Effects of Unilateral and Bilateral Auricular Transcutaneous Electrical Nerve Stimulation on Cutaneous Pain Threshold

ANN WOODWARD KRAUSE, JO ANN CLELLAND, CHERYL J. KNOWLES, and JAMES R. JACKSON

This study compared the effects of unilateral and bilateral auricular transcutaneous electrical nerve stimulation on cutaneous pain threshold. Auricular acupuncture points were stimulated with low frequency, high intensity TENS for 45 seconds. Sixty healthy, adult subjects were assigned randomly to one of two treatment groups or to a control group. The two treatment groups received low frequency, high intensity TENS either unilaterally or bilaterally. The control group did not receive auricular stimulation. Experimental pain threshold at the left wrist was determined with a painful stimulus before and after auricular stimulation. Both unilateral and bilateral auricular stimulation groups exhibited a significant increase ($p < .05$) in experimental pain threshold, but the control group did not. The mean change values between the unilateral and bilateral stimulation groups were not statistically different. These results suggest that both unilateral and bilateral auricular TENS can increase pain threshold.

Key Words: Ear, Electric stimulation, Pain, Physical therapy.

Approaches to pain management have improved over the years, but because of the serious side effects, many modern methods still are inadequate. A noninvasive and nonaddictive technique to relieve pain would be a welcome addition to current pain control methods. Transcutaneous electrical nerve stimulation is an example of a relatively new noninvasive and nonaddictive treatment for pain management.

Low frequency, high intensity TENS applied over acupuncture points is referred to as “acupuncture-like” TENS. Acupuncture points on the auricle of the ear are sometimes the sites for this type of TENS application. Auriculotherapy in various forms has been practiced for thousands of years. Many questions remain concerning the use of all types of auriculotherapy, including auricular TENS, for the treatment of pain.

Pain is the most common symptom causing patients to seek medical treatment. Researchers have posed many theories concerning the mechanism underlying pain perception and its possible management. The specificity theory proposes that a mosaic of specific pain receptors in body tissues project to a main center in the brain. The pattern theory is based on stimulus intensity and central summation being the critical determinants of pain, but this theory has been challenged because it does not explain the existence of specific end organs. Melzack and Wall suggested that the substantia gelatinosa acts as a gate control system that modulates the synaptic transmission of nerve impulses from peripheral fibers to central cells.

Transcutaneous electrical nerve stimulation is being used increasingly when other means do not yield pain relief. Two types of TENS, conventional (low intensity, high frequency) and acupuncture-like (high intensity, low frequency) have been shown to decrease pain. Acupuncture-like TENS is linked to the release of endorphins, and the gate control theory is implicated with conventional TENS.

Investigators have studied the endogenous opiate system and its relationship to pain relief. Sjölund and Eriksson found that analgesia produced by acupuncture-like TENS was mediated by inhibitory mechanisms releasing endogenous morphine-like substances. Sjölund et al also evaluated endorphin levels in cerebrospinal fluid following electroacupuncture delivered with surface electrodes for 45 minutes. The CSF was collected by lumbar puncture 30 minutes after stimulation. This experiment showed a release of endorphins during electroacupuncture. Increased amounts of $\beta$-endorphins in peripheral blood during electroacupuncture were found by Malizia and co-workers. Abbate and associates investigated the $\beta$-endorphin immunoreactivity in 12 patients undergoing thoracic surgery who were anesthetized by electroacupuncture and found an increase in $\beta$-endorphin levels in all of the patients.

Transcutaneous electrical nerve stimulation of acupuncture points on the auricle of the ear also has been used therapeutically. Some of the points on the ear that are suggested for stimu-
tion of the lower back, leg, heart, kidney, puncture loci that correspond to a so-
pean auriculotherapists. Nogier, a
lation vary between Chinese and Euro­
the somatotopic mapping of the body
Nogier vary in their somatotopic loca­
points identified by the Chinese and by
the same, the auricular acupuncture
French neurologist, developed auricu-
A physician with no prior knowledge of
15
the nervous system.
1
times and achieved normal range of mo­
ted bilaterally to the auricles and
thetic dystrophy, TENS was adminis­
troacupuncture.
In a case study on the
were stimulated bilaterally with elec­
terature laws prescribe stimulating the ears
ears to be treated. Traditional acupunc­
threshold of a control group measured
changes in pain threshold. A pencil electrode with a di­
meter of about 2 mm was the stimulat­
ing electrode, and a 10- × 8-cm moist
Instrumentation
A TECA CH3 chronaxie meter* was
used to determine experimental pain
threshold. A pencil electrode with a di­
ameter of about 2 mm was the stimulat­ing electrode, and a 10- × 8-cm moist
pad electrode was the dispersive elec­
trode. A Staodyn Insight† stimulator was
used to deliver TENS to auricular
points. This unit was equipped with a
spring-loaded probe tip for stimulation
and a 4- × 5-cm dispersive electrode.
Procedure
We randomly assigned the subjects
to one of three groups. Group 1 subjects
received unilateral TENS to four points
on the auricle: wrist, shen-men, lung,
and dermis (Fig. 1). The shen-men point
is associated with sedative, analgesic,
and tranquilizing effects; the lung
and dermis points often are associated
with reducing skin hypersensitivity.14,15

Fig. 1. Selected auricular points for treatment groups.

Shen-Men

Wrist

Lung

Dermis

that might have influenced their re-
sponse to TENS. Because transcutane­
ous electrical nerve stimulation usage is
contraindicated in people who are preg­
nant or use a pacemaker, people with
these conditions were excluded from our
study. The subjects were naive to the
procedure and the anticipated effects.
Data were collected between the hours
of 1 and 7 PM. The study was approved
by the Institutional Review Board for
Human Use at The University of Ala­

Oleson et al evaluated the accuracy of
the somatotopic mapping of the body
on the external ear, using 40 patients
with musculoskeletal pain as subjects.15
A physician with no prior knowledge of
the patients' medical conditions evalua-
eted the ears for areas of increased con-
ductivity or tenderness. The authors hy-
pothesized that tender auricular points
would coincide with the area of the pa-
tients' pain. Concordance between the
established medical diagnosis and the
auricular diagnosis was 75.2%. This
finding supports the hypothesis of a so-
matotopic organization of the body re-
presented on the auricle.

Auriculotherapy is viewed skeptically
by many practitioners of western medi-
cine. Research shows both benefi-
cial1,13,14,16-18 and ineffective results from
the treatment.19 Auriculotherapy has
been shown to be effective in treating a
wide variety of disorders such as reflex
sympathetic dystrophy in a child,13 an-
kle inversion sprains,16 migraine head-
aches,16 dental pain,17 arthritis, and sci­
tica.

A question that arises in the use of
auriculotherapy, including auricular
TENS, concerns the appropriate ear or
ears to be treated. Traditional acupunc-
ture laws prescribe stimulating the ears
bilaterally.14 Katide and Hyodo con-
ducted a study to determine whether bilat­
eral electroacupuncture of appro-
priate auricular points increased pain
threshold. Their results showed that pain
threshold was increased when ears
were stimulated bilaterally with elec­
troacupuncture.30 In a case study on the

treatment sooner than patients not receiving
auriculotherapy.14 Chun and Heather
used the site of the pain as the deciding
factor in which ear to treat.8 With uni-
lateral pain, the ipsilateral ear was used
for treatment; in bilateral involvement
or a midline lesion, both ears were used
for treatment. Nogier suggests treating
the side according to the dominant cer-
bral hemisphere of the individual,
whereas Chinese acupuncturists stimu-
late the left side predominantly.16

The purpose of our study was to com-
pare the effects of unilateral and bi-
lateral auricular TENS (acupuncture-
like) on cutaneous pain threshold. The
following hypotheses were posed: 1) Changes in experimental pain thresh­
old, measured at the wrist, after either a
unilateral or bilateral auricular TENS
treatment to appropriate auriculother­
apy points will be significantly greater
than changes observed in the pain
threshold of a control group measured
after a rest period and 2) changes in
experimental pain threshold, measured
at the wrist, after a bilateral auricular
TENS treatment to appropriate auricu-
lotherapy points will be significantly
greater than changes in pain threshold
after a unilateral auricular TENS treat­
ment to appropriate auriculotherapy
points.

METHOD

Subjects
Sixty healthy, adult men and women,
participated in our study. The majority
of subjects were university faculty and
staff members and students. All were
free from neurological abnormalities
who participated in our study. The majority
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Figure 2. Location of the stimulating electrode for determination of experimental pain threshold.

**TABLE 1**
Characteristics of Total Sample (N = 57)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Group 1 (Unilateral) (n = 20)</th>
<th>Group 2 (Bilateral) (n = 19)</th>
<th>Group 3 (Control) (n = 18)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of female subjects</td>
<td>9</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Number of male subjects</td>
<td>11</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Number of left-handed subjects</td>
<td>2</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Number of right-handed subjects</td>
<td>18</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>Mean age (yr)</td>
<td>26.2</td>
<td>24.0</td>
<td>23.8</td>
</tr>
</tbody>
</table>

Group 2 subjects received bilateral TENS to the same four points. Group 3 functioned as a control group and did not receive auricular TENS. The experimental pain thresholds of the Group 3 subjects were measured before and after a 10-minute rest period.

Subjects were positioned supine on a treatment table for the experimental pain threshold determination and auricular TENS treatment. Their skin at all electrode sites was wiped with cotton gauze and isopropyl alcohol to reduce skin impedance.

**Threshold measurement.** The investigator (A.W.K.) placed the dispersive electrode of the chronaxie meter behind the subject’s neck, from the level of the seventh cervical vertebra to the upper thoracic vertebrae, and held the stimulating electrode, which was moistened with conductive gel, on the skin overlaying the volar surface of the distal end of the left radius, avoiding the acupuncture point LI 5 (Fig. 2). The subjects were allowed to feel the current, before measurement, on the right wrist to familiarize them with the sensation. The stimulus consisted of 100-Hz rectangular waves of 5-msec duration. The intensity of the stimulus was increased systematically, stopping every 0.25 mA for about one second. The subjects were asked to report verbally the moment they felt any electric current at the wrist and the moment they experienced a painful “pinprick” sensation. The intensity at which a painful pinprick sensation was felt was recorded as the “pain threshold,” and these threshold values were recorded three consecutive times during both the pretreatment and posttreatment sessions. The threshold values were averaged, and the mean pain threshold value for each subject was recorded.

**Treatment.** The dispersive electrode of the auricular TENS unit was placed in the subject’s left hand. Any earrings or necklaces were removed by the subjects. Auricular stimulation points were located using acupuncture charts and by finding areas of decreased skin resistance through the aid of a visual signal from the stimulating unit. The auricular stimulus consisted of positive polarity direct current with a maximum output of 1,000 µA delivered at a frequency of 1 Hz. The width of the stimulus was constant, as preset in the unit. Each subject was asked to respond verbally the first moment the stimulus was felt by saying, “Feel it.” The stimulus was increased until the subject’s pain threshold was reached, at which time the subject said, “Stop.” Each auricular point was stimulated for 45 seconds, with the intensity maintained as high as the subjects could tolerate. Group 1 subjects received treatment to the left ear; Group 2 subjects received treatments to both ears. Group 3 subjects rested on the treatment table for 10 minutes, the maximum time required to complete an auricular TENS treatment. After the auricular TENS treatment or rest, pain threshold was remeasured at the wrist in all subjects. This treatment technique is similar to that used by Oliveri and co-workers.21

**Data Analysis**

Three subjects—two from Group 2 and one from Group 3—were excluded from the data analysis because their pain threshold values decreased more than three standard deviations from the means of their respective groups. Descriptive statistics were calculated for the pretreatment and posttreatment measurements and for the changes in mean pain threshold for each group. A two-factor split-plot analysis of variance (ANOVA) was used to test the research hypotheses for statistical significance. Because both hypotheses were stated in terms of change, a split-plot design was used with an interaction effect that tested the differences among the pretreatment and posttreatment means and to test the difference between the pretreatment and posttreatment means within each group. Pair-wise comparisons between groups were made with Duncan’s new multiple range test.22 An alpha level of .05 was selected for all tests.

**RESULTS**

The group characteristics regarding sex, hand dominance, and age are shown in Table 1. Descriptive statistics for pain threshold measurements by group are shown in Table 2. Mean pain threshold values for each group at pretreatment and posttreatment are shown in Figure 3. The ANOVA showed a statistically significant interaction between group and pretreatment-posttreatment effects (Tab. 3); therefore, a statistically significant difference existed among the groups in terms of mean pretreatment and posttreatment pain threshold changes. Follow-up pair-wise comparisons using Duncan’s new multiple range test showed statistically significant differences (p < .05) between the mean change for Group 3 and the mean changes for Groups 1 and 2 (Tab. 2). Thus, our first hypothesis was supported. Because a statistically significant difference did not exist between the
TABLE 2
Mean Pain Threshold Measurements (mA)

<table>
<thead>
<tr>
<th>Group</th>
<th>Pretreatment</th>
<th>Posttreatment</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1—Unilateral Points (n = 20)</td>
<td>3.92</td>
<td>4.40</td>
<td>0.47</td>
</tr>
<tr>
<td>Pretreatment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posttreatment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2—Bilateral Points (n = 19)</td>
<td>3.87</td>
<td>4.54</td>
<td>0.67</td>
</tr>
<tr>
<td>Pretreatment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posttreatment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3—Control (n = 18)</td>
<td>3.37</td>
<td>3.44</td>
<td>0.06</td>
</tr>
<tr>
<td>Pretreatment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posttreatment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pain Threshold:

<table>
<thead>
<tr>
<th></th>
<th>1.00</th>
<th>1.08</th>
<th>0.60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>(2.16-6.17)</td>
<td>(2.81-7.17)</td>
<td>(-0.58-1.92)</td>
</tr>
</tbody>
</table>

Fig. 3. Changes in experimental pain threshold for the three groups.

DISCUSSION

Other investigators have studied the effects of acupuncture, acupressure, and auriculotherapy on experimental pain thresholds in both animals and healthy adults and have found a significant increase in pain threshold with treatment. This investigation also supports the hypothesis that auricular stimulation increases pain threshold.

The results of this study suggest that unilateral auricular stimulation may be as effective as bilateral auricular stimulation for an increase in experimental pain threshold. Katide and Hyodo stimulated the ears bilaterally and found that pain threshold was increased. Chun and Heather stimulated only the ears bilaterally if the patient's pain was bilateral or produced by a midline lesion. If a patient's pain was unilateral, Chun and Heather stimulated only the ipsilateral ear. Sixty-four percent of their patients experienced at least 50% relief of their original pain when treated by this method.

Comparisons are difficult to make between our study and that of Melzack and Katz, which reported that auricular stimulation was not an effective therapeutic procedure for chronic pain. An important factor in our study was the use of high intensity TENS. Although Melzack and Katz stimulated auricular acupuncture points, the stimulation was not applied to the level of the patients' pain tolerance. Their stimulator produced a maximum current output of 200 µA, whereas the one used in our study produced a maximum current output of 1,000 µA.

Further research is needed to assess the most effective sites for administering TENS. Auricular TENS is often used in conjunction with stimulation at other body sites. In the treatment of ankle inversion sprains, Paris and associates stimulated six auricular acupuncture points in addition to six ankle acupuncture points. Patients receiving this treatment had decreased rehabilitation times and achieved normal ROM sooner than those receiving only standard physical therapy consisting of cryotherapy, elevation, and nonweight bearing. Leo treated a case of reflex sympathetic dystrophy by stimulation of six auricular acupuncture points and three body acupuncture points. The results were full passive ROM and increased active ROM of the involved extremity.

Duration of stimulation also could be a factor in the use of auricular TENS. Oliveri et al unilaterally stimulated, for...
Analysis of Variance for Pain Threshold

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>2</td>
<td>14.710</td>
<td>7.355</td>
<td>3.413*</td>
</tr>
<tr>
<td>Error</td>
<td>54</td>
<td>116.364</td>
<td>2.155</td>
<td></td>
</tr>
<tr>
<td>Group at pretreatment&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2</td>
<td>3.302</td>
<td>1.651</td>
<td>1.435</td>
</tr>
<tr>
<td>Group at posttreatment&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2</td>
<td>13.196</td>
<td>6.598</td>
<td>5.734*</td>
</tr>
<tr>
<td>Error</td>
<td>108</td>
<td>124.272</td>
<td>1.151</td>
<td></td>
</tr>
<tr>
<td>Pretreatment-posttreatment</td>
<td>1</td>
<td>4.774</td>
<td>4.774</td>
<td>32.603*</td>
</tr>
<tr>
<td>Error</td>
<td>54</td>
<td>7.908</td>
<td>0.146</td>
<td></td>
</tr>
<tr>
<td>Pretreatment-posttreatment (Group 1)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1</td>
<td>2.266</td>
<td>2.266</td>
<td>15.472*</td>
</tr>
<tr>
<td>Pretreatment-posttreatment (Group 2)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1</td>
<td>4.265</td>
<td>4.265</td>
<td>29.121*</td>
</tr>
<tr>
<td>Pretreatment-posttreatment (Group 3)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1</td>
<td>0.032</td>
<td>0.032</td>
<td>2.21</td>
</tr>
<tr>
<td>Error</td>
<td>54</td>
<td>7.908</td>
<td>0.146</td>
<td></td>
</tr>
<tr>
<td>Interaction</td>
<td>2</td>
<td>1.788</td>
<td>0.894</td>
<td>6.105*</td>
</tr>
<tr>
<td>Error</td>
<td>54</td>
<td>7.908</td>
<td>0.146</td>
<td></td>
</tr>
</tbody>
</table>

* <sup>a</sup>p < .05.
<sup>b</sup> Test of simple main effect.

90 seconds, the same four acupuncture points used in our study and found a 16.3% increase in mean pain threshold. In our study, unilateral auricular stimulation led to a 12.2% increase in mean pain threshold, and bilateral auricular stimulation led to a 17.4% increase in mean pain threshold. The finding that all of these values for increases in pain threshold are in a narrow range suggests that 45 seconds of unilateral stimulation at each point is sufficient to increase pain threshold significantly. Further studies are needed to assess whether less than 45 seconds of stimulation would increase pain threshold. The increases in pain threshold achieved in our study were small, and how these increases in experimental pain threshold might compare with clinical pain was not determined. Studies involving patients who are experiencing pain have yielded various results. The suppression of pain sensibility in a healthy laboratory subject may be a quite different phenomenon than the treatment-induced relief of patients who suffer from chronic pain. Increased knowledge about the most effective means of pain suppression in the experimental setting, however, could be an important step toward understanding the most effective means of pain suppression in the clinical setting.

**CONCLUSIONS**

In two groups of healthy subjects, the use of low frequency, high intensity auricular TENS administered either unilaterally or bilaterally led to small, but statistically significant, increases in pain threshold. A control group that received no auricular stimulation did not demonstrate an increase in pain threshold. These results suggest that unilateral auricular stimulation may be as effective as bilateral auricular stimulation for increasing experimental pain threshold. Further research about auriculotherapy and its role in pain relief with patients is needed.

**REFERENCES**