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Original article

Aortic stiffness is strikingly increased with age ≥50 years in clinically normal individuals and preclinical patients with cardiovascular risk factors: Assessment by the new technique of 2D strain echocardiography

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KEYWORDS
Aortic stiffness;
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Summary
Background: Various measures of aortic stiffness have been proposed as cardiovascular risk markers, but interest has now shifted to more direct and easier evaluation of aortic function. The present study was conducted to determine the feasibility of measuring aortic stiffness (β) with two-dimensional (2D) strain echocardiography and the impact of age and gender on preclinical atherosclerosis.
Methods and results: The peak circumferential strain of the abdominal aorta was measured using 2D strain echocardiography, and β was determined in 54 clinically normal individuals and 104 patients with cardiovascular risk factors and no evidence of cardiovascular disease. The β correlated significantly with age in all 158 patients. However, the relationship was nonlinear, and β was markedly greater in patients ≥50 years. In 54 clinically normal individuals, the relationship was comparatively linear. The systolic blood pressure and pulse pressure were significantly greater in patients ≥50 years. There were no significant differences in β and blood pressure parameters between genders.
Conclusions: The β increased dramatically with advanced age (≥50 years), regardless of gender, in clinically healthy and community-based patients with cardiovascular risk factors. The aortic circumferential strain was measured with 2D strain echocardiography which is a new tool that can be used to directly and easily evaluate aortic stiffness.

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Introduction

It is well recognized that physiologic aging [1—3] and cardiovascular risk factors [3,4] lead to structural and functional alterations in large arteries, and that also aortic stiffness is the best predictor of cardiovascular morbidity and mortality [5,6]. Therefore, there is increasing interest in the detection of preclinical vascular involvement [7,8]. Because invasive measurements of arterial stiffness are not feasible in routine clinical use, several noninvasive techniques, such as M-mode ultrasonography [9] and pulse wave velocity [10,11], have been proposed for the purpose. However, these techniques produce fairly imprecise approximation, are dependent on age or blood pressure, and have low reproducibility. Two-dimensional (2D) strain echocardiography has been developed to allow rapid, accurate, and simple determination of regional myocardial deformation [12]. Furthermore, it has been clarified that this novel approach is applicable to the evaluation of aortic stiffness [13]. The present study sought to investigate the feasibility and usefulness of the vascular strain analysis related to changes in aging in clinically normal individuals and patients with cardiovascular risk factors and no known heart disease by using 2D strain echocardiography as a new echocardiographic measure of aortic stiffness.

Methods

Study population

The study group consisted of 205 consecutive patients undergoing routine health check up at our hospital between 2008 and 2009. They had never been treated before. A total of 47 patients were excluded because the following exclusion criteria were fulfilled: left ventricular (LV) ejection fraction ≤60%, clinically significant valvular heart disease, known coronary artery disease, previous stroke, chronic obstructive pulmonary disease, renal disease, and aortic disease. The residual 158 patients (59 men, 99 women, mean age: 63 ± 19 years, range: 12—88 years) who had adequate acoustic windows, were divided into 2 groups; clinically normal individuals with no cardiovascular risk factors ($n = 54$) and patients with cardiovascular risk factors ($n = 104$). The latter group included current smokers ($n = 19$), body mass index ≥25 kg/m^2 ($n = 42$), hypertension with systolic (SBP) or diastolic blood pressure (DBP) >140 mm Hg or 90 mm Hg, respectively ($n = 85$), hyperlipidemia with total cholesterol >220 mg/dl or triglycerides >150 mg/dl ($n = 52$), and/or hyperglycemia with fasting glucose concentration ≥110 mg/dl with no retinopathy, nephropathy, or neuropathy ($n = 27$). In 104 patients with cardiovascular risk factors, one risk factor was observed in 50 patients, 2 risk factors in 33 patients, 3 risk factors in 17 patients, and 4 risk factors in 4 patients. These patients' flow is shown in Fig. 1.

The protocol used for the present study was approved by the ethics committee of the institution involved. An informed consent was given by all patients.

Aortic ultrasonography

A short-axis view of the abdominal aorta at a level of subcostal region was obtained at end-expiration breath holding with the use of a commercially available ultrasound system (Vivid 7, General Electric Medical Systems, Milwaukee, WI, USA) equipped with a harmonic 4.0-MHz variable-frequency phased-array transducer [13]. Two-dimensional image acquisition was performed at a frame rate of 70—90 frames per second, and 3 cardiac cycles were stored in cineloop format for subsequent analysis. Adequate tracking was verified in real time and corrected, if needed. The global strain was calculated with the use of entire circumferential length of the aortic wall. Using a dedicated software package (EchoPac, General Electric Healthcare, Waukesha, WI, USA), peak circumferential strain (Ao-S) was measured (Fig. 2).

The stiffness of the abdominal aorta was evaluated at the same position as 2D strain measurements by M-mode ultrasonography (Fig. 3), and determined by the stiffness parameter as validated by Hirai et al. [9]: stiffness $\beta_1 = \ln(\mathrm{SBP}/\mathrm{DBP})/[(D_{\max} - D_{\min})/D_{\min}]$, where $D_{\max}$ and $D_{\min}$ are maximal and minimal aortic diameters, respectively. Also, stiffness of the abdominal aorta was evaluated by 2D strain echocardiography: stiffness $\beta_2 = \ln(\mathrm{SBP}/\mathrm{DBP})/\text{Ao-S}$, where Ao-S is peak strain determined by aortic circumferential strain curve.

All 2D strain and M-mode ultrasonographic measurements were averaged for at least 3 consecutive beats.

Statistical analysis

Values are expressed as the mean ± standard deviation (SD). The differences in the mean values among the groups were compared using the one-way analysis of variance (ANOVA). The relationships between age and aortic stiffness measured by M-mode ultrasonography and 2D strain echocardiography were tested using linear and non-linear correlations, and the best fit was retained. A p-value less than 0.05 was considered statistically significant.

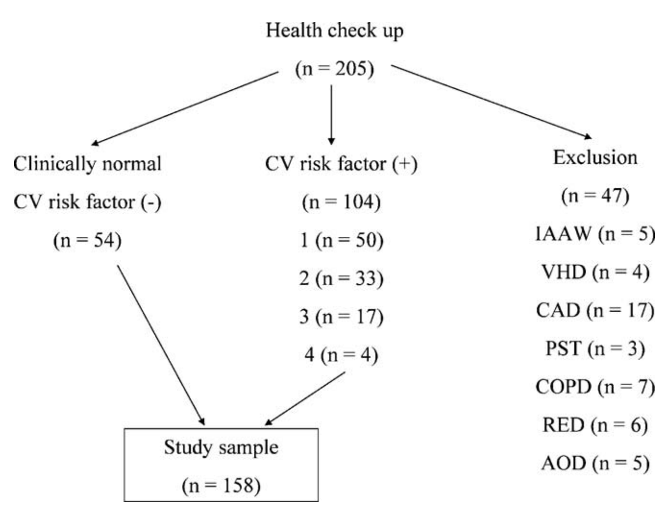

Figure 1 Patient flow of the study sample. CV, cardiovascular; IAAW, inadequate acoustic window; VHD, valvular heart disease; CAD, coronary artery disease; PST, previous stroke; COPD, chronic obstructive pulmonary disease; RED, renal disease; AOD, aortic disease.