MATERIALS AND METHODS

After approval of the local Ethic Committee and written informed consent, 38 opioid naive patients of both sex American Society of Anesthesiologists Grade I to III scheduled for elective posterior interbody fusion of 2 (PLIF 1) or 3 (PLIF 2) lumbar vertebrae were recruited on the preoperative day. A prospective randomized single-blinded, sham controlled study was designed to test the hypothesis that the administration of TENS influences the postoperative demand of piritramid given by the medical staff and by a patient-controlled analgesia (PCA) infusion pump.

Patients were divided in 3 groups based on random numbers by closed envelopes: group A—PCA plus TENS therapy for 30 minutes before skin incision, for 8 hours after skin closure, according to Likar's setting,[3] and 30 minutes on the first postoperative day; group B—PCA plus sham TENS therapy for 30 minutes before skin incision, plus TENS therapy for 8 hours after skin closure, and for 30 minutes on the first postoperative day; group C (control)—PCA plus sham TENS therapy for 30 minutes before skin incision, for 8 hours after skin closure, and for 30 minutes on the first postoperative day. In all groups preincisional TENS was started before the induction of anesthesia and postoperative TENS therapy was started when the patients were still anesthetized.

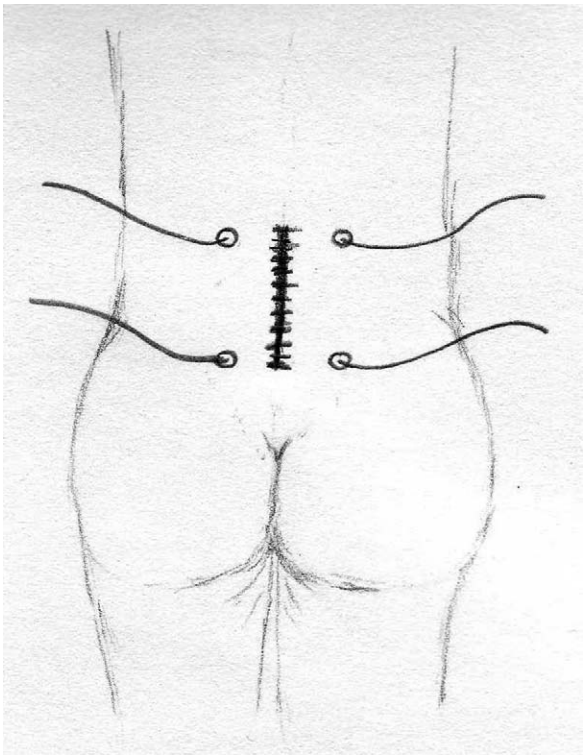

FIGURE 1. Four cutaneous electrode pads were positioned at the dermatomal levels corresponding to the vertical skin incision.

Similar to Hamza et al's[1] and Chen et al's[7] location in all groups 4 cutaneous self-adhesive electrode pads, sized 16 cm^2 (tens/ems, Promed GmbH, D-82490, Farchant, Germany) were attached on either side in a distance of 4 cm to the planned skin incision at dermatomal levels as illustrated in Figure 1 and TENS therapy was started immediately before induction of anesthesia.

The TENS electrodes were connected to the TENS device (tens 1000 s, D-82490, Farchant, Germany) and stimulated in a synchronized fashion with a bidirectional electrical current wave and a pulse width of 0.25 ms without bursts. The frequency was set on 100 Hz. Patients preferred 100 to 2 Hz. Both frequencies were shown equal in opioid sparing.[1] The intensity of the electrical stimulation was set at 0 mA for group C and for preincisional treatment of group B. Patients of group A and patients of group B, after skin closure, received an intensity of 10 to 20 mA (ie, the highest tolerated amplitude of electrical stimulation). Patients in group C and patients in group B, before skin incision, were told that they may not be able to feel the electrical stimulation; however, the "in use" light on TENS device was flashing in the usual manner when it was activated.

In all groups anesthesia was induced with propofol and maintained with sevoflurane. Remifentanil infusion was started before intubation, adapted on surgical stimuli, and was stopped after skin closure. Rocuronium was used for muscle relaxation. Body temperature was kept over 36°C by using a forced air patient warming system throughout the whole operation. Depending on the reason, hypotension was treated immediately either with fluids or with phenylephrine. Patients of all groups received piritramid 0.08 mg/kg intravenously (IV) and diclofenac 75 mg IV 20 minutes before the expected end of skin closure. No additional opioid analgesic medications were administered during the intraoperative period. Diclofenac 75 mg was administered IV to all the patients 12 hours after operation.

Standard 10-cm VAS (DoloMeter, Mundipharma Ges.m.b.H., A-1072 Wien, Austria) were used to assess the patient's level of pain (from 0, no pain to 10, worst pain imaginable) during TENS therapy.

The VAS assessments were performed when the patients were awake and able to obey simple commands, before leaving the recovery room, 24 hours postoperatively during rest, and optionally before administration of rescue medication.

Single injections of piritramid were given IV by the medical staff to achieve a VAS of 3 or less until the patients were able to handle the PCA pump.

TABLE 1. Distribution of Sex, Current, and Rescue Medication by Group

	All Patients (n = 38)		Treatment Group			
	n	%	A (n = 13)	B (n = 14)	C (n = 11)	*P**
Sex						
Female	19	50	7	8	4	NS (0.610)
Male	19	50	6	6	7	
Current (mA)						
0	11	28.9			11	< 0.0005 Including group C
2	1	2.6	1			Group A versus B: NS (0.670)
10	7	18.4	2	5		
15	11	28.9	5	6		
20	8	21.1	5	3		
Rescue medication						
No	32	84.2	11	14	7	0.035
Yes	6	15.8	2	0	4	

*Fisher exact test generalized for $2 \times k$ ($k > 2$).
NS indicates not significant.

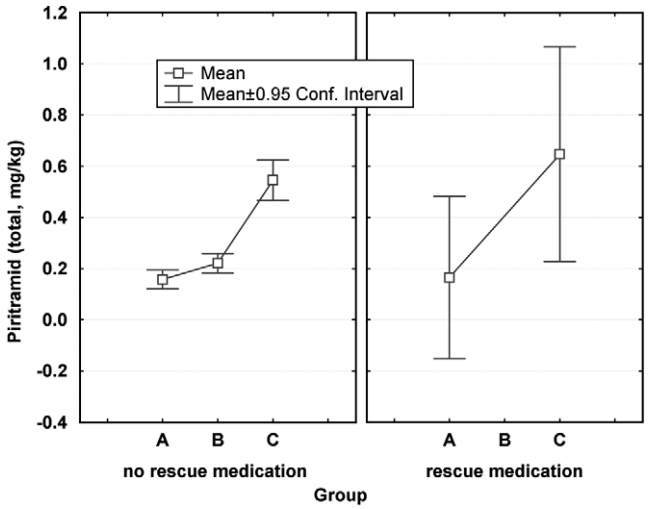

FIGURE 2. Total piritramid by treatment group and rescue medication.

The PCA pump was connected and explained before the patients were dismissed on ordinary ward. The bolus dose was piritramid 2 mg, the lockout time was 20 minutes, and the maximum dose within 4 hours was piritramid 15 mg.

Metamizol 1 g IV was prescribed as a supplemental rescue medication for all patients, if PCA therapy failed to achieve a VAS of 3 or less.

The total amount of piritramid was evaluated 24 hours after the end of operation.

Statistical Methods

In accordance with data sets from a previous study,[8] an a priori power analysis was performed.

Data were collected statistically and analyzed using SPSS 16 version (Chicago, IL). For data evaluation analysis of variance (ANOVA), Welch test, Student *t* test, generalized Fisher exact test, Kruskal-Wallis test, Median test, and Mann-Whitney test *U* test were applied. The Kolmogorov-Smirnov test was used to test whether data were normally distributed. A *P* value of < 0.05 was considered statistically significant.

RESULTS

All enrolled patients finished the study.

Concerning sex the groups did not differ significantly ($P = 0.61$). Due to constant 0 current in group C, it was only possible to test equality of means in groups A versus B. Obviously the mean current in both of these groups differs from 0 (group C). Regarding current no significant difference was found between groups A and B ($P = 0.67$) (Table 1).

The necessity of rescue medication differs significantly between groups A and C ($P = 0.035$) (Fig. 2).

For age, height, weight, and body mass index a regular ANOVA (with equal variances) was used to compare the mean. Concerning age ($P = 0.19$), height ($P = 0.92$), weight ($P = 0.97$), and body mass index ($P = 0.80$) no significant difference was found between the groups (Table 2).

Kolmogorov-Smirnov test, group A ($P = 0.89$), group B ($P = 0.80$), and group C ($P = 0.70$) showed that the values of piritramid (in the 3 groups separately) did not contradict the assumption of being normally distributed.

For piritramid, a modified ANOVA assuming nonequal variances (Welch test) was carried out. If one does not assume a normal distribution for piritramid, the nonparametric Kruskal-Wallis test ($P < 0.0005$) and the Median test ($P < 0.0005$) gave similar results.

The pairwise comparisons of piritramid (total) showed statistically significant differences, when data evaluation was carried out with a parametric method (*t* test) or with a nonparametric method (Mann-Whitney *U* test). All comparisons were statistically significant and ended up with $P < 0.020$ (Table 3).

No effect concerning the type of operation on piritramid was found, for PLIF 1 the mean was 0.292 mg/kg

TABLE 2. Range, Mean and SD of Age, Height, Weight, BMI, and Piritramid by Group

		Treatment Group			*P*
	All (n = 38)	A (n = 13)	B (n = 14)	C (n = 11)	(ANOVA)
Age (y)					
Range	37-82	37-77	48-82	47-79	
Mean (± SD)	60.9 (± 11.3)	56.9 (± 12.3)	61.2 (± 10.5)	65.4 (± 10.4)	NS (0.194)
Height (m)					
Range	1.58-1.88	1.58-1.82	1.58-1.88	1.60-1.78	
Mean (± SD)	1.70 (0.08)	1.69 (± 0.08)	1.69 (± 0.10)	1.70 (± 0.07)	NS (0.920)
Weight (kg)					
Range	59-113	59-113	65-100	63-107	
Mean (± SD)	79.7 (± 11.9)	79.7 (± 12.8)	80.2 (± 10.8)	78.9 (± 13.3)	NS (0.966)
BMI					
Range	21.2-35.7	21.2-35.7	23.3-35.4	21.6-33.8	
Mean (± SD)	27.7 (± 3.9)	27.8 (± 4.0)	28.2 (± 4.0)	27.1 (± 3.9)	NS (0.804)
Piritramid (total) (mg/kg)					
Range	0.060-1.000	0.10-0.27	0.060-0.360	0.440-1.000	
Mean (± SD)	0.304 (± 0.208)	0.158 (± 0.051)	0.221 (± 0.066)	0.583 (± 0.167)	< 0.0005

ANOVA indicates analysis of variance; BMI, body mass index; NS, not significant.

TABLE 3. Pairwise Comparisons of Piritramid (Total)

	Assuming Normal Distribution *t* Test	Not Assuming Normal Distribution Mann-Whitney *U* Test
Group A versus B	$P = 0.011$	$P = 0.018$
Group A versus C	$P < 0.0005$	$P < 0.0005$
Group B versus C	$P < 0.0005$	$P < 0.0005$

(SD = 0.18) and for PLIF 2 the mean was 0.368 mg/kg (SD = 0.34). No significant difference was found between both the methods (*t* test: $P = 0.62$). In each group (A, B, and C) were 2 patients who underwent a fusion of 3 lumbar segments (PLIF 2).

The 3 groups do not differ significantly with respect to the length of the operation or with respect to the frequency of hypotensive phases (Tables 4, 5).

There is no correlation between the length of the operation and the total amount of piritramid neither in the group as a whole (r = 0.043, $P = 0.799$) nor when controlling for the different treatment groups (r = 0.182, $P = 0.282$). No significant difference in mean piritramid was found between patients with and without hypotensive phases (*t* test: $P = 0.81$).

DISCUSSION

Because it is not possible to design a true "control" for the electrical tapping sensation, patients were told that the investigators were studying the effect of TENS therapy on their level of pain and that they may or may not feel the tapping sensation produced by the TENS device. The single-blind, sham controlled study design should have minimized the impact of patient bias on the study results.[1] Although a double-blind study design would have been preferable, the investigator bias was minimized by using only objective data in the statistical analyses. This contradicts studies, which have suggested that the analgesic effect of TENS therapy represents a pure placebo effect.[9,10]

Although the precise mechanism of action of TENS is not clarified several different modes of action were investigated. The gate theory of pain argues that stimulation of large diameter, myelinated A-β nerve fibers, which have a low threshold for stimulation by electrical current, can modify pain recognition in the substantia gelatinosa. Thereby the transmission of painful stimuli through the smaller diameter A-δ and C fibers is decreased.[11] Han et al[12] reported that electrical stimulation produced release of met-enkephalin and dynorphins into the spinal fluid and assumed a synergistic effect with exogenously administered opioid analgesics. Electroacupuncture decreases the content of the neurotransmitters, glutamate and aspartic acid, in the dorsal root ganglion and in the spinal cord in rat.[13] DeSantana et al[14] hypothesized that the analgesic effect of TENS in rat is caused by the activation of the ventrolateral periaqueductal grey, which sends projections through the rostral ventromedial medulla to the spinal cord to produce an opioid-mediated analgesia.

The use of high-intensity stimulation (10 to 15 mA) was well tolerated. This may enhance the opioid sparing effect of TENS, as it was shown by Wang et al[2] in transcutaneous acupoint stimulation.

This study proofs the opioid sparing effect of TENS on postoperative pain treatment after major spinal surgery.

The efficacy of TENS therapy is influenced by the anatomic site of operation. Posterior lumbar interbody fusion causes cutaneous, movement-associated incisional pain but no "deep" visceral pain.[15]

Beyond this, the effectiveness of preincisional electroacupuncture in reducing opioid requirements has been shown.[16,17] On the one hand, preincicsional TENS might produce differential effects on the production of pain-producing substances (eg, substance *P*, potassium, hydrogen ions, lactic acid, and bradykinin) immediately before skin incision. On the other hand, preincisional TENS influences the conductance of painful stimuli via κ-receptors by producing ir-dynorphin A.[18] We assume that both effects influence pain memory and contribute to the reduction of postoperative demand on piritramid. Concerning the reduction of rescue analgesics caused by TENS, our study shows results similar to Dawood and Ramos's[19] findings, who proofed an ibuprofen sparing effect of TENS in treating primary dysmenorrhea.

A beneficial effect of intraoperative transcutaneous electroacupoint stimulation on preventing postoperative nausea and vomiting has been found out in a recent study.[20] Relating to this further studies will be necessary to elucidate a possible effect of additional intraoperative TENS therapy on postoperative analgesic demand.

In conclusion, the use of TENS before skin incision and postoperative is noninvasive, safe, simple, and free of systemic side effects in postoperative pain treatment after major spinal surgery.

TABLE 4. Length of the Operation by Group

		Treatment Group			*P*
	All (n = 38)	A (n = 13)	B (n = 14)	C (n = 11)	(ANOVA)
Length of operation (min)					
Range	82-225	88-179	96-225	82-173	0.323 (NS)
Mean (± SD)	133.9 (± 31.5)	123.3 (± 25.6)	141.1 (± 37,5)	137.2 (± 28.9)	

ANOVA indicates analysis of variance; NS, not significant.

TABLE 5. Hypotensive Phases by Group

	All Patients (n = 38)		Treatment Group			
	N	%	A (n = 13)	B (n = 14)	C (n = 11)	*P*
Hypotensive phases						
No	32	84.2	12	11	9	0.642 (NS)
Blood pressure systolic between 71 and 80 mm Hg						
Yes	6	15.8	1	3	2	

NS indicates not significant.

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