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Original Article

Effect of electrode attachment location for transcutaneous electrical nerve stimulation for pain relief in lumbar vertebral body fractures

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Abstract. [Purpose] This study aimed to investigate the effect of the location of electrode attachment in transcutaneous electrical nerve stimulation on pain relief in patients with lumbar vertebral body fractures. [Participants and Methods] This study included 59 patients with lumbar vertebral body fractures, who were randomly assigned to receive transcutaneous electrical nerve stimulation to the lumbar region, lower limbs, or upper limbs, or no treatment, over a 4-week period. Pain, activities of daily living, and pain catastrophizing were assessed. [Results] Compared with the control group, transcutaneous electrical nerve stimulation to the lumbar region or lower limbs significantly reduced pain levels in the first 2 weeks. Although, activities of daily living and pain catastrophizing improved over time, no significant differences were observed between the groups. [Conclusion] Transcutaneous electrical nerve stimulation provides pain relief to patients during the early stages of lumbar vertebral body fractures. However, it had no effect on the activities of daily living, pain catastrophizing, or long-term pain-relief. For lumbar vertebral body fracture pain relief, transcutaneous electrical nerve stimulation electrodes should be attached to the lumbar region or lower limbs.

Key words: Lumbar vertebral body fracture, Pain relief, Transcutaneous electrical nerve stimulation

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INTRODUCTION

Lumbar vertebral body fractures are a common type of fracture among older individuals, and cause back pain and immobility[1)]. These fractures are typically treated conservatively with a corset; however, surgery is indicated in 11% of patients[2)]. When treated conservatively, resting promotes bone fusion and relieves pain, but also causes immobility-induced bone and muscle atrophy. Therefore, it is necessary to initiate physical therapy early while providing pain relief.

Transcutaneous electrical nerve stimulation (TENS) is a method of pain relief widely used in rehabilitation, as it is non-invasive and causes no adverse effects. Javed et al.[3)] reported that peripheral nerve electrical stimulation effectively relieved pain in patients with lumbar vertebral body fractures and reduced the amount of analgesic drugs required. In addition, Ikeda et al.[4)] found that TENS effectively improved walking ability and extension strength in patients with lumbar fractures. However, there are only a few reports on the effect of TENS on lumbar vertebral fracture, and methodology has not been sufficiently studied.

TENS-induced pain relief has been associated with the gate control theory[5)] and endogenous opioids[6)]. According to the gate control theory, the TENS electrode should be attached to the site of pain or the same dermatome as the sensory

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innervation of the site of pain[7]. However, because the endogenous opioid system modulates the descending pain suppression pathway through its action on the periaqueductal gray in the midbrain[8, 9], pain relief through this route should be independent of the electrode attachment site.

For lumbar vertebral body fractures, TENS electrodes are attached to the painful lumbar region. However, this makes it necessary to remove the corset, forcing the patient to perform painful movements. According to the gate control theory, attaching the TENS electrodes to the lower limbs on the same dermatome as the sensory innervation of the fractured vertebral body should produce the same pain relief as attaching the electrodes to the lumbar region. If this method is effective, TENS can be performed without removing the corset, sparing patients pain and discomfort. In addition, pain relief through the endogenous opioid pathway should be achieved with the above-mentioned electrode attachment method, or by attaching electrodes to a dermatome separate from the sensory innervation of the fractured vertebral body. However, the effectiveness of these methodologies has not been sufficiently investigated. Therefore, we investigated the effect of the TENS electrode attachment site on pain relief in patients with lumbar vertebral body fractures.

PARTICIPANTS AND METHODS

One hundred and sixteen patients admitted to our hospital for lumbar vertebral fractures and prescribed rehabilitation between July 2020 and July 2023 were considered for inclusion in this study. The exclusion criteria were as follows: (1) cognitive disturbance; (2) hearing, visual, or speech impairment; (3) assisted walking; (4) neurological diseases; (5) contraindications for electrical stimulation; (6) prior TENS use; (7) new fractures of multiple vertebrae; (8) no pain; and (9) neuropathic pain. Ultimately, 57 patients were excluded and the remaining 59 were enrolled in the study. The study was conducted in accordance with the principles outlined in the Declaration of Helsinki and was approved by the Ethics Committee of Hirosaki University's Graduate School of Health Sciences (Approval No. 2020-028). The study was explained to all participants, and each participant provided informed consent to participate in the study. The personal information of the participants was carefully protected.

The intervention period in this study began on the first day the patient got out of bed and ended at the fourth week after getting out of bed. The day to start getting out of bed was when the corset was completed and the doctor gave permission. If the patient was discharged before the four-week endpoint, the date of discharge was treated as the end of the intervention. Patients were allocated via the lottery method into the following four groups: (1) lumbar group, in which TENS was performed on the painful lumbar region; (2) lower limbs group, in which TENS was performed on both lower limbs on the same dermatome as the sensory innervation of the fractured vertebral body; (3) upper limbs group, in which TENS was performed on both upper limbs away from the painful lumbar region; and (4) control group, in which no TENS was performed. The upper limbs were selected because this site would not hinder the implementation of physical therapy, which often involves the movement of the lower limbs. TENS was administered concurrently with the physical therapy program for 60 min a day, five days a week. Standard physical therapy was performed in all groups.

An electrotherapy device (ESPURGE, ITO Co., Ltd., Tokyo, Japan) was used to perform TENS, with a frequency of 1–200 Hz and a pulse duration of 200 μs. The stimulus intensity was set at the sensory level that did not cause muscle contraction to ensure that it did not interfere with movement. Two pairs of adhesive PALS® electrodes (Axelgaard Manufacturing Co., Ltd., Fallbrook, CA, USA) were positioned, on the painful lumbar area in the lumbar group, on the lower limbs of the same dermatome in the lower limbs group, and on both upper arms in the upper limbs group. No electrodes were attached in the control group.

We measured three indices: pain, activities of daily living (ADL), and pain catastrophizing. The reason for including ADL and PCS in the evaluation indices was that if appropriate pain relief was achieved, it will influence ADL and pain catastrophizing, which will allow the patient to return to society sooner. Evaluations of pain and ADL were performed on the first day out of bed, and at the first, second, third, and fourth week afterward; pain catastrophizing was assessed at the first and last of these time points. Pain intensity was evaluated four times at each of these time points: before the start of TENS, 5 min after the start of TENS, 30 min after the start of TENS, and 30 min after the end of TENS. At each evaluation, participants were asked to quantify their pain during rising using a numerical rating scale (NRS) from 0 (no pain at all) to 10 (the worst pain imaginable). In the control group, evaluation was performed at three-time points: an arbitrary time and 30 and 90 min afterwards. The Functional Independence Measure (FIM) was used to evaluate ADL. Evaluations were performed by the attending physical therapist and nurse. Pain catastrophizing was assessed by patient self-reporting using the Pain Catastrophizing Scale (PCS).

The amount of change in NRS score was calculated at each time point in each group, with the baseline set at before the start of TENS. Split-plot analysis of variance (ANOVA) was performed on the amount of change in NRS score for each time point. When sphericity was not assumed, a Greenhouse–Geiser ε correction was performed. If the main effects or interactions were significant, a Shaffer t-test was performed. FIM and PCS were analyzed using Split-plot ANOVA with assessment date as a repeated measures factor. All statistical analyses were performed using modified R Commander 4.3.3, and the threshold for significance was set at $p=0.05$.

RESULTS

Of the 59 participants, one was lost to follow-up after contracting coronavirus disease 2019. Thus, 58 participants completed the study. The characteristics of the participants in each group are shown in Table 1.

Table 2 presents the mean and standard deviation (SD) of the change in NRS score from baseline at each evaluation time point in each group. The results of the ANOVA for the amount of change in NRS score showed that the main effects of group and repeated measures factors were significant, and the interactions were also significant by the third week. By the fourth week, only the main effect of repeated measurements was observed. On the first day out of bed, the NRS score was lower

Table 1. Characteristics of the patients in each group

	Lumber group	Lower limbs group	Upper limbs group	Control group
Number of patients	15	14	14	15
Sex, n				
Female	9	10	11	12
Male	6	4	3	3
Age, years	75.7 ± 8.8	80.7 ± 7.6	81.7 ± 5.4	75.9 ± 8.0
Fractured vertebra, n				
L1	8	6	6	7
L2	4	3	4	6
L3	2	4	2	2
L4	1	1	1	0
L5	0	0	1	0
Fracture style, n				
Compression	10	10	10	11
Burst	5	4	4	4

Age data are expressed as mean ± standard deviation.

Table 2. Changes in Numerical Rating Scale score compared with baseline

	Lumber group	Lower limbs group	Upper limbs group	Control group
First day				
After 5 min	−1.53 ± 1.68**$$##$	−0.93 ± 1.00**	−0.36 ± 0.50	0.00 ± 0.00
After 30 min	−1.33 ± 1.91$	−1.71 ± 1.38**$$	−0.93 ± 0.73**	−0.13 ± 0.35
After 90 min	−1.27 ± 1.53**$$	−1.64 ± 1.28**$$#	−0.36 ± 0.50	−0.13 ± 0.35
First week				
After 5 min	−1.14 ± 0.77**$$#	−1.29 ± 1.20**$$##	−0.36 ± 0.84	0.00 ± 0.00
After 30 min	−1.14 ± 1.10**$$	−1.79 ± 0.97**$$##	−0.50 ± 0.65	0.00 ± 0.00
After 90 min	−1.14 ± 0.66**$$##	−1.07 ± 1.14**$$##	−0.36 ± 0.50	0.00 ± 0.00
Second week				
After 5 min	−1.07 ± 0.83**$$##	−0.85 ± 0.38**$$##	−0.23 ± 0.44	0.00 ± 0.00
After 30 min	−1.14 ± 0.95**$$##	−0.85 ± 0.55**$$	−0.30 ± 0.48	0.00 ± 0.00
After 90 min	−0.93 ± 0.73**$$##	−0.77 ± 0.60**$$	−0.30 ± 0.48	0.00 ± 0.00
Third week				
After 5 min	−0.27 ± 0.47	−0.71 ± 1.14	0.00 ± 0.00	0.00 ± 0.00
After 30 min	−0.55 ± 0.69	−0.64 ± 1.15	0.00 ± 0.00	0.00 ± 0.00
After 90 min	−0.45 ± 0.52	−0.57 ± 0.94	0.00 ± 0.00	0.00 ± 0.00
Fourth week				
After 5 min	−0.44 ± 0.73	−0.36 ± 0.50	0.00 ± 0.00	0.00 ± 0.00
After 30 min	−0.56 ± 0.73	−0.36 ± 0.50	−0.13 ± 0.35	0.00 ± 0.00
After 90 min	−0.44 ± 0.53	−0.27 ± 0.47	−0.13 ± 0.35	0.00 ± 0.00

Data are expressed as mean ± standard deviation. *p<0.05, **p<0.01 vs. baseline in the same group; $p<0.05, $$p<0.01 vs. control group at the same time; #p<0.05, ##p<0.01 vs. upper limbs group at the same time.

in the lumbar group compared with the upper limb and control groups at 5 mins. At 30 mins, NRS scores were lower in the lumbar and lower limbs groups compared with the control group. At 90 mins, for the repeated measures factor, the NRS score in the lumbar group was lower at 5 and 90 mins compared to baseline. The NRS score in the lower limbs group was lower at 5, 30, and 90 mins compared to baseline. The NRS score of the upper limbs group was lower at 30 mins compared to baseline. In the first week, NRS scores were lower in the lumbar and lower limbs groups than compared with the upper limbs and control groups at 5 mins. At 30 mins, the NRS score was lower in the Lumbar group compared with the control group, and lower in the lower limbs than upper limbs and control groups. At 90 mins, NRS scores were lower in the lumbar and lower limbs groups compared with the upper limbs and control groups. For the repeated measures factor, the NRS score in the lumbar group was lower at 5, 30, and 90 mins compared to baseline. The NRS score in the lower limbs group was lower at 5, 30, and 90 mins compared to baseline. In the second week, NRS scores were lower in the lumbar and lower limbs groups compared with the upper limbs and control groups at 5 mins. At 30 and 90 mins, NRS scores were lower in the lumbar and lower limbs groups compared with the upper limbs and control groups. For the repeated measures factor, NRS scores in the lumbar and lower limbs groups were reduced at 5, 30, and 90 mins compared to baseline. In the third week, no differences were observed between groups and in the repeated measures.

Table 3 presents the mean and SD of the FIM scores on each evaluation day for each group and all participants. The results of the ANOVA for the FIM score showed that only the main effect of repeated measurements was observed.

Finally, Table 4 presents the mean and SD of the PCS scores before and after the four-week intervention period. The results of the ANOVA for the PCS score showed that only the main effect of repeated measurements was observed.

DISCUSSION

In the present study, we investigated the effect of TENS electrode placement on pain caused by lumbar vertebral body fractures. Our findings indicated that when the TENS electrodes were attached to the lumbar region or the lower limbs, significant pain relief was achieved until the second week after getting out of bed. TENS can selectively activate large-diameter A-β nerve fibers, and inhibit ongoing transmission of pain information in the spinal cord; this mechanism is known as the gate control theory[7, 10]. This theory explains the pain-relieving effect in the lumbar and lower limbs groups. In the upper limbs group, pain-relieving effect was observed only 30 mins after in first day, which can be explained by endogenous opioids. However, no pain-relieving effect was observed in the upper limbs group at other times, and the lumbar and lower limbs groups often had better pain-relieving effect than the upper limbs group. Therefore, the gate control theory may make a larger contribution to the pain-relieving effects of TENS. Diffuse Noxious Inhibitory Control (DNIC) was also considered as a possible mechanism of pain relief in the upper limbs group; however, the TENS stimulation intensity in this study was set at the sensory level, which may not have provided enough stimulation to induce DNIC[11]. A carryover effect was observed in the lumbar and lower limb groups. TENS causes long-term depression of pain transmission[12], possibly through changes in synaptic transmission efficiency, which affects the intraspinal pain-relieving system.

Venmans et al.[13] reported that 60% of patients with vertebral fractures achieved sufficient pain relief with conservative therapy within three months of injury. Similarly, we showed that pain decreased over time regardless of TENS performance, so that no differences in pain scores were observed after the third week. However, we do not believe that the significant differences in the results of the lumbar and lower limbs groups compared to the control group up to the second week, were due to natural healing or the effect of analgesics. The FIM and PCS results showed improvements over time in each group, but no differences were observed among the groups. Therefore, the differences in pain scores between the groups did not translate into differences in ADL or pain catastrophizing.

Table 3. Functional Independence Measure scores

	First day	First week	Second week	Third week	Fourth week
Lumber	63.1 ± 14.6	82.0 ± 17.3	94.0 ± 18.4	103.3 ± 16.5	109.2 ± 15.5
Lower limbs	60.1 ± 8.5	77.2 ± 14.5	85.8 ± 16.9	94.3 ± 15.5	100.6 ± 13.1
Upper limbs	56.8 ± 1.8	68.1 ± 5.0	76.8 ± 8.8	86.4 ± 8.9	97.1 ± 7.7
Control	65.0 ± 12.3	78.0 ± 20.3	87.1 ± 17.8	95.0 ± 17.2	102.4 ± 15.5

Table 4. Pain Catastrophizing Scale scores

	First day	Fouth week
Lumber	24.5 ± 11.5	14.5 ± 10.1
Lower limbs	21.1 ± 10.7	14.6 ± 11.4
Upper limbs	24.7 ± 12.3	17.6 ± 9.3
Control	23.1 ± 12.2	14.1 ± 13.2

This study has several limitations. First, the sample size was relatively small, and we included all types of lumbar vertebral body fractures; however, there may be differences in the effectiveness of TENS between compression and burst fractures. Second, we did not record the levels of analgesic drugs used by the participants. Finally, the sensory level was used for TENS in this study; however, the motor level has been reported to have greater pain-relieving effects[7, 10].

The results of this study show that TENS applied through electrodes attached to the lumbar region and lower limbs on the same dermatome as the sensory innervation of the fractured vertebral body provides effective pain relief in the early stages after lumbar vertebral body fractures. However, it had no impact on ADL and pain catastrophizing, and exhibited no long-term effects. There was no significant difference between electrodes placed on the lumbar region and the lower limbs in terms of the levels of pain relief achieved in the early stages after injury. These results suggest that for effective relief from pain caused by lumbar vertebral body fractures, TENS electrodes should be attached to either the lumbar region or lower limbs.

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Conflict of interest

None.

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