Vascular Responses to Manual PC6 Acupuncture in Nonsmokers and Smokers Assessed by the Second Derivative of the Finger Photoplethysmogram Waveform

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Abstract
Background: Smoking is reported to increase arterial stiffness. Indices obtained from the second derivative of digital volume pulse (SDDVP) waveform have been proposed to characterize vascular aging and arterial rigidity. PC6 (Neiguan) is a traditional acupoint in each forearm that has been shown to modify cardiovascular functioning.

Objective: To investigate the acute effects of manual needling with PC6 on SDDVP indices in healthy chronic smoker and nonsmoker subjects.

Subjects and Methods: Aging index (AI) was defined as \((b - c - d - e) / a\), B:A was calculated as the ratio of the absolute value for the height of the \(b\) wave (B) to that of the \(a\) wave (A), and D:A was calculated as the ratio of the absolute value for the height of the \(d\) wave (D) to that of the \(a\) wave (A). These indices derived of the wave components of SDDVP of healthy nonsmokers \((n=40; 28.3 \pm 3.0\) years old) vs. chronic smokers \((n=30; 29.9 \pm 2.9\) years old) were compared. The digital volume pulse (DVP) was obtained by measuring infrared light transmission through the finger. Of each subject, a DVP registration 20 minutes long was obtained. PC6 was stimulated unilaterally by manual needling for 5 minutes \((1-6\) minutes). SDDVP indices were compared in each subject in pre- vs. post-acupuncture periods \((30\) seconds vs. \(18\) minutes, respectively).

Results: At baseline, we found significant difference in B:A between nonsmokers and smokers. Comparing pre- vs. post-acupuncture periods, B:A and D:A did not show significant differences among nonsmokers, but B:A improved significantly in smokers and AI improved significantly in both nonsmokers and smokers.

Conclusion: These findings suggest that manual needling with PC6 could revert some of the deleterious effects on vascular functioning produced by chronic cigarette smoking.

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1. Introduction

Smoking is a major risk factor in the development and progression of cardiovascular disease [1]. Overwhelming evidence supports the conclusion that cigarette smoking causes various adverse cardiovascular events [2,3]. There is evidence that compliance of both large- and medium-sized arteries decreases immediately after smoking one cigarette [4,5]. McVeigh et al [6], using invasive methods, demonstrated abnormalities in the brachial artery pressure waveforms of chronic smokers. In older subjects, smoking is associated with increased carotid artery stiffness [7], even in the absence of atherosclerosis of the vessel. Impairment of vasodilatory function is one of the earliest manifestations of atherosclerotic changes in a vessel. In both animal and human models, several studies have demonstrated that both active and passive cigarette smoke exposure were associated with a decrease in vasodilatory function [8–12].

The second derivative of the finger photoplethysmogram (SDPTG) waveform permits the assessment of peripheral circulation and changes elicited by vasoactive agents by detailed analysis of digital volume pulse (DVP) analysis [13]. In particular, SDPTG allows more accurate recognition of the circulation phases, and it is easier to interpret than the DVP waveform. Epidemiologic studies have shown that the information extracted from the SDPTG waveform reflects both the elasticity of the aorta and peripheral arteries, and that it is associated closely with age and other risk factors for atherosclerotic vascular disease [14,15]. Hashimoto et al [16] reported that SDPTG depends on various factors in a manner different from brachial-ankle pulse wave velocity and may be useful for detecting vascular aging accelerated by hypertension and other factors.

Among many acupoints, we were interested in the PC6 (Neiguan) acupoint, because it has been considered to affect the cardiovascular system [17–19] and is one of the primary acupoints used clinically in traditional Chinese medicine to treat cardiovascular diseases [20–23]. A previous study showed that manual acupuncture at the PC6 acupoint produced acute effects on vascular pathophysiology in healthy and hypertensive subjects [24]. We examined the acute effects of manual needling PC6 on second derivative of digital volume pulse (SDDVP) indices in healthy nonsmoker and chronic smoker subjects.

2. Materials and Methods

Healthy volunteers were recruited from the local community around our institution by advertisement. The study group comprised 40 (18 female) healthy subjects, 30 (13 female) chronic smokers (refer to Table 1 for the mean age and standard deviation). All were normotensive (office blood pressure <140/90 mmHg) at the time of the study and none had total serum cholesterol values >200 mg/dL or fasting glucose values >95 mg%. None had cardiac disease or were taking any medications. The smoking habits were assessed with a questionnaire. The smokers smoked an average of 15 cigarettes per day for 5–9 years. The subjects were studied fasting, having abstained from caffeine, alcohol or smoking for 12 hours. The study was approved by Omega Clinical Research Ethics Committee, and all subjects gave written, informed consent.

The measurements were performed in the morning with each subject in supine position. All recordings were made in a laboratory with a temperature of 24°C ± 1°C. All subjects were allowed to rest and to acclimatize for at least 30 minutes before recordings commenced. A photoplethysmograph (TSD200; BIOPAC Systems, Goleta, CA, USA) transmitting infrared light at 860 ± 90 nm placed on the index finger of the right hand was used to obtain the DVP (Figure). Frequency response of the photoplethysmograph was flat to 10 Hz. Digital output from the photoplethysmograph was recorded through a 12-bit analog-to-digital converter with a sampling frequency of 200 points per second (MP100; BIOPAC Systems, Goleta, CA, USA) using the analysis platform provided by AcqKnowledge version 3.8.1 software (MP100; BIOPAC Systems, Goleta, CA, USA). Of each subject, a DVP registration 20 minutes long was obtained (Figure). PC6 was stimulated unilaterally by manual needling during 5 minutes (1–6 minutes). DVP indices were compared in each subject at pre- vs. post-acupuncture periods (30 seconds and 18 minutes, respectively). Eighteen minutes was chosen, because

<table>
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<tr>
<th>Table 1 Demographic and clinical data for study groups*</th>
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<tr>
<td>Demographic and clinical parameter</td>
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<tr>
<td>-------------------------------------</td>
</tr>
<tr>
<td>Female, n</td>
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<tr>
<td>Age (yr)</td>
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<td>Height (cm)</td>
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<td>Weight (kg)</td>
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<tr>
<td>Brachial systolic blood pressure (mmHg)</td>
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<tr>
<td>Brachial diastolic blood pressure (mmHg)</td>
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<tr>
<td>Heart rate (beats/min)</td>
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*Data are presented as mean ± standard deviation.
at this time, the analyzed indices attained steady values.

The second derivative of the DVP wave contour was obtained using the Origin, Scientific Graphing and Analysis Software version 7.5 (Microcal Software, Inc., Northampton, MA, USA) to specify inflection points (Figure). Typically, the d2DVP/dt2 waveform comprises five distinct waves: \( a \) to \( e \). To describe these SDDVP components quantitatively, the height of each wave was measured from the baseline, the values above the baseline being positive and those under it negative and was termed \( a \) to \( e \), as previously described [25]. Absolute values for the height of waves \( a \), \( b \) and \( d \) were referred to as \( A \), \( B \) and \( D \), respectively. The \( B:A \) ratio was calculated as the ratio of the absolute value for the height of the \( b \) wave (\( B \)) to that of the \( a \) wave (\( A \)), and the \( D:A \) ratio was calculated as the ratio of the absolute value for the height of the \( d \) wave (\( D \)) to a wave (\( A \)).

2.1. Statistical analysis

Data were expressed as mean±standard deviation. The Student’s \( t \) test was used for comparison of normally distributed continuous variables. A \( p \) value of <0.05 was considered significant. All statistical analyses were performed with SPSS version 11.5 (SPSS Inc., Chicago, IL, USA) software.

3. Results

Characteristics of the subjects are shown in Table 1. Demographic and cardiovascular data were not significantly different between the two subject groups for either gender.

The SDDVP indices before and its changes after acupuncture in nonsmokers are shown in Table 2. Comparing pre- vs. post-acupuncture periods, \( B:A \) and \( D:A \) did not show significant differences among nonsmokers. Otherwise, \( AI \) improved significantly in this group. The SDDVP indices before and its changes after acupuncture in smokers are shown in Table 3. \( AI \) and \( B:A \) improved significantly in this

<table>
<thead>
<tr>
<th>SDDVP index</th>
<th>Nonsmokers</th>
<th>Smokers</th>
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<tbody>
<tr>
<td>AI</td>
<td></td>
<td></td>
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<tr>
<td>Pre-acupuncture</td>
<td>-0.76±0.09</td>
<td>-0.72±0.11</td>
</tr>
<tr>
<td>Post-acupuncture</td>
<td>-0.91±0.11†</td>
<td>-0.75±0.14</td>
</tr>
<tr>
<td>B:A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-acupuncture</td>
<td>-0.14±0.01</td>
<td>-0.11±0.02</td>
</tr>
<tr>
<td>Post-acupuncture</td>
<td>-0.14±0.01</td>
<td>-0.14±0.01</td>
</tr>
</tbody>
</table>

*Data are presented as mean±standard deviation; †significantly different from pre-acupuncture values, \( p < 0.05 \). AI = aging index, defined as \((b – c – d – e)/a\); \( B:A \) = the ratio of the absolute value for the height of the \( b \) wave (\( B \)) to that of the \( a \) wave (\( A \)); \( D:A \) = the ratio of the absolute value for the height of the \( d \) wave (\( D \)) to \( a \) wave (\( A \)).
The salient findings of this study were that, in a population of chronic smokers, AI and B:A indices were improved with manual acupuncture in PC6, whereas in nonsmokers, only AI index was improved. Several arterial changes have been described with chronic cigarette smoking. Thoracic aortic atherosclerosis as assessed by transesophageal echocardiography was increased in cigarette smokers [26]. It has also been reported that both active and passive smoking are associated with a consistent increase in intimal-medial thickness of the carotid artery as assessed by carotid ultrasound [27,28]. Impairment of vasodilatory function is one of the earliest manifestations of atherosclerotic changes in a vessel. In both animal and human models, several studies have demonstrated that both active and passive cigarette smoke exposure were associated with a decrease in vasodilatory function [8,9,29,30]. In humans, cigarette smoke exposure impaired endothelial-dependent vasodilation in macrovascular beds, such as coronary and brachial arteries, and in microvascular beds [31,32].

The AI has been proposed specifically as a marker and for evaluation of vascular aging [14]. Takazawa et al [13] have reported that the second derivative AI was higher in subjects with any history of diabetes mellitus, hypertension, hypercholesterolemia and ischemic heart disease than in age-matched subjects with such a history. Acupuncture positively modified AI in both groups. At baseline, there was no significant difference in AI and D:A between nonsmokers and smokers. However, we found significant difference in index B:A between both groups.

4. Discussion

The salient findings of this study were that, in a population of chronic smokers, AI and B:A indices were improved with manual acupuncture in PC6, whereas in nonsmokers, only AI index was improved. Several arterial changes have been described with chronic cigarette smoking. Thoracic aortic atherosclerosis as assessed by transesophageal echocardiography was increased in cigarette smokers [26]. It has also been reported that both active and passive smoking are associated with a consistent increase in intimal-medial thickness of the carotid artery as assessed by carotid ultrasound [27,28]. Impairment of vasodilatory function is one of the earliest manifestations of atherosclerotic changes in a vessel. In both animal and human models, several studies have demonstrated that both active and passive cigarette smoke exposure were associated with a decrease in vasodilatory function [8,9,29,30]. In humans, cigarette smoke exposure impaired endothelial-dependent vasodilation in macrovascular beds, such as coronary and brachial arteries, and in microvascular beds [31,32].

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The b wave on the SDDVP mainly expresses the first vascular response to blood ejection from the ventricle, which is little affected by the reflection wave. Imanaga et al [33] reported the relationship between the B:A ratio and the distensibility of the carotid artery, suggesting that the B:A ratio reflects the stiffness of large arteries. The improvement of the B:A index with acupuncture suggested that chronic smokers had a decrease of large arteries distensibility, which could be partially reverted with acupuncture.

In conclusion, this study demonstrated an acute effect of manual acupuncture in PC6 on SDDVP indices in both healthy nonsmokers and chronic smokers. We believe that this can be attributed to the vasodilatory action of PC6. These results emphasize the importance of employing acupuncture in basic and clinical studies on stiffness and aging of vascular beds related to cigarette smoking.

References

23. Meng J. The effects of acupuncture in treatment of coro-