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학 술 논 문

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, nonthermal 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 out power and power density of 45 mW and 143 W/cm^2. 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, 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 ($p \leqq 0.006$), 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, h_1) 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 (T_1), duration of the systolic phase (T_4), and duration of the diastolic phase (T_5) 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-

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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.

Table 1. Subjects' physical indexes.

Subjects' physical indexes	Mean	Standard deviation
Age (year)	23.6	1.6
Height (cm)	173.5	2.0
Weight (kg)	65.3	2.5
Body mass index (kg/m^2)	22.7	1.3

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 corresponsive 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

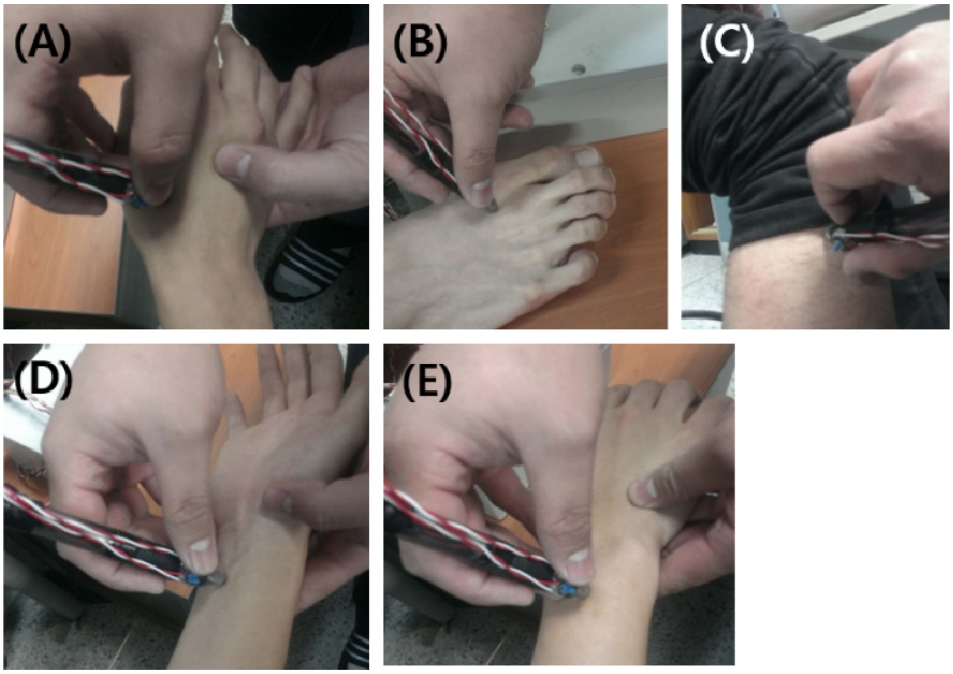

Fig. 2. Photographs of laser acupuncture operations. (A) LI-1 (Hegu), (B) Liv-3 (Taichong), (C) St-36 (Zusanli), (D) Pc-6 (Neiguan), and (E) SJ-5 (Waiguan).

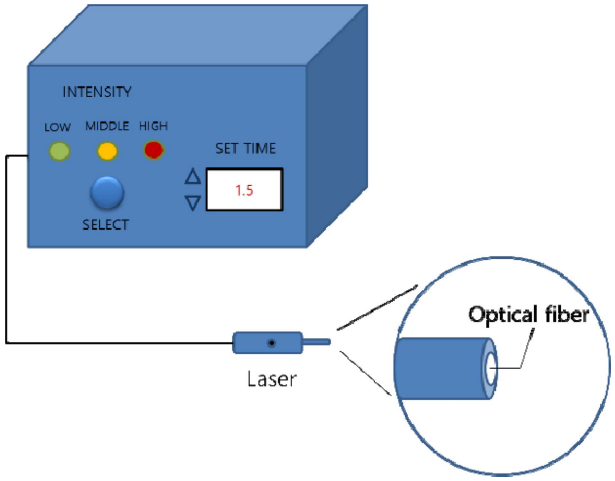

Fig. 3. Schematic diagram of laser pen.

he performed total 30 acupunctures for a subject: (5 acupunctures on right side + 5 acupunctures on left side) × 3 times = 30 acupunctures. Each laser acupuncture 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 acupuncture were 45 mW / (3.14 × 0.01 cm × 0.01 cm) ≈ 143 W/cm^2 and 143 W/cm^2 × 1.5 s ≈ 215 J/cm^2, respectively. Because he acupunctured 3 times for an acupuncture point, power density and energy density per an acupuncture point were 143 W/cm^2 × 3 times = 429 W/cm^2 and 215 J/cm^2 × 3 times = 645 J/cm^2, 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/cm^2)(10 points)(3 times)(1.5 s) ≈ 6.45 kJ/cm^2.

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 waveforms at the traditional palpation positions. The device uses a motor-actuated pressure sensor, which contains five sensing elements arrayed crosswise within 10 × 10 mm^2. Each sensing element is a piezo-resistive sensor of size about 2 × 3 mm^2. 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 measurement 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 expressed 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 parameters h_1, T, T_1/T, T_4/T, T_5/T, and T_4/T_5 as defined in Fig. 4(b) before and after laser acupuncture. Where h_1, T, T_1, T_4, and T_5 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 coefficients and the parameters after laser acupuncture are statistically significant or not using p-value driven

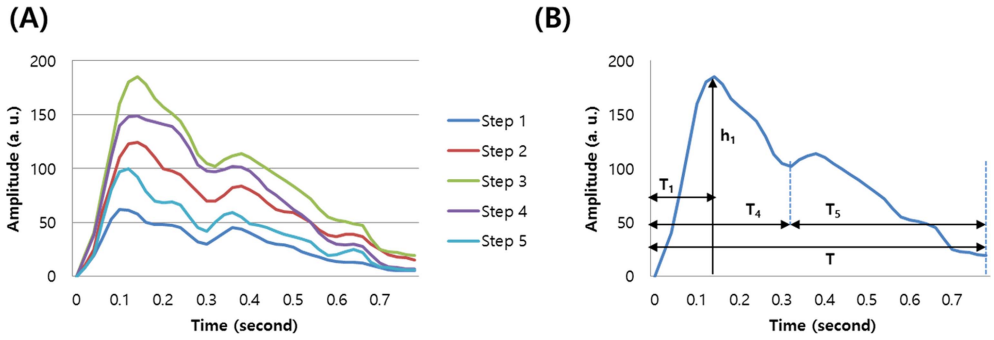

Fig. 4. (A) Five pulse waves obtained by a center sensing element with increasing applied pressures at five discrete steps from step 1 to step 5. (B) A typical arterial pulse waveform showing parameters h_1, T, T_1, T_4, and T_5.

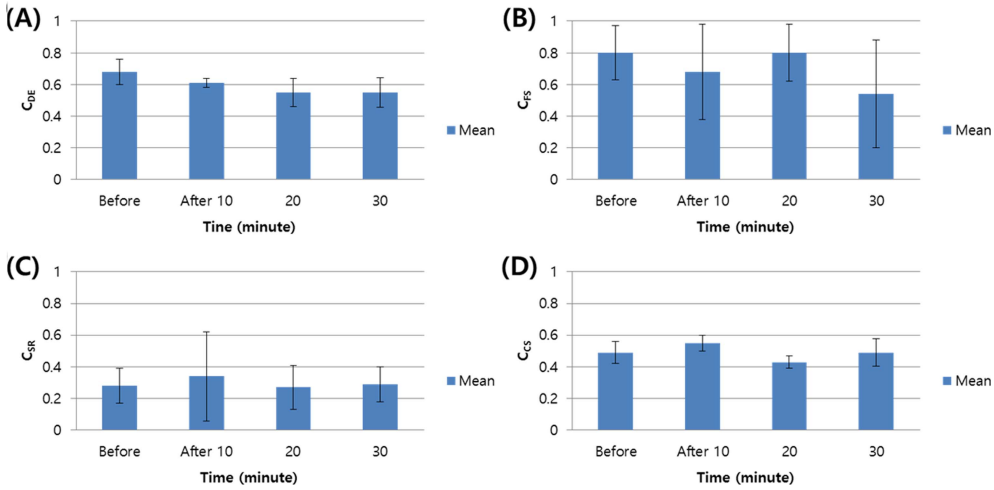

Fig. 5. Means (bars) and ± standard deviations (error bars) of coefficients of pulse qualities before and after 10, 20, 30 minutes of laser acupuncture. (A) Coefficient of deficient or excess, C_{DE}, (B) coefficient of floating or sinking, C_{FS}, (C) coefficient of slow or rapid, C_{SR}, and (D) coefficient of choppy or slippery, C_{CS}.

from a paired t-test. The criterion for significance was $p < 0.05$[12].

III. Results

1. Pulse Quality

Fig. 5(A) shows means (bars) and ± standard deviations (error bars) of coefficient 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, 30 minutes of laser acupuncture, respectively ($p \leqq 0.006$): 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. h1 decreased significantly after laser acupuncture compared to before acupuncture ($p < 0.05$).

Fig. 6(B,C,D,E) and (F) show means (bars) and ±

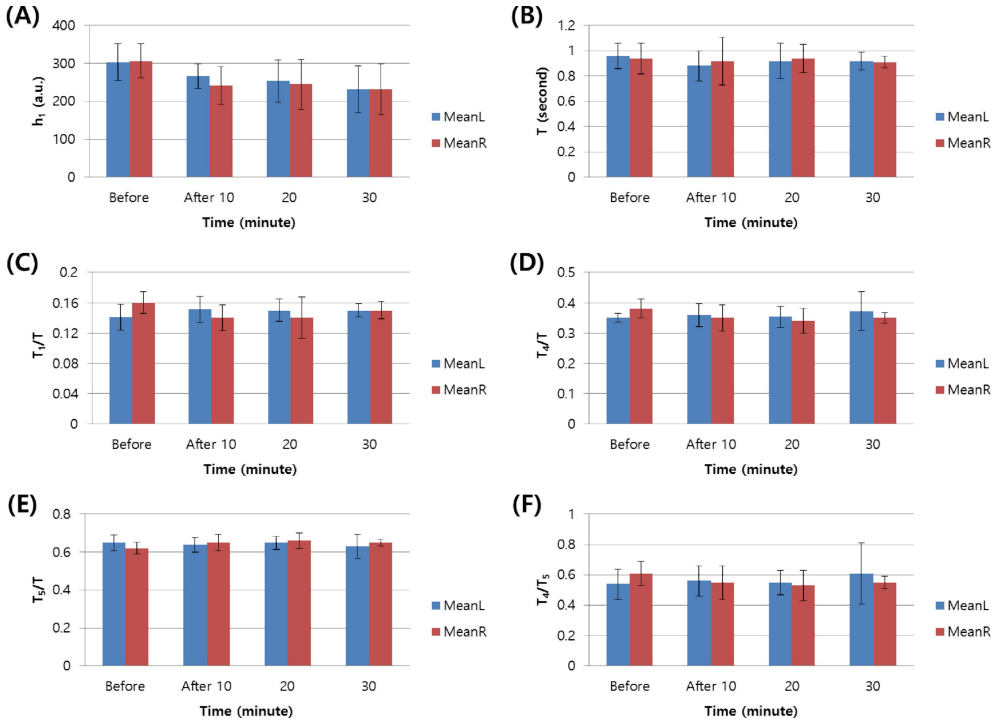

Fig. 6. Means (bars) and ± standard deviations (error bars) of pulse wave parameters before and after 10, 20, 30 minutes of laser acupuncture. (A) Amplitude of main peak (systolic function or aortic compliance), h_1, (B) duration of one cardiac cycle, T, (C) ratio of duration of rapid systolic ejection to duration of one cardiac cycle, T_1/T, (D) ratio of duration of the systolic phase to duration of one cardiac cycle, T_4/T, (E) ratio of duration of the diastolic phase to duration of one cardiac cycle. T_5 /T, and (F) ratio of duration of the systolic phase to duration of the diastolic phase T_4/T_5. MeanL and meanR denote means of left and right pulse wave parameters.

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 before laser acupuncture, and after 10 minutes, 20 minutes, and 30 minutes of laser acupuncture. 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 obtain by a center sensing element as a representative pulse wave and investigated the amplitude (h_1) of main peak of the representative pulse wave before and after laser acupuncture. We found a decrease in h_1 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 (T_1), duration of the systolic phase (T_4), and duration of the diastolic phase (T_5) 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 h_1 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/cm^2. 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), Pc-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/cm^2 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 ($p \leq 0.006$). 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, h_1) 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 (T_1), duration of the systolic phase (T_4), and duration of the diastolic phase (T_5) of left and right arterial pulses did not change significantly after laser acupuncture ($p > 0.05$). The decrease of h_1 supports the decrease of C_{DE} and the change from excess-like to balanced pulse. No significant change in the other parameters (T, T_1, T_4, and T_5) agrees with no significant change in pulse qualities such as floating or sinking, slow or rapid, and choppy or slippery.

References

[1] E. Ernst and A. White, "Life-threatening adverse reactions after acupuncture? A systematic review", *Pain*, vol. 71, pp. 123-126, 1997.

[2] ET. Peuker, A. White, E. Ernst, F. Pera, and TJ. Filler, "Traumatic complications of acupuncture: therapists need to know

human anatomy", *Arch. Fam. Med*., vol. 8, pp. 553-558, 1999.
[3] Peter Whittaker, "Laser acupuncture: past, present, and future", *Lasers in Medical Science*, vol. 19, pp. 69-80, 2004.
[4] S. Pankratov, "Meridians Conduct Light (In German)", *Raun und Zeit*, vol. 35, pp. 16-18, 1991.
[5] K. Thompson, "Laser Acupuncture in Your Practice: What you Need to Know", *Acupuncture Today*, vol. 14, pp. 05, 2013.
[6] I. Quah-Smith, PS. Sachdev, W. Wen, X. Chen, and MA. Williams. "The Brain Effects of Laser Acupuncture in Healthy Individuals: An fMRI Investigation", *PLoS ONE*, vol. 5, pp. e12619, 2010.
[7] J.U. Kim, Y.J. Jeon, Y.-M. Kim, H.J. Lee, and J.Y. Kim, "Novel diagnostic model for the deficient and excess pulse qualities", *Evidence-Based Complementary and Alternative Medicine*, Article no. 563958, 2012.
[8] S. Kown, H.J. Kang, Y.K. Yim, and Y. Lee, "A study on floating and sinking pulse by classification of pulse pattern through analysis of P-H volume curve at 5 applied pressure levels", *Korean J. Meridian Acupoint*, vol. 27 (Suppl. 1), pp. 13-22, 2010. [In Korean, English abstract]
[9] Y.B. Park, and W. Hur, "Research for quantification of slow, wan-maek and rapid pulse by pulse/respiration rate on hyperthyroidism and hypothyroidism patients", *J. Korea Inst. Orient. Med. Diagn*., vol. 3 (Suppl 1), pp. 20-27, 1999. [In Korean, English abstract]
[10] H.H. Ryu, J. Lee, Y.J. Jeon, Y.J. Lee, S.W. Lee, and J.Y. Kim, "Modern medical scientific study on the string pulse", *Korean J. Oriental Physiology & Pathology*, vol. 22 (Suppl. 3), pp. 535-539, 2008. [In Korean, English abstract]
[11] T.C.Yan, "Developing an objective traditional chinese medicine pulse diagnostic model in essential hypertension", *Thesis*, Hong Kong, China, Hong Kong Polytechnic University, 2009, pp. 57
[12] R. Nuzzo, "Scientific method: Statistical errors". *Nature* vol. 506, pp 7487, 2014.
[13] D. Pearl, E. Schillinger, "Acupuncture: its use in medicine", *West J. Med*., vol. 171, pp. 176-180, 1999.
[14] J. O'Connor and D. Bensky, *Acupuncture: a comprehensive text*, Seattle, USA, Eastland Press, 1981, pp. 89-91.
[15] J.U. Kim, Y.J. Jeon, Y.-M. Kim, H.J. Lee, and J. Y. Kim, "Novel Diagnostic Model for the Deficient and Excess Pulse Qualities", *Evidence-Based Complementary and Alternative Medicine*, vol. 2012, pp. 11, 2011.
[16] W. W. Nichols and M. F. O'Rourke, *McDonald's Blood Flow in Arteries. Theoretical, Experimental and Clinical Principles*, London, UK, Hodder Arnold, 2005, pp. 125-127.
[17] J.K. Won, S. K. Jung, D.E. Kim, J.Y. Lim, Y.D. Kwon, S.R. Yeom, S.K. Lee, and Y.S. Song, "Study on the Radial Pulse Wave Variables and Heart Rate Variability after Acupuncture Stimulation", *Korean J. Oriental Physiology & Pathology*, vol. 23, pp. 237-244, 2009.
[18] D. Smith, *Lamp Emission Spectra.,* New York, USA, PTI Technical Note, 2012, pp. 23-25.