Effect of Laser Acupuncture on Arterial Pulse

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Abstract: Laser acupuncture is defined as the stimulation of traditional acupuncture points with low-intensity, non-thermal laser irradiation. Possible advantages in using laser acupuncture are the noninvasive, painless and low risks of infection treatment. The purpose of this study is to assess the effect of laser acupuncture on the quality and waveform of arterial pulses. Ten acupuncture points were stimulated repeatedly three times in 30 individuals by laser with emission in the near infrared spectral region (808 nm) using an output power and power density of 45 mW and 143 W/cm². The analysis of pulse quality and waveform was performed based on the measurement of arterial pressure of the left and right wrist, using a 3-dimensional blood pressure pulse analyzer. Excess-like pulse quality of subjects before laser acupuncture changed significantly to balanced pulse quality after 10, 20, and 30 minutes of laser acupuncture; coefficient of deficient or excess, CDE, decreased significantly from 0.68 before acupuncture to 0.61, 0.55, and 0.55 after 10, 20, 30 minutes of laser acupuncture (p ≤ 0.006), respectively. Other pulse qualities, floating or sinking, slow or rapid, choppy or slippery did not change significantly by laser acupuncture (p > 0.05). Pulse waveform analysis showed that amplitude of main peak (systolic function or aortic compliance, h₁) of left and right artery pulse waves decreased significantly after 10, 20, and 30 minutes of laser acupuncture (p < 0.05). Other parameters, duration of one cardiac cycle (T), duration of rapid systolic ejection (T₁), duration of the systolic phase (T₄), and duration of the diastolic phase (T₅) of left and right artery pulses did not change significantly after laser acupuncture (p > 0.05).

Key words: laser acupuncture, arterial pulse, pulse analyzer, pulse quality, pulse waveform

I. Introduction

Although needle acupuncture’s incidence of adverse events is small, especially given the large number of treatments, complications such as hepatitis transmission and pneumothorax have occurred [1,2]. Such problems, coupled with many people’s aversion for needles, make laser therapy attractive. Laser acupuncture is defined as the stimulation of traditional acupuncture points with low-intensity, nonthermal laser irradiation [3].

Laser acupuncture is a noninvasive and low risk of infection, and painless potential alternative to traditional needle acupuncture. Researchers shined laser light on various parts of the body and found that light traveled under the skin to other acupuncture points, but it did not travel to places that were not on acupuncture meridians. It appears that the body contains a sort of fiber optic network—where light enters an acupuncture point, travels through the meridian and can be detected at other places along the meridian with a sensitive photon detector [4]. Studies show that laser acupuncture can help regenerate cells, decrease pain, reduce inflammation, and improve circulation [5]. Recent studies on laser acupuncture have included advanced brain imaging, as well as several other modern protocols for measuring various physiological effects to the body. These studies show that laser acupuncture has physiological effects, not only locally, but also in the brain, similar to needle acupuncture [6].

However published laser acupuncture studies have concentrated mostly on pain relief [3]. Few laser acu-
puncture studies have reported its effect on arterial pulse, which is a main diagnostic tool for practitioners. In this paper we report clinical effects of laser acupuncture on the quality and waveform of arterial pulse.

II. Experiments

The effect of the laser acupuncture on arterial pulse was tested by using it on 30 healthy male volunteers who consented to participate in this study. Males only were studied to control for possible gender variations. Table 1 shows mean and standard deviation of their ages, heights, weights, and body mass indexes.

Subjects’ left and right arterial pulse waveforms of Guan positions before treatment were recorded by using a 3-dimensional blood pressure pulse analyzer (DMP-3000, DaeyoMedi Co., Korea) as shown in Fig. 1. Guan position is one of the three typical palpation positions, Chon, Guan and Cheok of wrist used by oriental medical doctors. Then an oriental medical doctor with over 30 years of experience performed laser acupuncture on the subjects’ right side acupuncture points in the following order; LI-1 (Hegu), Liv-3 (Taichong), St-36 (Zusanli), Pc-6 (Neiguan), and SJ-5 (Waiguan) and then corresponding left side acupuncture points in the same order. The positions of the acupuncture points were shown in Fig. 2 and determined in accordance with WHO. He repeated this set of laser acupuncture three times. Therefore

Table 1. Subjects’ physical indexes.

<table>
<thead>
<tr>
<th>Subjects’ physical indexes</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (year)</td>
<td>23.6</td>
<td>1.6</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>173.5</td>
<td>2.0</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>65.3</td>
<td>2.5</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>22.7</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Fig. 1. Photograph of a pulse-taking operation showing palpation positions of Chon, Guan and Cheok.

1. Guan position is one of the three typical palpation positions, Chon, Guan and Cheok of wrist used by oriental medical doctors. Then an oriental medical doctor with over 30 years of experience performed laser acupuncture on the subjects’ right side acupuncture points in the following order; LI-1 (Hegu), Liv-3 (Taichong), St-36 (Zusanli), Pc-6 (Neiguan), and SJ-5 (Waiguan) and then corresponding left side acupuncture points in the same order. The positions of the acupuncture points were shown in Fig. 2 and determined in accordance with WHO. He repeated this set of laser acupuncture three times. Therefore

Fig. 2. Photographs of laser acupuncture operations. (A) LI-1 (Hegu), (B) Liv-3 (Taichong), (C) St-36 (Zusanli), (D) Pc-6 (Neiguan), and (E) SJ-5 (Waiguan).
he performed total 30 acupunctures for a subject: (5
acupunctures on right side + 5 acupunctures on left
side) × 3 times = 30 acupunctures. Each laser acu-
puncture took 1.5 seconds. Left and right arterial
pulse waveforms were again recorded using the pulse
analyzer 10, 20, and 30 minutes after the treatment.

The laser he used was assembled in our laboratory.
We used a continuous wave diode laser coupled with
a multimode optical fiber (200 μm in core diameter,
OMA Co.) to build a laser pen (Fig. 3). The wavelength
and output power of the laser were 808 nm (near
infrared) and 45 mW. When treating the end of optical
fiber directly contacted to subject’s skin.

Power density and energy density per an acu-
puncture were 45 mW / (3.14 × 0.01 cm × 0.01 cm) ≈ 143 W/
cm² and 143 W/cm² × 1.5 s ≈ 215 J/cm², respectively. Because he acupunctured 3 times for an acupuncture
point, power density and energy density per an acu-
puncture point were 143 W/cm² × 3 times = 429 W/
cm² and 215 J/cm² × 3 times = 645 J/cm², respectively.
Total energy dose and energy dose density per a subject
were (45 mW)(10 points)(3 times)(1.5 s) ≈ 20 J and
(143 W/cm²)(10 points)(3 times)(1.5 s) ≈ 6.45 kJ/cm².

The pulse analyzer was commercially available and
approved by the Korea Food and Drug Administration
(MFDS). It operates with the applanation tonometry
method to apply pressure and acquire pulse wave-
forms at the traditional palpation positions. The device
uses a motor-actuated pressure sensor, which contains
five sensing elements arrayed crosswise within 10 ×
10 mm². Each sensing element is a piezo-resistive
sensor of size about 2 × 3 mm². After an operator
places the sensor at the proximity of Guan, by an
automated algorithm, the device fine-tunes the sensor
location and measures pulse waveforms with varying
applied pressures at five discrete pressure steps: 28 ±
2, 64 ± 4, 99 ± 4, 133 ± 4, and 164 ± 4 mmHg (mean ±
standard deviation) in this study. Each pressure step
is maintained constant for five seconds [7].

We obtained twenty five pulse waves per a measure-
ment for each left and right arteries; (five sensing
elements) × (five pressure steps) = twenty five waves:
thus total fifty waves for left and right. Four pulse
qualities - deficient or excess, floating or sinking, slow
or rapid, and choppy or slippery were extracted using
fifty pulse waves of left and right arteries according
to the references [7-10]. The pulse qualities were ex-
pressed using coefficients: C_{DE}, C_{FS}, C_{SR}, and C_{CS}
for deficient or excess, floating or sinking, slow or rapid,
and choppy or slippery, respectively. The coefficients
had value between 0 and 1. If C_{DE}, C_{FS}, C_{SR}, and C_{CS}
are close to 0, the pulse is said to be deficient-like,
floating-like, slow-like, and choppy-like, respectively.
If C_{DE}, C_{FS}, C_{SR}, and C_{CS} are close to 1, the pulse is
said to be excess-like, sinking-like, rapid-like, and
slippery-like, respectively. If C_{DE}, C_{FS}, C_{SR}, and C_{CS}
are near 0.5, the pulse is said to be in balance.

To check change in pulse waveform before and after
laser acupuncture, among five pulse waves obtained
by a center sensing element, we choose a pulse wave
with largest main peak as a representative pulse
wave. For example among five pulse waves obtained
with increasing applied pressures at five discrete
steps from step 1 to step 5 in Fig. 4(a), the pulse
wave of step 3 has the largest main peak and is a
representative pulse wave. Then we analyzed para-
eters h₁, T, T₁/T, T₂/T, T₃/T, and T₄/T₅ as defined in
Fig. 4(b) before and after laser acupuncture. Where h₁,
T, T₁, T₂, and T₃ are amplitude of main peak (systolic
function or aortic compliance), duration of one cardiac
cycle, duration of rapid systolic ejection, duration of the
systolic phase, and duration of the diastolic phase [11].

We evaluated whether the changes of the co-
efficients and the parameters after laser acupuncture
are statistically significant or not using p-value driven
III. Results

1. Pulse Quality

Fig. 5(A) shows means (bars) and ± standard deviations (error bars) of coefficients of deficient or excess, $C_{DE}$, before laser acupuncture, and after 10 minutes, 20 minutes, and 30 minutes of laser acupuncture. Mean of $C_{DE}$ decreased significantly from 0.68 before acupuncture to 0.61, 0.55, and 0.55 after 10 minutes, 20 minutes, and 30 minutes of laser acupuncture, respectively ($p \leq 0.006$): thus excess-like pulse before laser acupuncture changed to balanced pulse after laser acupuncture.

Fig. 5(B), (C), and (D) show means (bars) and ± standard deviations (error bars) of coefficients of floating or sinking, $C_{FS}$, slow or rapid, $C_{SR}$, and choppy or slippery, $C_{CS}$, before laser acupuncture, and after 10 minutes, 20 minutes, and 30 minutes of laser acupuncture. $C_{FS}$, $C_{SR}$, and $C_{CS}$ did not change significantly after laser acupuncture ($p > 0.05$).

2. Pulse waveform

Fig. 6(A) shows means (bars) and ± standard deviations (error bars) of amplitude of main peak (systolic function or aortic compliance) of representative wave ($h_1$) before laser acupuncture, and after 10 minutes, 20 minutes, and 30 minutes of laser acupuncture. $R$ and $L$ denote pulse waveforms of right and left arteries. $h_1$ decreased significantly after laser acupuncture compared to before acupuncture ($p < 0.05$).

Fig. 6(B,D,E) and (F) show means (bars) and ±
standard deviations (error bars) of duration of one cardiac cycle ($T$), ratio of duration of rapid systolic ejection to duration of one cardiac cycle ($T_1/T$), ratio of duration of the systolic phase to duration of one cardiac cycle ($T_4/T$), ratio of duration of the diastolic phase to duration of one cardiac cycle ($T_5/T$), and ratio of duration of the systolic phase to duration of the diastolic phase ($T_4/T_5$). $T$, $T_1/T$, $T_4/T$, $T_5/T$ and $T_4/T_5$ did not change significantly after laser acupuncture ($p > 0.05$).

IV. Discussion

A central tenet of acupuncture contends that energy (Qi) flows through the body along defined subsurface paths [13,14]. The maintenance of good health requires that such flow be in balance. Conversely, any disturbance in this flow results in an energy imbalance, either an excess or a deficiency, which in turn results in disease. Practitioners palpate radial artery pulse and diagnose whether energy flow is in balance or not. Acupuncture attempts to regulate and restore energy balance by stimulating specific points along the paths and hence treat the disease [3].

The ten points - left and right LI-1 (Hegu), Liv-3 (Taichong), St-36 (Zusanli), Pc-6 (Neiguan), and SJ-5 (Waiguan) that we used for laser acupuncture are the representative points mostly used to regulate energy balance in common practice. Before and after treatment, we diagnosed left and right arterial pulses using a pulse analyzer. Results show that laser acupuncture changed subjects’ pulse from excess-like to balanced state (See Fig. 5(A)). But other qualities of pulse such as floating or sinking, slow or rapid, and choppy or slippery, showed no change with statistical significance after laser acupuncture.

Pulse pressure is a complex parameter determined by the interplay between several variables such as the amplitude of cardiac contraction, volume of blood
flow, and the tensile compliance of the arterial wall. An excess-like pulse is defined as having large pulse amplitude over a range of the hold-down pressures, while a deficient-like pulse is defined as one with small pulse amplitude [15].

The algorithm to determine if one’s pulse is excess-like or deficient-like is complicated. But it is mainly affected by pulse pressure. Pulse pressure is defined as the difference between systolic and diastolic blood pressure in a cardiac cycle and is equivalent to the maximum amplitude among the pulse amplitudes at five applied pressure steps [16]. Thus we choose a pulse wave with the largest main peak among five pulse waves obtained by a center sensing element as a representative pulse wave and investigated the amplitude (h₁) of main peak of the representative pulse wave before and after laser acupuncture. We found a decrease in h₁ after laser acupuncture (See Fig. 6(A)).

The decrease of h₁ is one of the factors that results in the decrease of C DE and the change of pulse from excess-like to balanced state. Other parameters, duration of one cardiac cycle (T), duration of rapid systolic ejection (T₁), duration of the systolic phase (T₄), and duration of the diastolic phase (T₅) did not change significantly after laser acupuncture; this is consistent with no significant change in pulse qualities of floating or sinking, slow or rapid, and choppy or slippery.

Similar regulatory effects have been reported by traditional needle acupuncture. J.K. Won et al. reported decrease of pulse energy and h₁ after traditional needle (0.3 mm × 30 mm) acupuncture on four acupuncture points, left and right LI-1 (Hegu, 1.5-2 cm penetration depth) and Liv-3 (Taichong, 1-1.5 cm penetration depth), which are the same four points out of our ten points, for 15 minutes [17].

It is interesting that laser acupuncture with low power 45 mW and short treatment time 1.5 seconds resulted in similar regulatory efficacy to traditional needle acupuncture penetrating 1-2 cm for 15 minutes. The near infrared laser (808 nm) that we used is known to penetrate into the skin as deep as 2-3 cm [18]. The incident beam diameter was as small as 0.2 mm as it was come out from an optical fiber, which is comparable with the diameter (0.2-0.3 mm) of a traditional needle used for acupuncture. The small beam diameter resulted in high power density 143 W/cm². These may result in the similar efficacy.

V. Conclusions

Laser acupuncture was performed three times on ten acupuncture points- left and right LI-1 (Hegu), Liv-3 (Taichong), St-36 (Zusanli), Pe-6 (Neiguan), and SJ-5 (Waiguan) of thirty healthy male subjects. We used a laser with output power 45 mW and power density 143 mW/cm² for 1.5 seconds on each acupuncture point. We investigated effects of the laser acupuncture on left and right arterial pulses using a pulse analyzer. Excess-like pulse quality of the subjects before laser acupuncture changed significantly to balanced pulse quality after 10, 20, and 30 minutes of laser acupuncture; coefficient of deficient or excess, C DE, decreased significantly from 0.68 before acupuncture to 0.61, 0.55, and 0.55 after 10, 20, 30 minutes of laser acupuncture, respectively (p ≤ 0.006). Other pulse qualities, floating or sinking, slow or rapid, choppy or slippery did not change significantly by laser acupuncture (p > 0.05). Pulse waveform analysis showed that amplitude of main peak (systolic function or aortic compliance, h₁) of left and right arterial pulses decreased significantly after 10, 20, and 30 minutes of laser acupuncture (p < 0.05). Other parameters, duration of one cardiac cycle (T), duration of rapid systolic ejection (T₁), duration of the systolic phase (T₄), and duration of the diastolic phase (T₅) of left and right arterial pulses did not change significantly after laser acupuncture (p > 0.05). The decrease of h₁ supports the decrease of C DE and the change from excess-like to balanced pulse. No significant change in the other parameters (T, T₁, T₄, and T₅) agrees with no significant change in pulse qualities such as floating or sinking, slow or rapid, and choppy or slippery.

References