Effect of Helium-Neon Laser Auriculotherapy on Experimental Pain Threshold

This study was conducted to examine the effects of helium-neon laser auriculotherapy on experimental pain threshold. Eighty healthy female and male subjects, aged 18 to 39 years, were assigned randomly to one of two treatment groups. Subjects in the Experimental Group (n = 41) received laser stimulation, and subjects in the Control Group (n = 39) received sham stimulation to appropriate acupuncture points on the left ear. Experimental pain threshold at the ipsilateral wrist was determined with an electrical stimulus immediately before and after treatment. The mean change (posttreatment minus pretreatment) for the Experimental Group was greater than the mean change for the Control Group (p < .05). The Experimental Group demonstrated a statistically significant (p < .05) increase in mean pain threshold after treatment, but the Control Group did not. Results indicate that helium-neon laser auriculotherapy can increase experimental pain threshold and suggest a possible alternative for patients intolerant of transcutaneous electrical nerve stimulation.

Key Words: Electrotherapy, electrical stimulation; Lasers; Pain; Transcutaneous electrical nerve stimulation.

Laser therapy has been reported to be a useful alternative to drug therapy in pain management and in facilitating a rapid return to functional status.¹ ² Physical therapists routinely use electrical stimulation for pain management. With the advent of laser therapy, we have the possibility of a more comfortable pain management method that produces neither a sensation of electrical current nor pain. Helium-neon laser stimulation is noninvasive, aseptic, painless, apparently noninjurious to tissue, and purported to be based on nonthermal mechanisms.³ ⁴ Although studies have been conducted that support the use of laser irradiation in pain management, there is a lack of well-controlled research in the literature. The purpose of this study was to examine the effects of low-power helium-neon laser auricular stimulation on experimental cutaneous pain threshold, measured at the left wrist. We hypothesized that the change in experimental pain threshold following an auricular laser treatment in an experimental group would be greater than the change observed in a control group.

Review of Literature

Laser is an acronym for light amplification by stimulated emission of radiation. The terms "high-power laser" and "low-power laser" distinguish a difference in optical energies, with high-power lasers designed to cut or destroy tissue and low-power, or "cold," lasers designed to stimulate tissue. Helium-neon, gallium-arsenide,
and neodymium glass lasers have been documented as effectively providing pain relief and enhancing wound healing. Helium-neon laser beams have been reported to penetrate human tissue in the range of 0.8 to 15 mm. Minimal tissue heating occurs with the cold laser; Boussignac reported changes of only 0.3°C to 0.6°C using 10- to 70-mW lasers, much higher powered than the 1-mW average-power helium-neon laser used in our study. These changes may be compared with hand and foot muscle and with hand and thumb joint-capsule temperature changes of up to 9°C resulting from hydrotherapy, paraffin wax, and dry heat treatments.

Javan et al developed the cold helium-neon laser, basing its mechanism on the transfer of excitation from helium to neon atoms by population inversion and continuous optical maser oscillation. Monochromaticity (single wavelength), coherence (wavelengths in phase), and minimal beam divergence allow helium-neon laser energy to be delivered into precise areas or points.

**Proposed Mechanisms of Action**

According to Kleinkort and Foley, one proposed mechanism of action of helium-neon laser biostimulation is based on Arndt's law: "Weak stimuli excite physiologic activity, moderately strong ones favor it, strong ones retard it, and very strong ones arrest it." Low-power laser stimulation, as a weak stimulus, therefore, may excite physiologic activity to produce stimulative effects in the form of pain relief and tissue healing. Low-power laser treatment has been described as having a stimulative effect on human tissue at a local cellular level or general systemic level, or both, by acceleration of the photobiological or photochemical process.

Other studies involving investigation of possible mechanisms of action of low-power laser irradiation suggest alteration of nerve tissue. Snyder-Mackler and Bork reported a statistically significant increase in the latency of the superficial radial nerve in healthy subjects that corresponded to a decrease in sensory nerve conduction velocity after helium-neon laser application, suggesting interference in sensory nerve transmission as a possible mechanism of action for helium-neon stimulation-produced analgesia.

Goldman et al suggested that cells or subcellular components of cells selectively absorb laser light, based on pigmentary differences. This absorption is dependent on wavelength used, with different effects seen in various levels of tissue. Vizi et al found increased acetylcholine release from Auerbach's plexus in the guinea pig ileum following ruby laser irradiation of an isolated longitudinal muscle strip of the ileum, indicating neurotransmitter involvement. Walker attributed laser analgesia to release of the neurotransmitter serotonin and endogenous opiates.

Other postulated mechanisms of laser biostimulation analgesia and wound healing include activation of vessels to induce fibrinolysis or increase of phagocytosis, resulting in restoration of a normal physiologic state, and a nonthermal mechanism based on the absorption or interaction of the laser beam with specific tissue substructures. Low-intensity laser irradiation has been theorized to affect abnormal pain-producing tissue (muscle spasm) by restoring normal properties of muscle tissue on a cellular level via adenosine triphosphate formation and enzyme activity.

Selbert and Gould, using a posttest-only control-group design, found a significant increase in radiant heat burning-pain threshold after helium-neon stimulation. Snyder-Mackler et al, in a double-blind study, found a significant increase in skin resistance elicited by helium-neon stimulation. A return to normal skin resistance or an increase in skin resistance was suggested to indicate resolution of pathologic conditions.

Seitz and Kleinkort, with auricular point laser stimulation, demonstrated a temperature decrease at the point of distal dysfunction, which they believed was indicative of a decrease in inflammation. They theorized the decrease in temperature or decrease in inflammation was induced by a reflexogenic or autonomic nervous system response.

**Pain Studies**

Well-controlled studies on the effects of laser stimulation on chronic pain are scarce. Goldman et al, in a double-blind study of patients with rheumatoid arthritis, examined the effects of unilateral hand stimulation with the neodymium glass laser (a Class IV laser, slightly more powerful and deeply penetrating than the helium-neon laser). Twenty-seven of 30 patients noted some improvement after laser therapy. Heat, erythema, pain, swelling, and tenderness improved in both hands over time. Grasp and fingertip pinch significantly improved in the stimulated hand over time, and the level of circulating immune complexes, measured by platelet aggregation, decreased during laser treatment.

Walker's double-blind study of chronic pain and helium-neon stimulation of peripheral nerves resulted in pain relief in 19 of 26 subjects, with subsequent discontinuation of pain medications. Large increases in the 24-hour urinary secretion of 5-hydroxyindoleacetic acid, the degradation product of serotonin, were found in the subjects, suggesting the laser's effect on increasing serotonin metabolism. Kroetlinger treated 77 patients with spondylitis, knee arthritis, vascular headache, vasomotor rhinitis, herpes zoster neuralgia, or trigeminal neuralgia with helium-neon laser irradiation and found that 59 (77%) subjectively improved, by patient report. Kleinkort and Foley, in three case studies, reported pain relief in one patient with foot pain, one with headache, and one with forearm pain, following a series of laser treatments to body and auricular acupuncture points. They also reported that laser stimulation was more effective than electrical
acupuncture point stimulation in treating acute and chronic pain in the majority of their clinical cases.\textsuperscript{2}

Stimulation of appropriate auricular acupuncture points with high-intensity, low frequency transcutaneous electrical nerve stimulation by Oliveri et al.,\textsuperscript{18} Krause et al.,\textsuperscript{19} and Noling et al.\textsuperscript{20} increased experimental pain thresholds in healthy adults. In our study to evaluate the effects of auricular helium-neon stimulation on experimental cutaneous pain threshold at the wrist, we used a method similar to that used by Oliveri et al.\textsuperscript{18}

Method

Subjects

Eighty-two healthy female and male subjects between 18 and 39 years of age were recruited for this study (Tab. 1). Individuals with the following contraindications or exclusionary criteria were excluded: pregnancy, pacemaker use, cancer or history of cancer, sensory problems, pain or injuries of the left ear, pain or injuries of the left upper extremity, and opiate-based pain medication use.\textsuperscript{3,5} Subjects did not know the anticipated effects of the procedure. Data were collected between the hours of 4 and 8 PM. This study was approved by the Institutional Review Board for Human Use at The University of Alabama at Birmingham (UAB).

Instrumentation

The TECA CH3 chronaxie meter\textsuperscript{*} was used to determine cutaneous pain threshold. This machine is equipped with a meter marked in 0.5-mA intervals and delivers a low-voltage direct current. A 2-× 2-mm rubber-pencil electrode was the stimulating electrode. The dispersive electrode was a 10-× 8-cm pad. The stimulus current characteristics were 5-msec-duration square waves at 100 Hz delivered every half second, as used in previous studies to determine experimental pain threshold.\textsuperscript{18–20} An OmniProbe helium-neon laser\textsuperscript{*} was used to stimulate auricular points. This unit applies nonthermal low-power laser energy at a wavelength of 632.8 nm in the red visible spectrum; the unit contains a 3-mW continuous helium-neon laser with 1-mW average fiber tip power.\textsuperscript{5} Stimulus characteristics were continuous pulse rate, peak power of 1 mW, and average power of 1 mW.\textsuperscript{5} Application was with the standard probe rather than the flexible or curved fiber-optic laser delivery system.

Protocol

Data collection took place in the Division of Physical Therapy, UAB. Subjects were volunteers from the Birmingham, Ala, area, including individuals from the UAB student body and faculty. Each subject was assigned a number to ensure confidentiality. Immediately before the experimental session, the subjects were questioned briefly to determine age and current pain problems and to exclude those contraindicated from laser stimulation. We read a statement to each subject describing the procedure, and each subject signed a statement of informed consent.

The subjects were assigned randomly to one of two groups: 1) the Experimental Group (n = 41), which received laser stimulation to points on the auricle purported to produce analgesia at the wrist, or 2) the Control Group (n = 39), which received sham stimulation to the same points. After group assignment, each subject was positioned supine on a treatment table for experimental cutaneous pain threshold measurement and subsequent laser or sham treatment.

Determination of Cutaneous Pain Threshold

The back of each subject’s neck (dispersive electrode site), left ear, and left wrist were cleaned with isopropyl alcohol to reduce skin resistance. The chronaxie meter’s dispersive electrode was placed behind the subject’s upper back and centered below the level of the seventh cervical vertebra. Before beginning the experiment, the principal investigator (CEK) trained the subjects to recognize the painful pin-prick sensation at the right wrist. A consistent response was obtained for three consecutive trials on the right wrist before the study was initiated using the left wrist. After the practice session at the right wrist, the stimulating electrode was placed on the skin of the volar aspect of the left wrist at the most prominent distal end of the radius, avoiding the LI5 acupuncture point (Fig. 1). The investigator then systematically increased the chronaxie meter intensity, stopping every 0.25 mA for approximately one second. The subject was instructed to report verbally the moment any electrical current was felt at the stimulating

Table 1. Characteristics of Treatment Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Experimental (n = 41)</th>
<th>Control (n = 39)</th>
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</thead>
<tbody>
<tr>
<td>Number of female subjects</td>
<td>27</td>
<td>27</td>
</tr>
<tr>
<td>Number of male subjects</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>Age (yr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\bar{x}$</td>
<td>24.4</td>
<td>23.2</td>
</tr>
<tr>
<td>s</td>
<td>5.0</td>
<td>4.5</td>
</tr>
</tbody>
</table>

\textsuperscript{*}TECA Instruments Corp, 3 Campus Dr, Pleasantville, NY 10570.

\textsuperscript{1}Physio Technology, Inc, 1925 W Sixth St, Topeka, KS 66606.
Location of stimulating electrode - distal end of left radius

Fig. 1. Location of stimulating electrode for determination of experimental pain threshold

Fig. 2. Selected auricular points for Experimental and Control Groups.

electrode site and again the moment that a distinct painful pin-prick sensation was experienced. The second value was recorded as "pain threshold." The threshold was recorded three consecutive times for each subject during both pretreatment and posttreatment sessions. The three threshold values were averaged to determine mean cutaneous pain thresholds for each subject. The reliability of this mean was found to be .97 for pretreatment measurements using an intraclass correlation coefficient (ICC[3,k], k = 3) as the index of reliability.

Treatment

Subjects in the Experimental Group received laser stimulation to four points on the left auricle: shenmen, wrist, lung, and dermis (Fig. 2). Anyone wearing jewelry on the left ear, neck, or left hand and wrist removed it before treatment. Each of the four auricular points was stimulated with the laser for 30 seconds in the continuous setting, as advocated by Seitz and Kleinkort. Control Group subjects were unaware that they did not receive laser stimulation; the probe was placed on the same four points in the same order as for the Experimental Group, providing tactile stimulation from the laser tip. The laser tip pressure was moderate and consistent for subjects in both groups, as determined subjectively by the principal investigator. After auricular laser treatment or sham treatment, cutaneous pain thresholds were immediately remeasured in all subjects.

Data Analysis

Descriptive statistics were calculated by group for pretreatment, posttreatment, and change (posttreatment minus pretreatment). The data were tested for statistical significance using a two-factor analysis of variance (ANOVA). The two factors were group and time of measurement; time was a repeated-measures factor. For this design, the interaction effect in the ANOVA is a test of the difference among pretreatment-posttreatment changes for the two groups. The ANOVA also provides tests of simple main effects, which can be used to test the difference among pretreatment and posttreatment group means, as well as to test the difference between pretreatment and posttreatment means within each group. An alpha level of .05 was the criterion for statistical significance.

Results

Eighty-two subjects agreed to participate in this study. Two subjects were excluded. One subject reported a history of vestibular system disease and was taking medications; a second exclusion was due to the subject's description of a "neuroma" in the left ear lobe. The Experimental Group contained two subjects whose cutaneous pain threshold increases (3.58 and 6.00 mA, respectively) seemed extreme compared with the next largest increase (1.83 mA) in their group. The Control Group also had three subjects whose cutaneous pain threshold decreases (-3.58, -2.25, and -1.92 mA, respectively) seemed extreme compared with the next largest decrease (-1.00 mA) in their group. We could not discount these values on the basis of coding error, invalid performance, or equipment
Table 2. Descriptive Statistics for Pain Threshold (in Milliamperes)

<table>
<thead>
<tr>
<th>Group</th>
<th>Pain Threshold</th>
<th></th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
<td>s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental (n = 41)</td>
<td>3.15</td>
<td>1.45</td>
<td>3.00</td>
<td>(1.00-8.42)</td>
</tr>
<tr>
<td>Pretreatment</td>
<td>3.69</td>
<td>2.01</td>
<td>3.12</td>
<td>(1.00-9.92)</td>
</tr>
<tr>
<td>Change^a</td>
<td>0.54</td>
<td>1.18</td>
<td>0.25</td>
<td>(−1.33-6.00)</td>
</tr>
<tr>
<td>Control (n = 39)</td>
<td>3.42</td>
<td>1.93</td>
<td>2.92</td>
<td>(1.42-11.08)</td>
</tr>
<tr>
<td>Pretreatment</td>
<td>3.22</td>
<td>1.73</td>
<td>2.75</td>
<td>(1.17-8.42)</td>
</tr>
<tr>
<td>Change^a</td>
<td>−0.21</td>
<td>0.88</td>
<td>−0.08</td>
<td>(−3.58-1.25)</td>
</tr>
</tbody>
</table>

^aPosttreatment minus pretreatment.

malfuion. Because these extreme values may have unduly biased the results in favor of our hypothesis, we analyzed the data with and without these subjects. We also analyzed the data using nonparametric statistical tests, which do not assume normal distributions. All of these analyses agreed in terms of statistical significance; thus, we will report the ANOVA results for the entire sample (Tab. 3).

Characteristics of the groups are summarized in Table 1. Comparison of the groups showed no statistically significant differences between the two groups in mean age or numbers of female and male subjects.

Descriptive statistics for pain threshold are presented in Table 2, and Figure 3 presents the pretreatment and posttreatment mean pain threshold values for the two groups. As shown in the ANOVA summary table (Tab. 3), the interaction was statistically significant, indicating that the mean change scores for the two groups were different. Tests for simple main effects showed a statistically significant increase from pretreatment to posttreatment measurements in the Experimental Group, but not in the Control Group. The tests of simple main effects also revealed that the two groups did not differ in pretreatment mean pain threshold.

An increase in pain threshold was found in 29 (71%) of the subjects in the Experimental Group, whereas only 13 subjects (33%) in the Control Group showed increases ($\chi^2 = 9.09$, $df = 1$, $p < .01$). These results supported our hypothesis that the change in experimental pain threshold following laser auriculotherapy would be greater than the change after sham stimulation.

Discussion

Our results showed a statistically significant increase in experimental pain threshold following laser auriculotherapy. Other studies using similar methods to ours have shown that TENS auriculotherapy also increases experimental pain threshold. Because laser stimulation is more comfortable than TENS, it should be more tolerable for many patients. Additional research indicating an elevation in pain threshold following laser auriculotherapy may indicate that laser therapy is a treatment of choice. The difference between the effects of auricular TENS and auricular laser stimulation, however, may be quite different in patients with clinical pain. Thus, studies of patients with pain are needed.

Seibert and Gould found a significant experimental pain threshold increase at the left fifth distal phalanx after helium-neon stimulation, but pain threshold in their study was recorded as a burning pain sensation and measured in number of seconds for the sensation to occur, as opposed to our use of a painful pin-prick sensation and measurement of current.
intensity (in milliamperes) to sensation. They stimulated skin over the left ulnar nerve, lateral to the flexor carpi ulnaris tendon at the wrist for 15 seconds,16 as opposed to our study's 30-second stimulation of four auricular acupuncture points corresponding to the left wrist, our site of pain threshold measurement. Mean burning pain threshold was 14.2 ± 5.8 seconds for the stimulation group and 9.9 ± 9.7 seconds for the control group in their study.16 The smaller difference in mean pain threshold in our study may be due to a different stimulus.

Whereas our study examined the effects of laser stimulation on experimental pain following a single treatment, Kleinkort and Foley, in a clinical study consisting of multiple treatment sessions, applied laser stimulation to body acupuncture points and auricular points in three patients with chronic pain.2 After 10 treatments, the three patients had complete pain relief and full range of motion.2 Seitz and Kleinkort noted some patients' pain reduction after only two or three laser treatments.5 Several treatments with the laser may have an additive effect and therefore result in more clinically significant changes. Walker et al found a statistically significant reduction in the pain intensity in patients with trigeminal neuralgia following three helium-neon laser treatments per week for 10 weeks.7 Clinically significant decreases in pain thus may require many laser treatments.

Walker stimulated the skin overlying peripheral nerves for 20 seconds to each site, accompanied by skin stimulation over painful facial areas for 30 to 90 seconds.7 We stimulated only ear points associated with analgesia of the left wrist, and each point was stimulated for 30 seconds. The 30-second stimulation time is advocated for treatment of acute pain,5 which was appropriate for our study. Localized stimulation sites, increased stimulation time, or additive effects of multiple treatment areas may further increase analgesic effects of laser treatment. Optimal stimulation time would need to be determined by such factors as rationale for treatment (acute vs chronic pain) and intended physiological response (eg, pain relief, wound healing).

Lundeberg et al found no significant differences between laser treatment and placebo (sham) treatment in alleviating tennis elbow pain in 82 patients, using a laser wand held 1 mm from the skin over body acupuncture points for 60 seconds of stimulation.21 The results of their study conflict with other studies resulting in decreased clinical pain after laser treatment.1,2,6-8 Laser beam divergence may have occurred because of the distance from the wand to the tissue, yielding decreased energy density,3 as opposed to our study's method of contacting the skin with the laser probe.

Our study involved ear point stimulation only. Combining ear and body point stimulation has been suggested as an effective pain-relief method.2,22 Kleinkort and Foley reported decreased pain and other positive healing outcomes in patients with chronic pain using laser stimulation of combined ear and body points.2 Delay of maximum analgesia following auricular TENS has been suggested by Noling et al20 and following electroacupuncture by Kitade and Hyodo.22 Kitade and Hyodo reported that the analgesic effect of auriculotherapy persisted after stimulation and that several subjects reached maximum pain threshold at 50 minutes after initiation of electrical stimulation of six auricular acupuncture points.22 Noling et al found continued pain threshold increases at 5 and 10 minutes after cessation of auricular TENS.20 Vizi et al alluded to a 3- to 10-minute delayed effect of ruby laser (694 nm) irradiation and a continued response lasting for 25 to 30 minutes.14 Because we took threshold measurements immediately post-treatment in the present study, future laser studies could look at the possibility of continued increases in experimental pain threshold by taking additional measurements in timed increments following treatment.

**Conclusions**

In a group of 41 healthy subjects, the use of helium-neon laser auriculotherapy resulted in a statistically significant increase in experimental pain threshold. The Control Group, receiving sham stimulation, did not exhibit a statistically significant increase in
pain threshold. These results suggest that helium-neon laser auriculotherapy may be an effective noninvasive pain management technique. Laser stimulation is comfortable, providing only a mild tactile sensation, and may be an alternative to TENS. This alternative is important to physical therapists because of some patients' intolerance of electrical stimulation. To determine whether this form of treatment is effective in a clinical setting, additional research involving patients with pain is needed.

References

4. Boussignac, referred to in Basford J: Low-energy laser treatment of pain and wounds: