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Vascular Effects of Auricular Acupuncture Evaluated via Two Digital Volume Pulse Measurements

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1. Introduction

Stimulation of some auricular acupoints produces changes in the radial pulse (Nogier, 1989), and electric stimulation of the auricular acupoint stomach can modify the radial artery pulse wave (Ikezono et al., 2003). Measurement of light transmission through the finger pulp during the cardiac cycle (photoplethysmography) provides a digital volume pulse (DVP). Changes in the contour of the DVP associated with aging, vascular disease, and drugs have been described (Dillon & Hertzman, 1941; Morikawa, 1967). The contour of the DVP is mainly influenced by the systemic vasculature (Nichols, 2005).

A previous study has shown that the acute effects of manual acupuncture at the acupoint 6 of pericardium channel (PC6) on vascular pathophysiology in healthy and hypertensive subjects (Rivas-Vilchis et al., 2007), and non-smokers *versus* smokers (Rivas-Vilchis et al., 2008) can be detected by changes in the indices obtained from the second derivative of the DVP. Two indices derived from the DVP have been proposed. RI_{DVP} as an index of pressure wave reflection and SI_{DVP} as an estimate of pulse wave velocity (PWV) in the aorta and large arteries, i.e., an index of large artery stiffness (Chowienczyk et al., 1999; Millasseau et al., 2002; Millasseau et al., 2003). The purpose of the present study was to assess the acute differential vascular effects of auricular acupoints located in the right and left ear using two DVP indices.

2. Materials and methods

2.1 Subjects

Forty healthy volunteers, 23.4 ± 1.44 years of age (mean \pm SD), were recruited by advertisement from our university. Studies were performed with the approval of the Research Ethics Committee of the División de Ciencias Biológicas y de la Salud, Universidad Autónoma Metropolitana at Iztapalapa, conducted in accordance with the Declaration of Helsinki (2008) of the World Medical Association, and with the informed and written consent of the subjects. Subjects were randomly assigned to group A ($n=20$) or B ($n=20$), corresponding to recordings obtained for the left or right ear, respectively. The experimental design is depicted in Table 1. Each treatment was followed by a 1-week washout period in order not to carry over vascular effect according previous experiments not depicted.

Group A	Left auricular acupoint Shenmen	One week washout period	Left auricular acupoint Knee
Group B	Right auricular acupoint Shenmen		Right ear auricular acupoint Knee

Table 1. Experimental groups and treatments.

2.2 Methods

Measurements were obtained while subjects were in the supine position after an overnight fast and at least 20 min rest in a quiet temperature-controlled clinical laboratory (25±1°C) in order to achieve standard conditions in all participants.

Acquisition of DVP. A photoplethysmograph (MP100, BIOPAC Systems, Goleta, CA, USA), which transmitted infrared light at 860±90 nm, was placed on the index finger of either the right or left hand to obtain the DVP. The frequency response of the photoplethysmograph was flat at 10 Hz. Digital output from the photoplethysmograph was recorded through a 12-bit analog-to-digital converter with a sampling frequency of 200 points/s using the analysis platform provided by AcqKnowledge v. 3.9 software (BIOPAC Systems).

In each subject, a 7-min-long registration DVP was obtained. The acupuncture needle was inserted unilaterally and guided within a plastic tube into the designated auricular acupoint at a depth of 2 mm. The needle was manually unilaterally stimulated for 5 s (60-65 s of registration period), contralateral to the side of the DVP recording, and was then immediately withdrawn.

The DVP indices obtained for each subject, corresponding to basal (25-35 s of the 1 min period before acupuncture) and post-acupuncture (365-385 s) periods, i.e, 5-min after acupuncture stimulation, were calculated using the average of 10 waves.

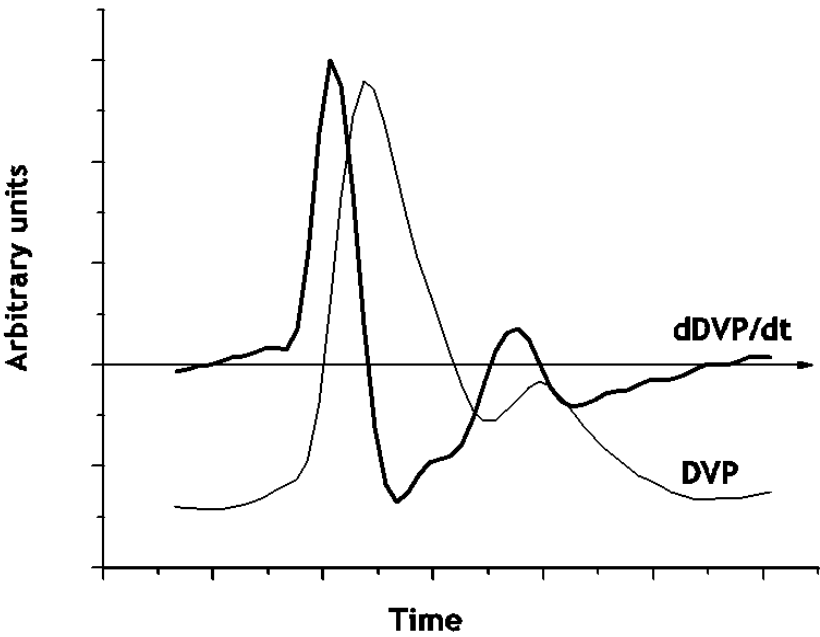


Fig. 1. DVP recording obtained by measuring the transmission of infrared light through the finger pulp, and its first derivative (dDVP/dt).

The first derivative of the DVP wave contour was obtained using the Origin graphics analyzer v. 7.5 (Microcal Software, Inc., Northampton, MA, USA) to specify inflection points (Figure 1). RI_{DVP} was determined as the height of the diastolic peak (or inflection point if no peak was present) and expressed as a percentage of the amplitude of the systolic peak. SI_{DVP} was calculated based on the subject's height (h) and the time between the systolic peak and diastolic peak/inflection points in the waveform (ΔT_{DVP}): $SI_{DVP} = h/\Delta T_{DVP}$.

RI_{DVP} was thus determined based on the relative amplitudes of the systolic and diastolic components of the DVP and SI_{DVP} according to the relative timing of these components (Figure 2). The diastolic peak/inflection point was defined as the point at which the first derivative of the waveform was closest to zero (Millaseau et al., 2002). A distinct peak occurred when the first derivative was zero (positive-to-negative zero crossing). In the absence of a distinct peak, the point of inflection was defined as the point at which the first derivative was closest to zero.

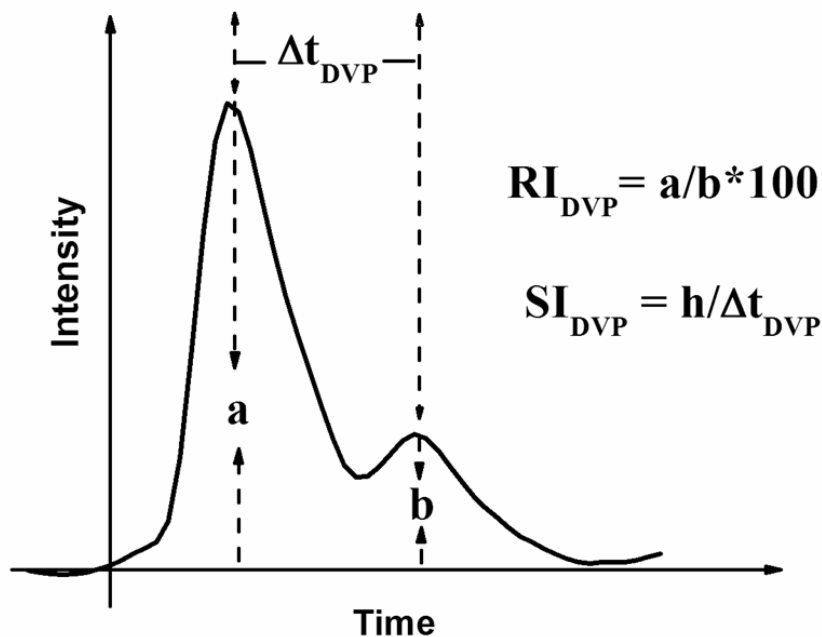


Fig. 2. RI_{DVP} and SI_{DVP} indices.

Acupuncture treatment. Acupuncture therapy was administered by a physician trained in both Western and traditional Chinese medicine. We used 1-cm long, 0.22-mm wide disposable stainless steel needles (Hwato, Suzhou, China), with no additional electrical or laser stimulation. The acupuncture needle was inserted unilaterally into the auricular acupoints Shenmen or Knee in the right or left auricle (Figure 3), gently stimulated for 5 s, and then removed. With respect to the primary objective of the study, the clinical investigators responsible for calculating the DVP indices were blinded and did not know whether the data belonged to the Shenmen or Knee auricular acupoints in either the left or right ear.

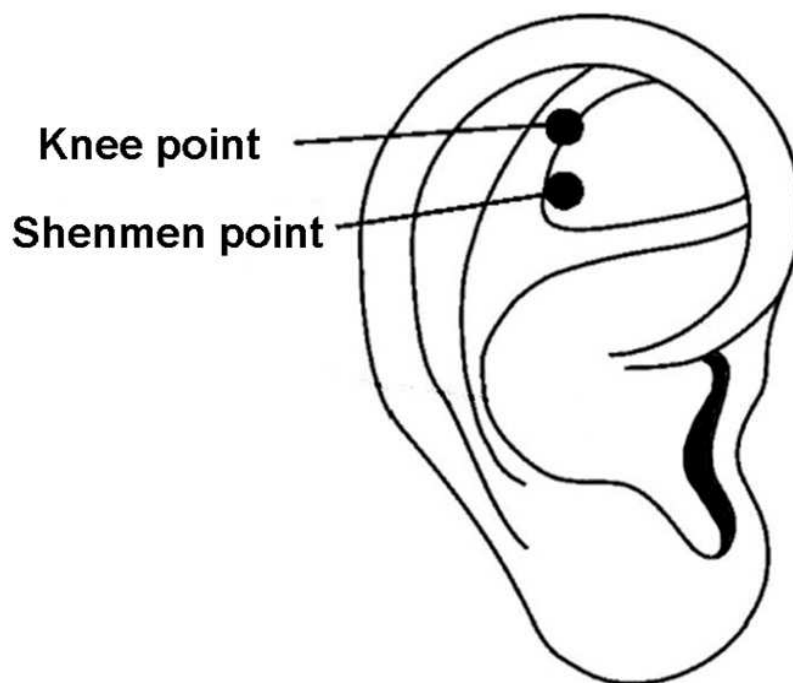


Fig. 3. Shenmen and Knee auricular acupoints.

Statistical analyses. Data are presented as means \pm SD (subject characteristics) or as means \pm SE (results). The Student's *t* test was used to compare normally distributed continuous variables. $p < 0.05$ was considered as significant, and all tests were two-sided. All statistical analyses were performed using SPSS software version 11.5 (SPSS Inc., Chicago, IL, USA).

3. Results

The study population consisted of 40 healthy male subjects having a global mean age of 23.4 ± 1.44 (21–26) years. The experimental groups did not significantly differ with regard to age, body mass index, or other relevant cardiovascular characteristics. Figures 4 and 5 show the changes observed in the RI_{DVP} and SI_{DVP} indices between the pre- and post-acupuncture periods.

In healthy subjects, manual stimulation of the right Knee auricular acupoint significantly reduced the RI_{DVP} (Figure 4) and manual stimulation of the left Knee auricular acupoint significantly increased the SI_{DVP} index (Figure 5), when comparing the pre- vs. post-acupuncture periods. Comparison of the post-acupuncture values revealed that the left Shenmen and Knee auricular acupoints elicited higher RI_{DVP} index values than their counterpoints on the right ($p < 0.05$ and $p < 0.001$, respectively).

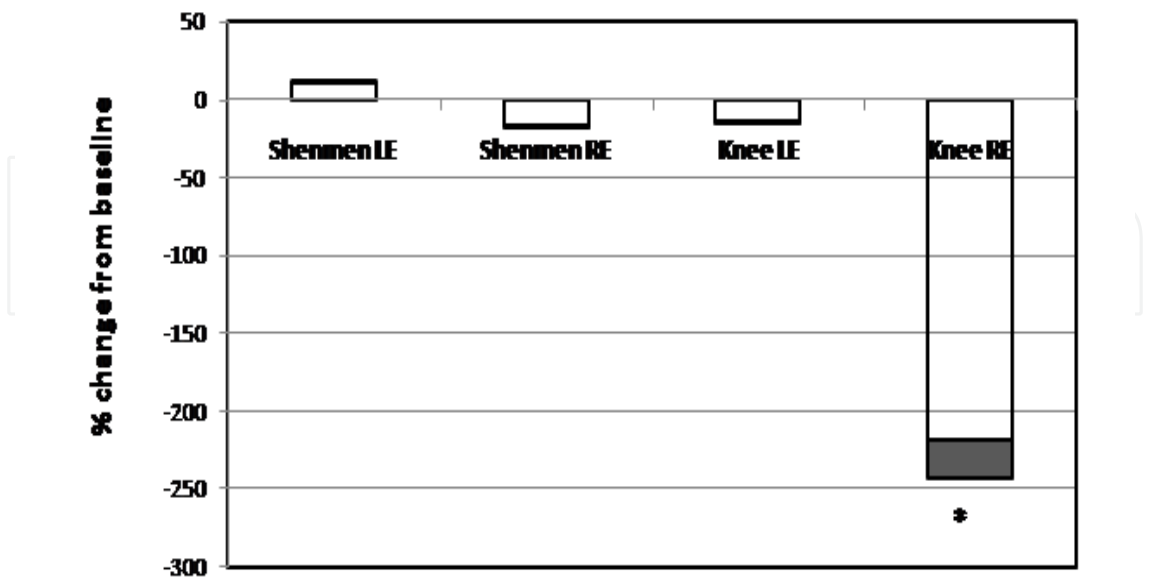


Fig. 4. Changes in percent units from baseline in RI_{DVP} index in healthy men (*n*=20) after 5 min of the five seconds acupuncture stimulation at the left or right auricular acupoints. LE = left ear; RE = right ear. **p* < 0.05.

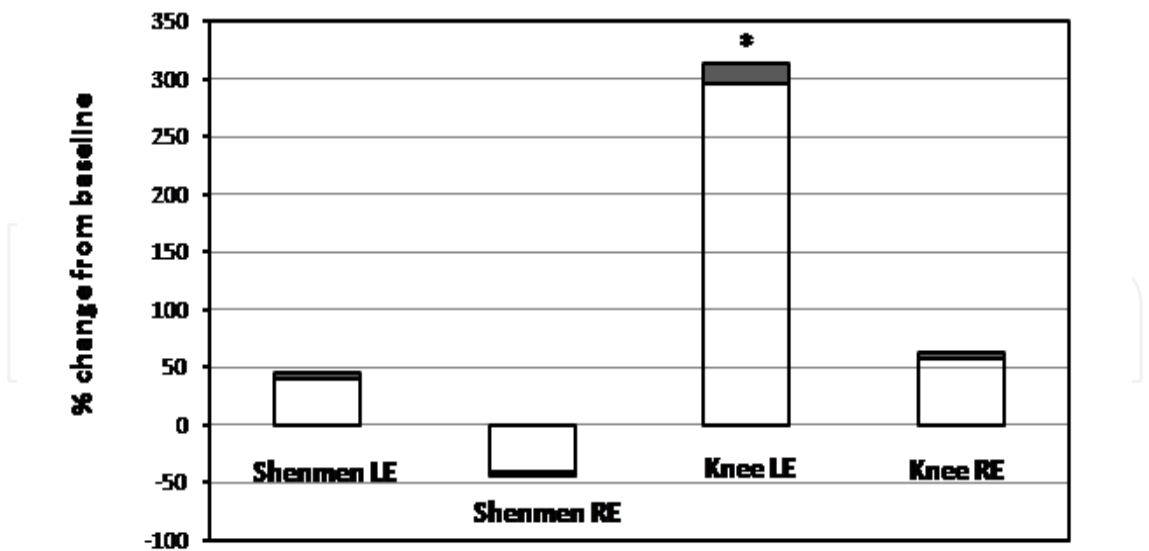


Fig. 5. Changes in percent units from baseline in SI_{DVP} index in healthy men (*n*=20) after 5 min of the five seconds acupuncture stimulation at the left or right auricular acupoints. LE = left ear; RE = right ear. **p* < 0.05.

4. Discussion

The principal findings of the present study were that manual stimulation of the right and left Knee auricular acupoints in healthy subjects were associated with a significant decrease and increase in the RI_{DVP} and SI_{DVP} index, respectively. Auricular acupuncture elicited significant differences in RI_{DVP} indices between the left and right ears for both the Shenmen and Knee acupoints, with lower values detected for the right auricular acupoints in both cases.

The principal findings of the present study were that manual stimulation of the right Knee acupoint was associated with significant decrease in the RI_{DVP} and the left Knee acupoint was associated with significant increase in SI_{DVP} index. Auricular acupuncture elicited significant differences in RI_{DVP} indices between the left and right ears for both the Shenmen and Knee acupoints, with lower values detected for the right auricular acupoints in both cases.

Photoplethysmography provides a simple means of deriving the DVP. Several studies have revised the usefulness of the reflection and stiffness indices to assess and quantify effects of vasoactive drugs and nitrates in systemic haemodynamics, such as changes in heart rate and blood pressure (Wagner et al., 1990; Millasseau et al., 2006). To the best of our knowledge, RI_{DVP} and SI_{DVP} have not been previously used to study the vascular mechanisms of auricular acupoints. It has been suggested that DVP consists of a direct component arising from pressure waves propagating from the heart to the finger, as well as a delayed component arising from pressure waves reflected backward from the peripheral arteries, mainly in the lower body, which then propagate to the finger and possess a complex but predictable relationship with the aortic pulse pressure (Chowienczyk et al, 1999).

The RI_{DVP} index provides a measure of the amount of wave reflection in systemic circulation (Millasseau et al, 2006). The RI_{DVP} index is also sensitive to vasodilator inputs (Kelly et al., 2001; Stewart et al, 2003), it has been shown that nitrovasodilators such as glyceryl trinitrate produce reduction in RI index (Chowienczyk et al., 1999). SI_{DVP} is derived from the subject's height and the timing of the diastolic peak/inflection point of the waveform (Figure 2). It provides an estimate of the pulse wave velocity (PWV) in the aorta and large arteries, and therefore the stiffness of the large artery (Chowienczyk et al., 1999; Millasseau et al., 2003). Therefore, it has been shown that the powerful vasoconstrictor angiotensin II increase SI_{DVP} index (Millasseau et al., 2003).

Auricular acupoints have been shown to produce therapeutic effects on cardiovascular pathophysiology (Huang & Liang, 1992), as well as vascular peripheral modifications (Ikezono et al., 2003). The present findings demonstrating a correlation between needling the right Knee auricular acupoint and a decreased RI_{DVP} index probably indicates that this procedure evoked a vagal response. On the other hand, the correlation between needling the left Knee auricular acupoint and an increased SI_{DVP} index demonstrated herein indicates an increase in the PWV, most likely related to a sympathetic response. The RI_{DVP} and SI_{DVP} indices were selected because of their usefulness in assessing cardiovascular changes elicited by a variety of chemical and pharmacological stimuli. Our results clearly demonstrate the potential for auricular acupoints to modify these DVP indices.

5. Conclusions

The present study has one potential limitation, in that only two acupoints were analyzed. The mechanisms of the differences observed between right and left stimulation remain to be

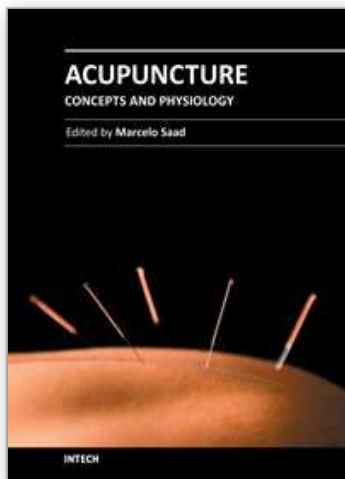
elucidated. Contour analysis of the DVP provides a rapid means of evaluating vascular tone and arterial stiffness, and therefore can be used to assess the cardiovascular effects and the related mechanisms associated with auricular acupoints.

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