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The association of metabolic syndrome and its components with brachial-ankle pulse wave velocity in south China

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ABSTRACT

Background: Brachial-ankle pulse wave velocity (baPWV) can reflect both central and peripheral arterial stiffness. Metabolic syndrome (MS) and its components may increase arterial stiffness and the risks of cardiovascular diseases. However, the correlation of MS and its components with arterial stiffness has not been not well studied. The aim of this study was to investigate the correlation between MS/its components and arterial stiffness by the measurement of baPWV in south China population.
Methods: A total of 8599 subjects were selected from those who underwent health examination in our hospital. MS was defined by Joint Scientific Statement. BaPWV, waist circumference, blood pressure (BP), fasting plasma glucose (FPG), lipid profile and serum uric acid (UA) were measured. The relationship between baPWV and MS/its components was analyzed.
Results: BaPWV was significantly higher in the subjects with MS than in those without MS ($P < 0.001$ for both genders). By multivariate regression analysis, all the metabolic components were correlated to baPWV in the male and female subjects except low HDL-C and high UA in the male group. BP and FPG had the strongest correlation factors. The values of baPWV were positively correlated with the advanced age ($P < 0.001$) and the values of the MS components, and this correlation was stronger in the females than in the males ($P < 0.001$).
Conclusion: Metabolic syndrome and its individual components were positively correlated with baPWV. Monitoring baPWV is helpful to identify early stage of arterial stiffness in those people with MS.

1. Introduction

Cardiovascular diseases (CVD) are the major causes of morbidity and mortality worldwide. In 2011, the World Health Organization (WHO) reported that approximately 17.3 million people died of CVD, representing 30% of all global deaths [1]. By 2030, it is estimated that there will be 23.6 million deaths from CVD. The situation is not optimistic also in China. The National Center of CVD in China has reported that about 1 in 5 Chinese adults has CVD, and the morbidity rate is on the rise in 2014 [2]. Furthermore, stroke can cause, in addition to death, various serious sequelae including disturbance of vision, aphasia, dysphagia, paralysis, urinary and fecal incontinence and so on. These consequences not only lower the patients' quality of life, but also increase the burden on the family even the whole society.

Metabolic syndrome is a cluster of atherosclerosis and CVD risk factors such as central obesity, hypertension, dyslipidemia and glucose intolerance [3]. It often presents before the onset of CVD, and its components are usually related to the development and progression of CVD. Arterial stiffness is also related to atherosclerosis and CVD, and has been considered to be a strong independent predictor of coronary events and cardiovascular mortality in several patient groups. Arterial stiffness can be evaluated by the measurement of pulse wave velocity (PWV) along the arterial tree. PWV is an effective index of arterial stiffness of large arteries, and it is widely used for non-invasive assessment of atherosclerosis [4]. Some publications report that a PWV measurement can predict future cardiovascular events in hypertensive patients and elderly individuals, and is useful for evaluating carotid arteriosclerosis [5]. Researches have demonstrated good validity and reproducibility of brachial-ankle PWV (baPWV), as well as its strong association with central PWV [6,7].

The association of MS with arterial stiffness has been investigated in some studies [8–15]. Most of these studies have shown

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increased PWV in subjects with MS or with a larger number of MS components [8–12]. However, most of them were small sample researches or community-based researches [13]. Some studies were based on specific subjects, such as patients with systemic lupus erythematosus [14], and patients newly detected with suspected hypothyroidism [15]. Therefore, the results of these studies could not explain the association of MS with PWV very well. The aim of the present study was to evaluate the relationship between baPWV and MS and its individual components in a large sample size of 8599 subjects.

2. Material and methods

2.1. Study population

This study included 8599 subjects (6659 men and 1940 women, age range from 18 to 75 years) who underwent physical examinations in Sir Run Run Shaw Hospital of the Zhejiang University School of Medicine from January 2011 to December 2013. All subjects were from Zhejiang Province, Jiangsu Province, Jiangxi Province and so on, which located in the southern part of China. Subjects with atherosclerotic cardiovascular disease, or stroke, or cardiomyopathy, or on medications for hypertension or diabetes were excluded. This study was approved by the Medical Ethics Committee of the Sir Run Run Shaw Hospital. Written informed consent was obtained from all the participants.

2.2. Measurement techniques

Participants were asked to avoid a high fat and sugar diet for three days before the examination. Fasting blood samples were obtained from each subject, typically from 7 to 8 AM. The samples were immediately centrifuged and analyzed within 1 h. Fasting plasma glucose levels were measured by the hexokinase method (Abbott c16000, USA). Triglyceride levels were measured by the glycerol phosphate oxidase method (Abbott c16000, USA). HDL cholesterol levels were measured by the clearance assay method (Abbott c16000, USA).

Waist circumference measurement was according to the WHO recommended method. It was measured midway between the lowest rib and the iliac crest by an anthropometric tape. Blood pressure was measured by the method recommended in China Hypertension Prevention Guidelines (2010 Edition) from the left arm of the patient on seated position. The mean of two blood pressure values obtained by two individual physicians was used for analysis.

2.3. Definition of the MS

MS definition is based on the Joint Scientific Statement (A Joint Interim Statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity, Publish in Circulation, 2009) [3]. Obesity is defined by the WHO Asian Region. A person has metabolic syndrome if the waist circumference is increased ($\geq$85 cm for men and $\geq$80 cm for women) and at least two of the following factors are present: triglyceride (TG) level $\geq$ 1.7 mmol/L, systolic blood pressure (SBP) $\geq$ 130 mmHg or diastolic blood pressure (DBP) $\geq$ 85 mmHg, fasting plasma glucose (FPG) $\geq$ 5.6 mmol/L, and high-density lipoprotein (HDL) cholesterol <1.0 mmol/L in men or <1.30 mmol/L in women.

2.4. Measurements of brachial-ankle pulse wave velocity (baPWV)

The baPWV was assessed by a non-invasive arterial atherosclerosis measuring system, VP-1000 (BP-203RPEII). Subjects took three deep breaths and rested in a supine position for at least 5 min before examination. The cuffs were wrapped on both sides of the brachium and ankle, which contained a plethysmographic sensor to determine the wave data. Blood pressure was measured by the oscillometric method. The baPWV was calculated as follows: baPWV = (La−Lb)/Tba (La: the path length from the heart to the ankle; Lb: the path length from the heart to the brachium; Tba: the time delay between the arrival of the pulse wave at the brachium and ankle). The mean of the right and left baPWV values was used for analysis. This method has been validated previously.

2.5. Quality control

Data were collected by the coordinator who received strictly training. All the equipment was inspected. All the biochemical indices were assayed by the designated staff on fixed instruments. These indices were controlled using standard quality control serum.

2.6. Statistical analysis

Input of the descriptive data was performed by a designated staff, and statistical analysis was carried out by SPSS version 19.0 (SPSS Inc., Chicago, IL, USA). The quantitative data were described as mean ± SD. A multiple linear regression model with step-wise selection and logistic regression analysis were used to estimate the correlation between MS/its components and baPWV in each group stratified by age. Standardized effect size (β value) was calculated to compare the relationship in each group. Kruskal–Wallis test was used for the comparisons among multiple groups. Variables with p values <0.05 were considered significant.

3. Results

Complete data were obtained from 8599 subjects (6659 men and 1940 women), whose characteristics are summarized in Table 1. The ages of the male and female subjects were 46.2 ± 9.5 years and 46.2 ± 9.6 years, respectively (P = 0.004). BaPWV and the other variables except for HDL were significantly higher in men than in women.

The values of baPWV among different age groups were statistically significant in both the males and females. The changes of baPWV with age for the males and females are displayed in Fig. 1. The results showed that the values of baPWV were increased according to the advancing age in both gender ($p < 0.001$). And the effect of age on baPWV was greater in the females than that in the males.

The correlation of MS and its components with baPWV values were analyzed in the males and females. The MS components were associated with increased baPWV in both the males and the females except for the low HDL-cholesterol level in the males as shown in Table 2. Elevated BP and FPG were the strongest factors affecting baPWV. The baPWV was significantly higher in both the male and female subjects with metabolic syndrome.

A multiple logistic regression model was performed to examine the correlation between MS/its components and baPWV status in the males and females (Table 3). In this model, metabolic syndrome and its components were associated with increased baPWV in both the males and females except for the low HDL-cholesterol level in the males. High BP and high FPG are the most important factors for baPWV. The OR values were 4.5 for high BP, 2.2 for high FPG, 1.7 for