34th Annual International Conference of the IEEE EMBS
San Diego, California USA, 28 August - 1 September, 2012

Utility of noninvasive brachial-ankle pulse wave velocity measurement in people with spinal cord injury

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Abstract— **The purpose of the present study was to examine the utility of non-invasive brachial-ankle pulse wave velocity measurement in people with spinal cord injury based on the comparison of the data of the compliance of common femoral artery measured by ultrasonography. Five physically active persons with spinal cord injury volunteered for this study. Subjects were in a supine position on the bed, and estimate brachial-ankle pulse wave velocity and the compliance coefficient of common femoral artery. The brachial-ankle pulse wave velocity measurement is related to was significantly (p<0.05) related to the compliance coefficient of common femoral artery. The brachial-ankle pulse wave velocity measurement may be helpful for assessment of arterial stiffness in people with spinal cord injury.**

I. Introduction

The life expectancy of people with spinal cord injury (SCI) has increased to near that of able-bodied individuals[1]. As a result, chronic diseases associated with aging and sedentary life style (e.g. hypertension) are increasing in younger and older people with SCI [1]. The part of the body below the spinal lesion is paralysed and extremely inactive, which may affect vascular properties [2]. According to the data measured by quantitative Doppler ultrasound, people with SCI show a smaller diameter, lower blood flow, and lower compliance of common femoral artery (CFA) than able-bodied people [2,3]. However, the measurements using ultrasonography need specialized technical skills and take much time for analysing arterial compliance, which is a measure of the capacity of a volume-contracting structure.

The non-invasive measurement of pulse wave velocity (PWV), which calculates the transit time of pressure wave travelling between two arteries, is widely used as an index of arterial wall distensibility or arterial stiffness. Loss of arterial elasticity will both reduce arterial compliance and increases the PWV. The measurement of carotid-femoral PWV is one of the major assessment methods of arterial stiffness. A simple device to measure the brachial-ankle PWV (BA-PWV), which measure the pulse volume record at the upper arm and ankle oscillometrically, has been developed recently [4,5]. However, it is not clear whether BA-PWV has been used to evaluate arterial stiffness for people with SCI. Thus, the purpose of the present study was to examine the utility of BA-PWV in persons with SCI based on the comparison of the data of the compliance of CFA measured by ultrasonography.

*Resrach partly supported by Grant-in-Aid for Young Scientists (B) 70363653 from Japan Society for the Promotion of Science.

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II. Methods

A. Subjects

Five physically active male subjects with SCI, who have participated in physical training for over 2 hours/day and 2 days/week for at least 2 years, volunteered for this study. The mean and SD of the subjects' age, height, and body mass were 27.8 ± 7.3 years, 171.4 ± 7.4 cm, and 56.2 ± 4.1 kg, respectively. The spinal cord lesions of subjects were all complete and the anatomical levels of impairment were to between C6 and C7. The average length of time that had passed since the accident which had caused their cervical cord injury was 6.5 to 9.9 (7.8 ± 3.3) years. None of the subjects used medication likely to affect the cardiovascular system, and none had cardiovascular disease. All subjects were informed of the purpose and method of the study before the experiment began, and each completed written consent forms to participate.

B. Experimental procedure.

The BA-PWV and arterial compliance measurements were in a supine position on the bed after at least 5-min rest. All measurements were done between 9:00 and 13:00, at a room temperature of 24-26 °C. At least 2 hours before they were tested, subjects were not allowed to exercise vigorously, smoke, and consume food and drinks containing caffeine.

Brachial-ankle PWV measurement: Two pulse waves of the right brachial and right tibial arteries were recorded by using a volume-plethymographic cuff apparatus with semiconductor pressure sensor (CUF-129MR and CUF-130ML, Fukuda Denshi Corporation, Japan). The BA-PWV was automatically calculated with the use of a computer instrument with computer analysing system with a 16 bits analog-to-digital converter at a sampling rate of 1 kHz (VS-1000, Fukuda Denshi Corporation, Japan). The instrument recorded the volume pulse form for the brachium and ankle for 5 s with automatic gain analysis. The distance between sampling points of BA-PWV was calculated automatically according to the height of the subject. The path length from the aortic valve to the right ankle (*La*) and right brachium (*Lb*) were expressed automatically using the following equation. The formula was uniquely investigated by Fukuda Denshi Corporation.

$$La\text{-}Lb = 0.594 \cdot \text{height of the subject (cm)} + 14.2$$

The time from the onset of the rise in the pulse volume record of the right brachial artery to the onset of the rise in the pulse volume record of the right tibial artery (Δt) was analyzed for the computer system. Then, BA-PWV was calculated with the following equation.

$$\text{BA-PWV (m/sec)} = (La - Lb)/100/\Delta t$$

The validity and reproducibility of the BA-PWV measurement have been described elsewhere [4,5]. Systolic blood pressure (BP) and diastolic BP were also obtained on right BA.

Arterial compliance measurement: An examination of the right CFA were conducted with an ultrasound scanner (SSA-550A,Toshiba, Japan) via the B-mode with a linear 7.5MHz transducer (PLM-703AT, Toshiba, Japan). We obtained the average of 10 measurements in each parameter. The transducer was positioned at about 2 cm proximal to each bifurcation area of CFA by monitoring the picture of the vessel wall. The sample volume covered the diameter of the artery. The vessel wall area was adjusted parallel to the transducer. The diastolic diameter and systolic diameter were measured by synchronous recording with the ECG. The diastolic diameter was determined during the smallest lumen diameter after the R peak in the ECG. The systolic diameter was determined during the largest lumen diameter after the T peak in the ECG. The compliance coefficient was calculated as the change in cross-sectional area relative to pulse pressure [2].

Compliance coefficient (mm^2/kPa) = π · diastolic diameter · (systolic diameter - diastolic diameter) / pulse pressure.

To estimate pulse pressure, systolic BP and diastolic BP were measured on right posterior tibial artery with a mercurial manometer.

C. *Statistics*

Data is shown as mean ± SD. The relationships among variables were determined by a Pearson's correlation analysis. The level of statistical significance was set at $p<0.05$. These statistical analyses were performed with SPSS software for Windows (11.0)

III. RETSULT

Systolic BP and diastolic BP of the right brachial artery were 113.8 ± 8.5 mmHg and 67.6 ± 5.2 mmHg, respectively. The diastolic diameter and systolic diameter of CFA were 5.57 ± 0.55 mm and 5.83 ± 0.66 mm, respectively. The compliance coefficient of CFA was 0.83 ± 0.48 mm^2 / kPa. The BA-PWV was significantly related to the arterial compliance of CFA (r=-.91, p<0.05, Figure 1) but not age (r=.21), height (=.07), body mass (r=-.26), systolic BP (r=.33), diastolic BP (r=.63), diastolic diameter (r=-.53), and systolic diameter (r=-.61).

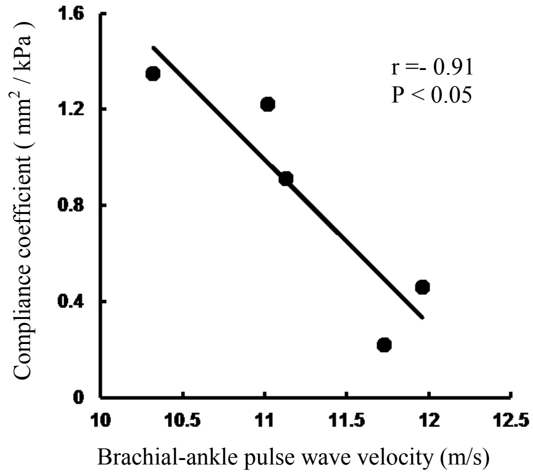

Figure 1. The relationships between brachial-ankle pulse wave velocity and compliance coefficient of common femoral artery. Each data point is a single measurement on a single subject.

IV. DISCUSSION

The relationships between BA-PWV and CFA compliance coefficient would indicate useful of BA-PWV measurement for people with SCI. The BA-PWV measurement in the present study seems to possess some practical benefits. First, there is no specialized technical skill for BA-PWV measurement compared to measurement of arterial compliance by ultrasonography and other PWV measurements, because the examiner has only to wrap cuffs on the brachium and ankle. Second, the subjects do not need to remove their clothes. Because it is hard for SCI individuals to remove their clothes, BA-PWV measurements make it more usable for screening a large population with SCI than previous methods. Moreover, recent studies reported that BA-PWV is useful for prediction of the presence of coronary artery disease [6]. Even though we need to examine whether BA-PWV relates to cardiovascular disease for people with SCI in a large population, BA-PWV measurement may be helpful for assessment of arterial stiffness and for predicting of cardiovascular disease associated with aging and sedentary life style for people with SCI.

ACKNOWLEDGMENT

The authors would like to thank the subjects for their cooperation. This study was partly supported by Grant-in-Aid for Young Scientists (B) 70363653 from Japan Society for the Promotion of Science.

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