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Case Study

Transcutaneous electrical nerve stimulation effects on patients with subacute vertebral fracture: a case report using an ABAB study design

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Abstract. [Purpose] This study investigated the effects of transcutaneous electrical nerve stimulation on trunk extension muscle strength, walking ability, and the Japanese Orthopedic Association Back Pain Evaluation Questionnaire items of gait disturbance in one case of a subacute osteoporotic vertebral fracture. [Participant and Methods] An 88-year-old female with the first and third lumbar vertebral fractures underwent standard physical therapy (A1 and A2 phases) and transcutaneous electrical nerve stimulation to the sclerotome region of the fractured vertebra (B1 and B2 phases). Assessments were performed before the A1 phase and the day after each phase. Assessment items included the Visual Analog Scale scores for pain during rest, getting up, standing up, and walking; isometric trunk extension muscle strength; walking ability (10-meter walking, continuous walking distance); and the Japanese Orthopedic Association Back Pain Evaluation Questionnaire items. [Results] Even though the pain intensity did not change, isometric trunk extension muscle strength, continuous walking distance, and the Japanese Orthopedic Association Back Pain Evaluation Questionnaire items of gait disturbance were improved in phase B compared to phase A. [Conclusion] Standard physical therapy and transcutaneous electrical nerve stimulation to the sclerotome area may improve trunk extension muscle strength, walking ability, and the Japanese Orthopedic Association Back Pain Evaluation Questionnaire items of gait disturbance in patients with subacute osteoporotic vertebral fractures.

Key words: Transcutaneous electrical nerve stimulation, Subacute, Vertebral fracture

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INTRODUCTION

Osteoporotic vertebral fractures (OVFs) may cause prolonged back pain, spinal deformity due to vertebral body compression, functional disability, decreased quality of life, adjacent vertebral fractures, and increased short- and long-term mortality[1)]. OVFs have a reported prevalence of 30% or more in persons aged 65 years or older and are associated with an increase in serious illnesses and significant health problems worldwide[2)]. In Japan, OVF occurs in many older patients as proximal humerus fractures, proximal femur fractures, and distal radius fractures. While surgical treatment is the first choice

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of treatment for upper and lower extremity fractures, conservative treatment is the first choice for the management of OVF, except in cases of severe neuropathy or pain. We encounter many cases of OVF in our hospital daily, which are resolved with physical therapy and pain management. The treatment strategies for OVF include percutaneous vertebroplasty, nerve blocks, and conservative treatment[1]. Longo et al. reported that conservative treatment of OVF includes rest, brace, analgesic medication, and physical therapy, but the optimal management in the acute phase of OVF conservative treatment has not yet been defined[3].

Electrophysical agents can be used in combination with exercise therapy or as a primary intervention. Transcutaneous electrical nerve stimulation (TENS) is a non-pharmacologic intervention used clinically for acute and chronic analgesia[4].

The analgesic mechanisms of TENS include intraspinal pain suppression based on the gate control theory[5], endogenous opioid release[6, 7], and descending pain suppression[7]; its effectiveness is influenced by the patient's tolerance to electrical stimulation, stimulation intensity, and electrode placement. TENS has been shown to elevate opioids in the cerebrospinal cord and improve high analgesia and tolerance when modulated at lower to higher frequencies than at specific frequencies[8, 9]. Previous studies have reported the use of TENS for pain management of acute and chronic musculoskeletal pain[10, 11], neuropathic pain[12], and internal disorders[13], and its efficacy for osteoarthritis of the knee[14], shoulder disorders[15, 16], post-operative diseases of the hip joint[17] and other bone and joint disorders has been reported in Japan. On the other hand, in lumbar diseases, there are many reports on non-fractured acute and chronic patients[4, 18], and the effect on OVF, which is frequently experienced in clinical practice, has not been reported[19]. OVF pain is reported to be caused by shear stress on the bony beams due to the progressive crushing of the fractured vertebra, which stimulates the periosteum[20]. However, in studies on lumbar diseases, Inman et al.[21] reported the presence of the sclerotome as a medullary node of bone, and the effect of TENS with reference to the sclerotome has already been verified in patients with knee osteoarthritis[13] and postoperative hip disease[16]. Therefore, TENS should be performed in the area referring to the medullary nodes of the fractured vertebral body when the pain site also coincides with the sclerotome area for OVF. However, the effect of TENS on the sclerotome area after OVF is unclear as far as wading is concerned. The importance of exercise therapy for OVF has been reported. Although the importance of TENS for OVF has been reported, we believe clarifying the effects of TENS for acute illness and the combined intervention of exercise therapy and TENS regarding the sclerotome could be a useful tool for pain management to make exercise therapy more effective in the subacute phase when activity levels increase. This study, therefore, aimed to determine the effect of a combined intervention of standard exercise therapy and sclerotome-referenced TENS on a patient with OVF in the subacute phase.

PARTICIPANT AND METHODS

An 88-year-old female patient (height 149 cm, weight 49.0 kg) diagnosed with fractures of the first and third lumbar vertebrae was admitted to the orthopedics department of our hospital due to increased back pain. The patient's history consisted of an open osteosynthesis for a left femoral transverse fracture and an open osteosynthesis for a left distal radius fracture two and three years before admission, respectively. Socially, the patient was living with her son in an apartment. Before admission, the patient's activities of daily living (ADL) were as follows: fully independent in self-care, independent in-home ambulation, and ambulation with a T-cane outside the home with supervision. Two months before admission, the patient developed low back pain with no clear injury mechanism, but she could live at home with the use of a soft brace.

The patient's main complaints on admission were "I have difficulty getting up because of back pain" and "My back hurts when I walk for a long time". Her goals following treatment were "I want to be able to walk outside without feeling pain as before" and "I want to be able to do things by myself at home". At the time of the initial evaluation, the patient scored 30/30 on Hasegawa's Dementia Scale-Revised and 109 points (74 motor and 35 cognitive) on the Functional Independence Measure (FIM). Based on the results of X-ray and magnetic resonance imaging (MRI) examinations, the patient was diagnosed with fresh vertebral fractures of the first and third lumbar vertebrae and was admitted to the general ward in a wheelchair 19 days later. On the day of admission, the patient was allowed to move from the bed with a rigid brace, and physical therapy was initiated. On the 13th hospital day, the patient was transferred from the general ward to the community comprehensive ward, and on the 61st day, the patient was discharged home with a T-cane. The physical therapy intervention was performed 40 minutes a day for seven days each week while in the general ward and 60 minutes a day for six days each week after transfer to the community comprehensive ward. The patient did not receive any outpatient physiotherapy after discharge. Interventions focused on gait practice, trunk extension muscle strengthening, and ADL activities in response to pain. Trunk extension muscle strengthening was performed in the standing position using a Thera-Band, based on a report by Akabane et al[22]. For analgesia, the patient was prescribed Celecoxib (100 mg twice a day) on day 0, but the prescription was terminated on day 12. Contraindications during hospitalization included wearing a rigid brace all day, except when bathing and changing clothes, and active movements involving joint movements of the spinal column. This study was conducted with the approval of the Ethics Committee of the author's institution (Approval No. 22-7). The participant provided oral and written informed consent to participate in the study. Permission to perform TENS was obtained from the attending physician.

This single-case study utilized an ABAB research design. The basic level phases (A1 and A2) consisted of standard physical therapy (gait practice, strengthening of trunk extensor muscles, and ADL practice) only, and the operation introduction phases (B1 and B2) consisted of standard physical therapy and TENS. Each phase took place over one week. The TENS pulse

width was set to 100 μs, and the intensity was set at the maximum amount of current that did not induce pain or discomfort. The frequency was modulated from 1 to 250 Hz to prevent adaptation to TENS and to release various opioids. The duration of stimulation was 40 minutes, and standard physical therapy was administered simultaneously. The pain was located around the fracture site but was interpreted as pain of bony origin because tenderness of the fractured vertebral body's erector spinae was observed without tenderness of the lumbar erector spinae muscle group. Therefore, we referred to the sclerotome, a periosteal medullary node, and affixed a 2-channel electrode to sandwich the first and third lumbar vertebrae.

The main outcome was the Visual Analog Scale (VAS) scores for pain (resting supine position, getting up, standing, and walking). The secondary outcomes were isometric trunk extension muscle strength, walking ability (10 m walking speed and continuous walking distance), and the Japanese Orthopedic Association Back Pain Questionnaire (JOABPEQ) for low back pain specific patient-reported outcomes, which provides patients' reports of their introspection during the implementation of TENS were considered. Isometric trunk extension muscle strength was measured using a handheld dynamometer (μTas F-1, Anima Corp., Tokyo, Japan) based on the method of Endo et al[23]. The continuous walking distance was measured using a horseshoe walker in a straight corridor of the ward with a round-trip distance of 50 m and was terminated when general fatigue reached a modified Borg Scale score of 5. The 10 m walking speed was measured within a 3-m start and end interval. The five severity scores on the JOABPEQ ranged from 0 to 100 points, with higher values indicating a better condition[24, 25]. The initial assessment (pre-A1) was conducted before the A1 phase, and subsequent assessments were conducted the day after each of the A1, B1, A2, and B2 phases, for a total of five measurements. Reports of reflection during physical therapy were obtained as needed. All interventions, measurements, and data analysis were carried out by physiotherapists specializing in musculoskeletal physiotherapy and TENS with 7 years of experience.

RESULTS

Table 1 shows the progression of pain and physical function. After the A1 phase, the VAS scores for pain at rest and during movement (getting up, standing up, and walking) showed marked improvement of less than 10 mm, and the effect was sustained after that. The isometric trunk extension muscle strength and continuous walking distance tended to improve in phase B compared to phase A.

Table 2 shows the changes in the JOABPEQ. Factors other than social life dysfunction showed improvement after period A1 compared to before period A1, followed by improvement over time for psychological disorders. Gait disturbance tended to improve in period B. No adverse events due to electrical stimulation were observed. During the study period, the patient mainly used a horseshoe walker to move around in the ward, but during the B2 phase, the patient walked independently with a T-cane and was discharged with a rigid brace on the 61st day of the study period. The vertebral compression rate (on admission/at discharge) was 45%/83% for the first lumbar vertebra and 40%/51% for the third lumbar vertebra, and the total FIM at discharge was 123 points (88 motor, 35 cognitive).

Table 1. Progression of pain, isometric trunk extension muscle strength and gait ability

		Pre A1	A1	B1	A2	B2
Pain (VAS) (mm)	At rest	83	0	3	0	0
	Getting up	100	3	0	4	5
	Standing	43	3	4	4	0
	Gait	15	3	0	0	0
Muscle strength	Isometric trunk extension (kgf•m/kg)	6.8	6.3	9.7	8.2	9.1
Gait ability	10 m Walking Speed (m/s)	1.9	2.0	2.0	2.0	2.4
	Continual walking distance (m)	200	240	610	600	910

VAS: Visual Analog Scale.

Table 2. Progress of JOABPEQ

		Pre A1	A1	B1	A2	B2
JOABPEQ (points)	Pain-related disorders	0	57.1	57.1	28.6	28.6
	Lumbar spine dysfunction	0	41.7	41.7	41.7	41.7
	Gait disturbance	0	21.4	64.3	64.3	71.4
	Social life dysfunction	8.1	13.5	35.1	54.1	32.4
	Psychological disorders	18.4	44.7	50.5	54.4	56.3

JOABPEQ: Japanese Orthopedic Association Back Pain Questionnaire.

DISCUSSION

This study investigated the effects of TENS on trunk extension muscle strength, walking ability, and JOABPEQ in a patient with an osteoporotic subacute vertebral fracture using a single-case study ABAB design. The results showed that the VAS scores at rest, getting up, standing, and walking improved after the A1 phase compared to the pre-A1 phase, and they did not worsen until the end of the B2 phase. The isometric trunk extension muscle strength, continuous walking distance, and JOABPEQ items of gait disturbance were improved in the B phase. In other words, the patient's improvement in walking ability and gait disturbance resulted from TENS rather than the passage of time.

The improvement in VAS scores at rest and during movement after the A1 phase may be due to an increase in bed rest time due to hospitalization, external fixation with a rigid brace, or the effect of physical therapy under pain management. Based on the pre-A1 evaluation, the pain in this case was determined to originate from the periosteum. Reportedly, following vertebral fractures, progressive compression of the vertebral body results in shear stress on the bony beams, which stimulates the periosteum and induces osseous pain[20]. The rigid brace prescribed after admission was a frame-type thoracolumbar orthosis, which is considered the best orthosis for managing severe vertebral fractures[26]. The patient had been fitted with a soft lumbosacral orthosis before hospitalization, and we believe that the change to a rigid brace resulted in firm trunk bracing. The change of walking aid from a T-cane to a horseshoe walker was also considered to have reduced the compressive and shear load on the fracture. However, during TENS, the patient stated, "It doesn't hurt so much because my back is shaking", and "I think I can exercise a little more". TENS intervention using sclerotome in patients with knee osteoarthritis and postoperative proximal femur fracture has shown a high analgesic effect[13, 16], and it is expected that the same analgesic effect was obtained in the present case. During hospitalization, physiotherapy focused on strengthening trunk extension muscles in the standing position and gait practice with a walking aid according to pain level, and the VAS of walking pain during TENS showed an immediate effect from 50 mm to 20 mm. The reason the pain did not worsen from the A1 to the B2 phase is thought to be that the frequency modulation did not cause analgesic tolerance to TENS[8, 9] and that incremental physical therapy could be developed while maintaining a high analgesic effect. The progression of kyphosis deformity with the progression of vertebral body compression can cause secondary compartment syndrome during exercise[20]. Furthermore, walking distance has been reported to be related to depression, life satisfaction, and self-esteem[27], and we believe that the improvement in "mobility" and "self-care", which were the patient's hopes, influenced the psychological improvement. Therefore, the simultaneous implementation of TENS and exercise therapy, in addition to external fixation with a rigid brace and the selection of appropriate walking aids, may have prevented exacerbation of pain during and after exercise therapy and thus contributed to effective exercise therapy with a higher exercise load.

There are three limitations of this study. First, we could not measure changes in gait or muscle activity of the erector spinae during TENS. Second, this study was based on a single case; hence, the results may differ depending on the TENS parameter settings, age, fracture type, and ADL level before admission. Third, the results were biased due to the lack of blinding in intervention and measurement. Future perspectives should include the need to clarify the effects of TENS in combination with analgesia and exercise therapy in cases of vertebral fractures, which are under-reported, and the assessment of the standing posture of patients with low back pain in intervention studies, such as double blind randomized controlled trials. Furthermore, the number of cases needs to be increased and the long-term effects clarified.

In conclusion, the purpose of this study was to clarify the effects of TENS interventions on the sclerotome area combined with standard physical therapy on the physical function of a patient with a subacute osteoporotic vertebral fracture who had worsening back pain after a vertebral fracture. The results suggest that this combined approach may positively affect isometric trunk extension muscle strength and gait ability. We believe TENS can easily and effectively improve patients' physical function and quality of life when used in combination with standard physiotherapy. We will continue accumulating cases and verifying the effectiveness of the combined intervention of exercise therapy and TENS in patients with vertebral fractures.

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There are no conflicts of interest, financial or otherwise to disclose in this study.

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