

Comparison of Percutaneous Electrical Nerve Stimulation with Transcutaneous Electrical Nerve Stimulation for Long-Term Pain Relief in Patients with Chronic Low Back Pain

Masataka Yokoyama, MD, Xiaohui Sun, MD, Satoru Oku, MD, Naoyuki Taga, MD, Kenji Sato, MD, Satoshi Mizobuchi, MD, Toru Takahashi, MD, and Kiyoshi Morita, MD

Department of Anesthesiology and Resuscitology, Okayama University Medical School, Okayama City, Japan

The long-term effect of percutaneous electrical nerve stimulation (PENS) on chronic low back pain (LBP) is unclear. We evaluated the number of sessions for which PENS should be performed to alleviate chronic LBP and how long analgesia is sustained. Patients underwent treatment on a twice-weekly schedule for 8 wk. Group A ($n = 18$) received PENS for 8 wk, group B ($n = 17$) received PENS for the first 4 wk and transcutaneous electrical nerve stimulation (TENS) for the second 4 wk, and group C ($n = 18$) received TENS for 8 wk. Pain level, degree of physical impairment, and the daily intake of nonsteroidal antiinflammatory drugs (NSAIDs) were assessed before the first treatment, 3 days after Week 2, Week 4, and Week 8 treatments, and at 1 and 2

mo after the sessions. During PENS therapy, the pain level decreased significantly from Week 2 in Groups A and B ($P < 0.05$ or 0.01), and physical impairment and required NSAIDs decreased significantly from Week 4 ($P < 0.05$ or 0.01) in Group A but only at Week 4 in Group B ($P < 0.05$ or 0.01). These effects were sustained until 1-mo follow-up ($P < 0.01$) in Group A but not in Group B; these effects were not observed at 2-mo follow-up even in Group A. In Group C, pain level decreased significantly only at Week 8 ($P < 0.05$). Our results indicate that repeated PENS is more effective than TENS for chronic LBP but must be continued to sustain the analgesic effect.

(Anesth Analg 2004;98:1552–6)

Low back pain (LBP) is one of the most common medical and social problems. Although pharmacologic analgesic therapies may be effective for patients with acute LBP, they are unsatisfactory for many patients. The use of pharmacologic therapy can interfere with physical activity and produce side effects (1). These concerns have increased interest in nonpharmacologic therapies for LBP, such as transcutaneous electrical nerve stimulation (TENS) (2), electroacupuncture (3), and percutaneous electrical nerve stimulation (PENS) (4–6). Among these, PENS is now attracting attention as a novel, electroanalgesic therapy. PENS combines the advantages of TENS and electroacupuncture (6).

Several clinical reports document that PENS is effective in relieving several kinds of pain, including

LBP (4–10). Although PENS has been shown to produce short-term benefits in chronic LBP treatment (4–6), its long-term effectiveness is unclear. The number of treatment sessions and the period of treatment required to sustain analgesia after therapy are also unclear. Most investigators performed PENS three times a week for 2 or 3 wk in studies that failed to show a sustained analgesic effect after the PENS treatments (4–6). If PENS treatments are performed more often or for a longer period, the analgesic effect may continue after the discontinuation of therapy. The purpose of this study was to assess the effectiveness of PENS as treatment for chronic LBP, evaluate the effects of different numbers of PENS sessions on pain relief, and determine the length of time the analgesic effect is sustained. We also included a control group receiving TENS therapy.

Methods

IRB and ethics committee approval were obtained for this study, and all participants gave informed consent. Sixty patients were enrolled who reported having LBP for more than 6 mo and who reported peak pain

Accepted for publication November 26, 2003.

Address correspondence and reprint requests to Masataka Yokoyama, MD, Department of Anesthesiology and Resuscitology, Okayama University Medical School, 2-5-1 Shikata-cho, Okayama City, Okayama 700-8558, Japan. Address e-mail to masayoko@cc.okayama-u.ac.jp.

DOI: 10.1213/01.ANE.0000112312.94043.DF

intensity of more than 40 on a visual analog scale (VAS; 0–100, where 0 is no pain and 100 is the worst pain ever). Their pain intensity had been maintained at a stable level with oral nonsteroidal antiinflammatory drugs (NSAIDs) for at least 3 mo before enrollment in the study. These patients had never received PENS treatment but had received nerve blocks, NSAIDs, and physical therapy. At the time of the study, nerve blocks and physical therapy were discontinued, but patients were allowed to continue NSAIDs as desired during the study. Patients with the following conditions were excluded: pregnancy, osteomyelitis of the spine, discitis, tumor, ankylosing spondylitis, recent vertebral fracture, structural scoliosis, or previous low back surgery.

Patients were randomly assigned to one of three groups and underwent treatment on a twice-weekly schedule for 8 wk (16 sessions). Group A ($n = 20$) received PENS for 8 wk, Group B ($n = 20$) received PENS for the first 4 wk and TENS for the second 4 wk, and Group C ($n = 20$) received TENS for 8 wk. The sessions were conducted between 9 AM and 12 PM. PENS therapy was performed basically according to previous reports (4–6) because the response to PENS is influenced by the location (11), frequency (5), and duration (6) of electrical stimulation. Basic therapy consisted of the placement of 10 32-gauge (0.2-mm) stainless steel acupuncture-like needle probes (ITO, Tokyo, Japan) into the soft tissue or muscle in the low back region to a depth of 2–4 cm according to the dermatomal distribution of the pain. The needle probes were connected to five bipolar leads (with each lead connected to one positive and one negative probe) from a low-output electrical generator, which was calibrated before each series of treatments. The electrical current was DC, and the duty cycle was continuous. These probes were then stimulated at 4/30 Hz for 20 min. The intensity of the electrical stimulation was adjusted to produce the most intense tolerable electrical sensation without muscle contractions. Standard TENS therapy consisted of the placement of 4 medium-sized (2.5-cm) cutaneous electrode pads in a standardized dermatomal pattern. These electrodes were also stimulated at a frequency of 4/30 Hz for 20 min.

The study protocol is illustrated in Figure 1. After enrollment, the subjects underwent a 2-wk preobservation, after which treatment was started. Patients rated the peak level of pain they experienced on an assessment day by VAS (peak pain). A physician also assessed the patient's degree of impairment on a multiple-choice form. Zero to four points were awarded for the following responses: no impairment = 0; mild, not affecting most activities = 1; moderate, cannot perform some strenuous activities = 2; limited, can participate in only light activities = 3; and severely limited = 4. Pain level and degree of physical

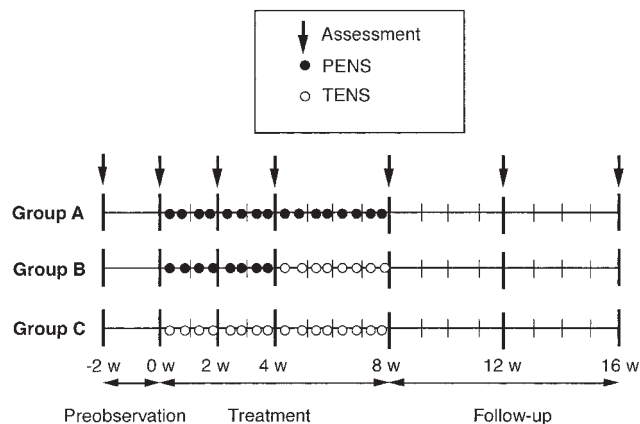


Figure 1. Study protocol.

impairment were scored, and the daily intake of oral NSAIDs (number of pills) was recorded. Assessment was performed at 2 wk before initiating the first treatment, just before the first treatment (baseline), and 3 days after Week 2, Week 4, and Week 8 treatments. Follow-up assessment in all groups was performed at 1 and 2 mo after the sessions ended.

Data are expressed as mean \pm SD. One-way analysis of variance followed by the Duncan method was used to analyze between-group differences in age and number of months patients had experienced pain. The changes in the VAS scores were analyzed using repeated-measures analysis of variance and Student's *t*-test. Physical impairment scores and daily intake of NSAIDs were analyzed by the Kruskal-Wallis test followed by the Dunn method. Differences were considered statistically significant at $P < 0.05$.

Results

Seven of the 60 patients enrolled dropped out after the study began: 2 patients in Group A, 3 patients in Group B, and 2 patients in Group C. One patient in each group dropped out because of dislike of the therapy, and the other 4 patients dropped out because of impossibility of receiving the therapy (common cold, traffic accident, and other private reasons). In subsequent analyses, these dropouts were excluded; thus, 53 patients (Group A: $n = 18$, Group B: $n = 17$, and Group C: $n = 18$) participated in this study until completion of follow-up.

The 3 patient groups were similar in male:female sex ratio (Group A: 7:11, Group B: 8:9, and Group C: 8:10), age (Group A: 60 ± 12 yr, Group B: 58 ± 14 yr, and Group C: 59 ± 13), and duration of LBP (Group A: 15 ± 7 mo, Group B: 15 ± 8 mo, and Group C: 13 ± 6 mo).

There were no differences in VAS scores of peak pain among groups at preobservation and baseline (Group A: 55 ± 11 , Group B: 56 ± 9 , and Group C: 57

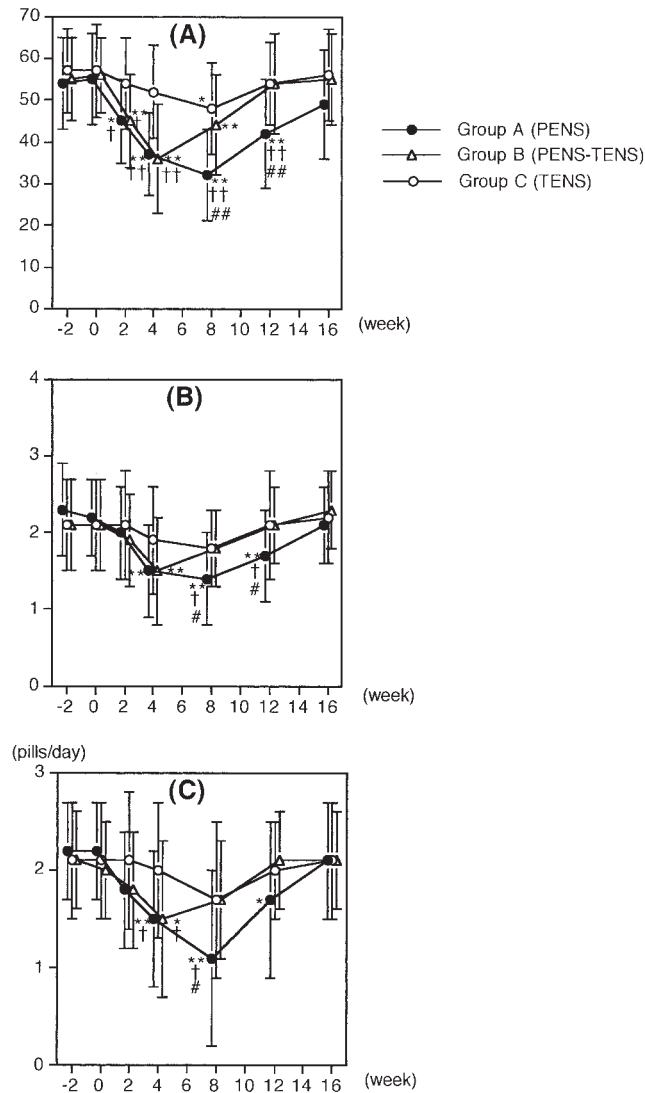


Figure 2. (A) Changes in visual analog scale (VAS: 0–100) scores of peak pain. (B) Changes in degree of physical impairment on a multiple-choice form (0 to 4 points). (C) Changes in the daily intake of oral nonsteroidal antiinflammatory drugs (number of pills). Values are mean \pm SD; Group A: $n = 18$, Group B: $n = 17$, and Group C: $n = 18$. * $P < 0.05$ versus baseline scores; ** $P < 0.01$ versus baseline scores; # $P < 0.05$ versus Group B; ## $P < 0.01$ versus Group B; † $P < 0.05$ versus Group C; †† $P < 0.01$ versus Group C.

± 11) (Fig. 2A). During treatment in Group A, VAS scores decreased significantly compared with baseline scores (2 wk: 45 ± 10 ; $P < 0.05$; 4 wk: 37 ± 10 ; $P < 0.01$; 8 wk: 32 ± 11 ; $P < 0.01$). At 1-mo follow-up (12 wk), significantly low peak pain scores (42 ± 13 ; $P < 0.01$) remained, but scores at 2-mo follow-up (16 wk: 49 ± 13) had returned to pretreatment values. The lowest VAS score was seen at 8 wk, and this value was significantly lower than those at 2 and 12 wk ($P < 0.01$) but not significantly different from the score at 4 wk. VAS scores of peak pain were significantly lower in Group A than in Group C during treatment (2 wk: $P < 0.05$, 4 wk: $P < 0.01$, and 8 wk: $P < 0.01$) and at

1-mo follow-up ($P < 0.01$), and VAS scores in Group A were also significantly lower than those in Group B at 8 and 12 wk ($P < 0.01$). In Group B, VAS scores of peak pain decreased significantly during treatment in comparison to baseline scores (2 wk: 45 ± 11 , 4 wk: 36 ± 13 , and 8 wk: 44 ± 12 ; $P < 0.01$), but these values had returned to pretreatment values at 1-mo follow-up (12 wk: 54 ± 12). The lowest VAS score was observed at 4 wk (8 sessions), and this was significantly lower than scores at 2 and 8 wk ($P < 0.05$). VAS scores of peak pain were significantly lower in Group B than in Group C at 2 wk ($P < 0.05$) and 4 wk ($P < 0.01$). In Group C, VAS scores decreased significantly only at 8 wk in comparison to baseline scores (48 ± 11 ; $P < 0.05$).

There were no differences in degree of physical impairment among groups at preobservation and baseline (Group A: 2.2 ± 0.5 , Group B: 2.1 ± 0.6 , and Group C: 2.1 ± 0.6) (Fig. 2B). During treatment in Group A, the degrees of physical impairment at 4 wk (1.5 ± 0.6) and 8 wk (1.4 ± 0.6) decreased significantly compared with baseline scores ($P < 0.01$). At 1-mo follow-up (12 wk), the significantly low value of physical impairment scores (1.7 ± 0.6 ; $P < 0.01$) remained, but values at 2-mo follow-up (16 wk: 2.1 ± 0.5) had returned to pretreatment values. The degrees of impairment were significantly lower in Group A than in Groups B and C at 8 and 12 wk ($P < 0.05$). In Group B, the degree of physical impairment at 4 wk decreased significantly compared with baseline scores (1.5 ± 0.7 ; $P < 0.01$), but the values had returned to pretreatment values at 8 wk (1.8 ± 0.5). There were no significant differences in physical impairment scores throughout the study in Group C.

There were no differences in the daily intake of oral NSAIDs among groups at preobservation and baseline (Group A: 2.2 ± 0.5 , Group B: 2.0 ± 0.5 , and Group C: 2.1 ± 0.6) (Fig. 2C). In Group A, the daily intake of oral NSAIDs decreased significantly at 4 wk (1.5 ± 0.7) and 8 wk (1.1 ± 0.9) compared with baseline intake ($P < 0.01$), and this significantly small dosage of NSAIDs remained at 1-mo follow-up (1.7 ± 0.8 ; $P < 0.05$), but intake at 2-mo follow-up (16 wk: 2.1 ± 0.6) had returned to pretreatment values. The dosages of NSAIDs at 4 and 8 wk in Group A were significantly smaller than those in Group C, and the dosage at 8 wk in Group A was also significantly smaller than that in Group B. The dosages of NSAIDs in Group B decreased significantly at 4 wk (1.5 ± 0.8), and this dosage was significantly smaller than that in Group C. There were no significant differences in dosages of NSAIDs throughout the study in Group C.

Discussion

Our results showed that repeated PENS therapy was more effective than repeated TENS therapy in relieving chronic LBP. We observed cumulative effects of PENS

on pain and physical impairment in patients with chronic LBP during treatment. However, there were no significant differences in pain and physical impairment scores between four and eight weeks of PENS treatment. Furthermore, the effects were not sustained at the two-month follow-up. Our results indicate that even though PENS is an effective treatment for chronic LBP, treatments need to be continued to sustain analgesia.

A cumulative analgesic effect of PENS on chronic LBP during treatment has been reported (4-6). Ghoname et al. (4) noted that their patients began to report more sustained beneficial effects on their level of pain and physical activity after three or four PENS treatments. The current study also showed that pain level decreased significantly after four PENS treatments and that this effect was sustained during treatment. Why 3 to 4 or more treatments are required remains unclear; it is likely that a minimum of four PENS treatments is required to improve chronic LBP.

In a randomized, single-blind, and cross-over study, PENS therapy has been proven to be more effective than TENS therapy in providing short-term pain relief and improved physical function in patients with long-term LBP (4). However, most previous studies failed to show a sustained analgesic effect after the PENS treatments, with the pain levels returning to baseline values within 1 week after discontinuation of therapy (4-6). These investigators performed PENS three times a week for two or three weeks. The number of treatment sessions and the period of treatment required to sustain analgesia after PENS are unclear. We evaluated the effects of different numbers of PENS sessions on pain relief and determined the length of time the analgesic effect was sustained. Our present results showed that PENS administered twice a week for four weeks failed to sustain an analgesic effect but that eight weeks of PENS therapy could sustain the effect for one month after discontinuation. However, even eight weeks of PENS failed to sustain an analgesic effect for two months.

There is only one report of the analgesic effects of PENS being maintained over the long-term at follow-up (12). Weiner et al. (12) reported that twice-weekly PENS and physical therapy for six weeks resulted in significant reductions in chronic LBP intensity and pain-related disability at posttreatment and that these effects were maintained at three-month follow-up. Subjects were community-dwelling adults aged 65 years and older, and physical therapy was a key therapy in the treatment regimen. Improvement in the PENS group of that study was actually a result of the combined effects of PENS and physical therapy. In addition, the physical therapy program administered contained primary pain management components, such as instruction in how to manage pain flares and in the use of nonpharmacological analgesics (e.g., heat

and ice). Therefore, the true efficacy of PENS may have been diluted by these factors.

The mechanism of the long-term analgesic effect of PENS is not clear. There is evidence that acupuncture needles placed in nonacupuncture points lead to pain reduction because of stimulation of endorphin release via a mechanism called diffuse noxious inhibitory control (13). One significant consequence of electroacupuncture is the release of endogenous opioids such as β -endorphin (14), which generally produces analgesia for up to two hours (15,16). Thus, the short-term analgesic effect of PENS on chronic pain is rather easy to explain, but the explanation for any long-term effect is controversial. The placebo effect might be related. The main reason electrical stimulation remains a controversial treatment is that double-blind placebo-controlled trials are extremely difficult to perform. Sham PENS may be used for control, but patients can easily distinguish differences between active and nonactive stimulation. We used TENS for the control group, but patients can easily distinguish differences between stimulation with and without needles, and the attending physicians always knew which method was being applied. Thus, concomitant placebo effects, hypnotic effects, or patients' psychological expectations might have contributed to the current results. Therefore, the only way to resolve such problems with control treatment is by accumulating data through a well-designed protocol.

Our results indicate that there may be a ceiling effect in PENS treatment of chronic pain, as well as a cumulative effect of PENS, although the mechanisms underlying these effects are not clear. Most participants in our study were elderly. In younger adults, back pain often results from physical stress on normal spinal structures (16), whereas in the elderly, osteoarthritis of the intervertebral bodies is almost invariably present (17). Age-related body changes may contribute to the ceiling effect we observed, and if this is the case, a ceiling effect would also be observed for treatments other than PENS. It has also been proposed that accumulation of anti-opioid substances within the central nervous system may account for the development of tolerance to electroacupuncture (18,19), suggesting that long-term PENS treatments could lead to tolerance. However, it is clear that PENS is more effective than TENS, and even if the analgesic effects of PENS were caused by the placebo effect, patients with chronic LBP would benefit. Numerous patients, mostly elderly, suffer from chronic LBP. These patients often take NSAIDs, which may cause severe side effects. Compared with other treatments, PENS seems to have a reduced risk.

The duration of stimulation per session and the frequency at which the stimulation is given are important factors in the relief of pain (5,6). Hamza et al. (6)

reported that the recommended duration of electrical stimulation with PENS is 30 minutes. Although controversy still surrounds the optimal frequency of electrical stimulation for TENS (20), it seems that both PENS and TENS therapies are most effective when administered at mixed frequencies of electrical stimulation (5). We performed electrical stimulation with PENS for 20 minutes at 4/30-Hz mixed frequencies. Our preliminary study showed that most patients felt 10 minutes was too short and 30 minutes was too long, and most felt more comfortable at mixed frequencies of 4/30 Hz than at a low or high frequency alone.

In conclusion, repeated PENS sessions resulted in decreased pain and physical impairment in patients with chronic LBP during treatment, but the analgesic effect was not sustained for long after the end of treatment. Further long-term follow-up studies of PENS should be performed to clarify the relation between duration of treatment and duration of analgesic effects for this modality.

References

1. Hadler NM. Workers with disabling back pain. *N Engl J Med* 1997;337:341-3.
2. Melzack R, Vetere P, Finch L. Transcutaneous electrical nerve stimulation for low back pain: a comparison of TENS and massage for pain and range of motion. *Phys Ther* 1983;63:489-93.
3. Lehmann TR, Russell DW, Spratt KF, et al. Efficacy of electroacupuncture and TENS in the rehabilitation of chronic back pain patients. *Pain* 1986;26:277-90.
4. Ghoname EA, Craig WF, White PF, et al. Percutaneous electrical nerve stimulation for low back pain: a randomized crossover study. *JAMA* 1999;281:818-23.
5. Ghoname EA, Craig WF, White PF, et al. The effect of stimulus frequency on the analgesic response to electrical nerve stimulation in patients with chronic low back pain. *Anesth Analg* 1999;88:841-6.
6. Hamza MA, Ghoname EA, White PF, et al. Effect of the duration of electrical stimulation on the analgesic response in patients with low back pain. *Anesthesiology* 1999;91:1622-7.
7. Ahmed HE, Craig WF, White PF, et al. Percutaneous electrical nerve stimulation: an alternative to antiviral drugs for acute herpes zoster. *Anesth Analg* 1998;87:911-4.
8. Ahmed HE, Craig WF, White PF, Huber P. Percutaneous electrical nerve stimulation (PENS): a complementary therapy for the management of pain secondary to bony metastasis. *Clin J Pain* 1998;14:320-3.
9. Ghoname EA, White PF, Ahmed HE, et al. Percutaneous electrical nerve stimulation: an alternative to TENS in the management of sciatica. *Pain* 1999;83:193-9.
10. Hamza MA, White PF, Craig WF, et al. Percutaneous electrical nerve stimulation: a novel analgesic therapy for diabetic neuropathic pain. *Diabetes Care* 2000;23:365-70.
11. White PF, Craig WF, Vekharina AS, et al. Percutaneous neuromodulation therapy: does the location of electrical stimulation effect the acute analgesic response? *Anesth Analg* 2000;91:949-54.
12. Weiner DK, Rudy TE, Glick RM, et al. Efficacy of percutaneous electrical nerve stimulation for the treatment of chronic low back pain in older adults. *J Am Geriatr Soc* 2003;51:599-608.
13. Le Bars D, Dickenson AH, Besson JM. Diffuse noxious inhibitory controls (DNIC). I. Effects on dorsal horn convergent neurons in the rat. *Pain* 1979;6:283-304.
14. Ulett GA, Han S, Han J. Electroacupuncture: mechanisms and clinical application. *Biol Psychiatry* 1998;44:129-38.
15. Christensen PA, Noreng M, Andersen PE, Nielsen JW. Electroacupuncture and postoperative pain. *Br J Anaesth* 1989;62:258-62.
16. Frank AA. Low back pain. *BMJ* 1993;307:323-4.
17. Grant DJ, Bishop-Miller J, Winchester DM, et al. A randomized comparative trial of acupuncture versus transcutaneous electrical nerve stimulation for chronic back pain in the elderly. *Pain* 1999;82:9-13.
18. Han JS, Tang J, Haung BS, et al. Acupuncture tolerance in rats: anti-opiate substrates implicated. *Chin Med J* 1979;92:625-7.
19. Ungar G, Ungar AL, Malin DH, Sarantakis D. Brain peptides with opiate antagonistic action: their possible role in tolerance and dependence. *Psychoneuroendocrinology* 1977;2:1-10.
20. Rao VR, Wolf SL, Gersh MR. Examination of electrode placement and stimulating parameters in treating chronic pain with conventional transcutaneous electrical nerve stimulation (TENS). *Pain* 1981;11:37-47.