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● *Original Contribution*

ECHO-TRACKING TECHNOLOGY ASSESSMENT OF CAROTID ARTERY STIFFNESS IN PATIENTS WITH CORONARY SLOW FLOW

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Abstract—Coronary slow flow (CSF) in coronary angiography (CAG) is a well-recognized clinical entity. Previous studies have suggested that microvascular abnormalities and endothelial dysfunction are responsible for CSF. Accordingly, we hypothesized that the CSF phenomenon is a form of atherosclerosis including both small vessels and epicardial coronary arteries. The echo-tracking (ET) technique is a non-invasive detection method for early prediction of arterial atherosclerosis. Therefore, we investigated carotid elasticity with the ET technique in patients with CSF. Fifty patients with CSF and 50 patients with normal coronary artery blood flow, as determined by CAG, with a similar distribution of risk factors were recruited. The stiffness parameter (β), pressure–strain elastic modulus (E_p), arterial compliance (AC), augmentation index (AIx) and local pulse-wave velocity (PWV) were determined at the level of the bilateral common carotid artery (CCA) with using the ET technique. Levels of serum high-sensitivity C-reactive protein (hs-HSCRP) were determined for the two groups. β, E_p and PWV were significantly higher in the CSF group than in the control group (β: 11.4 ± 3.76 vs. 9.22 ± 3.28, $p < 0.01$; E_p: 153.44 ± 47.85 vs. 126.40 ± 43.32, $p < 0.01$; PWV: 7.26 ± 1.10 vs. 6.55 ± 1.02, $p < 0.01$), but AC was lower in the CSF group than in the control group (0.62 ± 0.20 vs. 0.74 ± 0.24, $p < 0.01$). The elasticity parameters of the bilateral common carotid artery did not significantly differ. The level of hs-HSCRP was correlated positively with β ($r = 0.306, p = 0.015$), E_p ($r = 0.358, p = 0.005$) and PWV ($r = 0.306, p = 0.015$), but negatively with AC ($r = -0.236, p = 0.049$). In conclusion, the ET technique is a simple practical method for evaluating carotid artery elasticity, and there is a significant correlation between carotid artery stiffness and level of hs-HSCRP in patients with CSF. (E-mail: dezhao.w@126.com or 168hewen@sina.com) © 2014 World Federation for Ultrasound in Medicine & Biology.

Key Words: **Ultrasonography, Carotid artery, Coronary slow flow, Echo-tracking technology, High-sensitivity C-reactive protein.**

INTRODUCTION

The coronary slow flow (CSF) phenomenon, described for the first time 42 y ago by Tambe et al. (1972), is defined as an angiographic pattern characterized by delayed distal vessel opacification despite the absence of obstructive coronary artery disease (Kopetz et al. 2012). The role of arterial stiffness in the development of coronary artery disease has recently been emphasized. Even though the carotid pulse has been studied extensively, there is little information on the mechanical properties of large arteries in patients with CSF. Moreover, Information about carotid artery stiffness and its clinical significance in patients with CSF is lacking. The aims of this study were to assess the carotid mechanical properties in patients with CSF using a high-spatial-resolution echo-tracking (ET) system and to determine whether these patients have increased carotid artery stiffness beyond that associated with aging and/or cardiovascular risk factors.

METHODS

Study population

This study included 50 consecutive patients (mean age: 59.5 ± 12.1 y) with isolated CSF (defined as an angiographic pattern characterized by delayed distal vessel opacification despite the absence of obstructive coronary artery disease). The control group consisted of 50 consecutive patients (mean age: 61.1 ± 11.6 y) with normal coronary flow based on the results of coronary

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Conflicts of Interest: The authors declare that they have no conflicts of interest and ethical adherence.

angiography (CAG). The following clinical data were collected: age, gender, height, body mass index, heart rate, blood pressure, history of smoking, hypertension (defined as history of hypertension requiring medical therapy), diabetes mellitus, dyslipidemia and levels of fasting glucose, glycated hemoglobin, creatinine, low-density lipoprotein and high-sensitivity C-reactive protein (HSCRP). Information regarding currently used medications was also obtained. There were no significant differences between the study cohort and control cohort in the administration of angiotensin-converting enzyme inhibitors, angiotensin receptor blockers, calcium channel blockers and β blockers.

Carotid artery stiffness assessment

All patients were studied after 15 min of rest in the supine position, in a temperature-controlled environment. Studies were performed using a color Doppler echocardiography machine (Prosound α-10, Aloka, Tokyo, Japan) with a 7.5-MHz linear array probe, implemented with a high-resolution echo-tracking system allowing accurate measurements of carotid diameter changes. The location to be measured was the common carotid artery approximately 2.0 cm proximal to the carotid bulb. Pressure waveforms were non-invasively obtained using arterial diameter change waveforms calibrated on the basis of systolic and diastolic blood pressure values measured with a cuff-type manometer applied to the upper arm. Five consecutive beats were ensemble-averaged to obtain a representative waveform. The maximum and minimum values of the diameter-change waveform were obtained and the main indices of arterial stiffness (β index, arterial compliance [AC], augmentation index [AIx], pulse wave velocity [PWV], pressure–strain elastic modulus [E_p]) were automatically calculated, as a mean of five beats, according to established formulas:

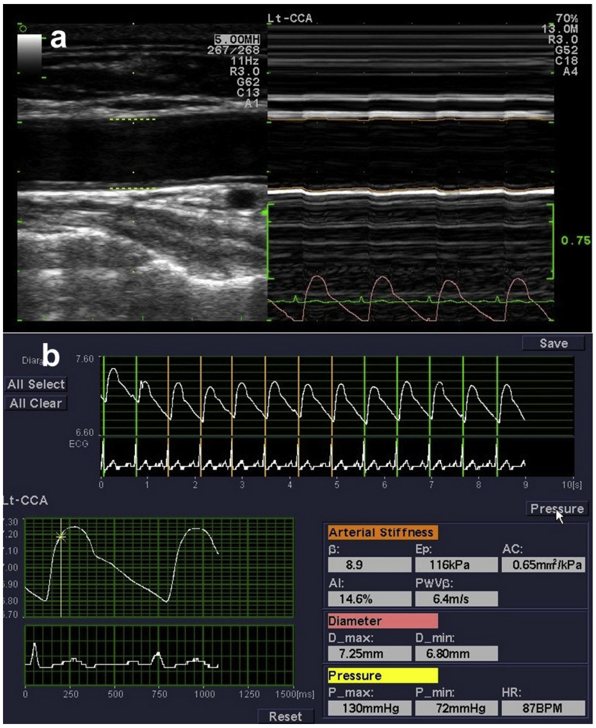
$$\beta = \ln(P_s/P_d)/(D_s - D_d/D_d) \tag{1}$$

$$\mathrm{AC} = \pi(D_s \times D_s - D_d \times D_d)/4(P_s - P_d) \tag{2}$$

$$\mathrm{AIx} = [\Delta p/(P_s - P_d)] \times 100 \tag{3}$$

$$E_p = (P_s - P_d)/[(D_s - D_d)/D_d] \tag{4}$$

where systolic blood pressure (P_s) and diastolic blood pressure (P_d) are the maximal and minimal blood pressure values, systolic diameter (D_s) and diastolic diameter (D_d) are the maximal and minimal diameters of the bilateral common carotid artery (CCA) with the heartbeat cycle and Δp is the difference between maximal pressure and pressure at the first peak (shoulder) on the carotid pressure waveform (Fig. 1). Local PWV is derived from β. The testing process was recorded together with the electrocardiogram (ECG). All measurements were performed by the same sonologist throughout the study. Our study adopted the single-blind method, which means the sonologist did not know the results of CAG.



Arterial Stiffness
β: 8.9
Ep: 116kPa
AC: 0.65mm²/kPa
AI: 14.6%
PWVβ: 6.4m/s
Diameter
D_max: 7.25mm
D_min: 6.80mm
Pressure
P_max: 130mmHg
P_min: 72mmHg
HR: 87BPM

Fig. 1. (a) Echo-tracking sampling gate location and carotid artery diameter change curves. (b) E-DMS system (Shenzhen teng lixin Co., LTD, Shenzhen, Guangzhou, China) for analysis of parameters off-line. β = Stiffness parameter; E_p = pressure-strain elastic modulus; AC = arterial compliance; PWV = local pulse-wave velocity; AIx = augmentation index; D_max = maximal diameter; D_min = minimal diameter; p_max = systolic blood pressure; p_min = diastolic blood pressure; HR = heart rate.

The study was approved by the institutional ethics committee, and informed consent was obtained from all patients.

Determination of serum index

Venous blood (0.5 mL) was drawn from the arm of all patients and sent to the laboratory for measurement of glucose, low-density lipoprotein and HSCRP with an automatic biochemical analyzer (AU760, Olympus, Tokyo, Japan).

Statistical analysis

Statistical analysis was performed using the SPSS software package (Version 18.0, SPSS, Chicago, IL, USA). Categorical variables are expressed as numbers and percentages. χ^2 statistics were used to assess differences between categorical variables. Continuous variables are expressed as the mean ± standard deviation and analyzed with the independent sample *t*-test.