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Influence of cardiovascular risk factors on longitudinal motion of the common carotid artery wall

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ABSTRACT

Background and aims: Carotid artery longitudinal wall motion (CALM) is a new biomarker, which can be measured together with carotid intima-media thickness and distensibility measurements in the same session. Our objective was to study the relationship between these indicators of vascular health and cardiovascular risk factors in a large and well-characterized study population.

Methods: The study population consisted of 465 subjects aged 30–45 years. Successful measurements were performed in 287 participants.

Results: The peak-to-peak and retrograde amplitudes of the longitudinal motion were inversely correlated with systolic blood pressure (SBP; $r = -0.152$, $p<0.05$ and $r = -0.189$, $p<0.01$), diastolic blood pressure (DBP; $r = -0.170$, $p<0.01$ and $r = -0.256$, $p<0.001$) and body mass index (BMI; $r = -0.158$, $p<0.01$ and $r = -0.291$, $p<0.001$). In addition, retrograde amplitude of longitudinal motion indirectly correlated with total cholesterol and triglycerides ($r = -0.163$, $p<0.01$ and $r = -0.228$, $p<0.001$, respectively). Amplitude of antegrade longitudinal motion was directly correlated with DBP, total cholesterol, LDL-cholesterol, triglycerides and BMI ($r = 0.198–0.274$, $p<0.001$ for all). Antegrade longitudinal motion increased and retrograde longitudinal motion decreased with the increasing number of cardiovascular risk factors.

Conclusions: The magnitude of correlation coefficients between CALM parameters and risk factors was comparable with those for carotid intima-media thickness and distensibility. However, the correlation profile for various risk factors was different and CALM gives additional information regarding arteriosclerosis and risk factors.

1. Introduction

Several non-invasive imaging techniques have been developed to investigate alterations representing different features of the arteriosclerotic and atherosclerotic process [1]. Carotid intima-media thickness (CIMT) measured by ultrasound is a widely used method to reveal atherosclerotic plaque disease and structural changes in the vascular wall [1], and it is known to correlate with cardiovascular risk factors, LDL-cholesterol, triglycerides, systolic and diastolic blood pressure, body mass index and smoking [2]. Carotid artery distensibility (Cdist) is used to evaluate the local stiffness of the vascular wall. A number of cardiovascular risk factors identified in childhood have been associated with decreased

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Cdist values in adulthood [3]. Cdist has been found to decline in young adults with metabolic syndrome in both sexes [4]. Decreased Cdist has been implicated also as an independent predictor of cardiovascular events in the elderly [5,6].

In our previous studies, we found that arterial stiffening is associated with alterations in carotid artery longitudinal motion (CALM) [7–9]. Some evidence suggests that CALM may also reflect vascular health [10–13]. Some evidence has been found on cardiovascular risk factors correlating with CALM in smaller study groups; significantly lower common carotid artery (CCA) wall longitudinal motion mean amplitudes have been shown in older patients with type 2 diabetes [12], and patients with CCA plaques have shown significantly lower CALM compared to controls [10]. Patients with periodontal disease also show significantly lower CALM than healthy controls [14]. In addition, there is evidence that low CALM may be a significant independent 1-year predictor of major adverse cardiovascular events in patients with suspected coronary disease [11].

However, associations of CALM with traditional risk factors of cardiovascular diseases have not been studied before in a large study population of young adults representing healthy subjects or subclinical disease phase. To investigate the associations between CALM and cardiovascular risk factors, we measured CALM in a large population where individuals were participants in the Cardiovascular Risk in Young Finns Study.

2. Materials and methods

2.1. Subjects and study design

The Cardiovascular Risk in Young Finns Study is a five-center ongoing follow-up study of atherosclerosis risk factors in Finnish children and adolescents. The first cross-sectional survey was conducted in 1980 with 3596 children and adolescents participants. The original sample age range was from 3 to 18 years, and participants were randomly chosen from each area in Finland from a national register. In this cohort, follow-up studies were conducted at regular intervals from 3 to 6 years during the period 1980–2007. The study was approved by local ethics committees. The subjects provided written informed consent.

Kuopio University Hospital is one of the five centers involved and investigates the population of Eastern Finland. The present cross-sectional study consists of the Kuopio center data from 2007, when the subjects were aged 30–45 years and vascular ultrasound studies were available for 465 subjects. Successful longitudinal motion analyses were performed for 292 subjects. Five women were excluded due to pregnancy, hence the final study population included 287 participants.

2.2. Assessment of risk factors

Height was measured to an accuracy of 1 cm and weight to an accuracy of 1 kg. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. Systolic and diastolic blood pressures (SBP, DBP) were measured from the brachial artery using a random zero sphygmomanometer (Hawksley & Sons Ltd, Lancin, UK) in the sitting position. The average of three measurements was used in the analysis. Smoking habits were ascertained with a questionnaire. Smoking was processed as dichotomous variable (smoking/non-smoking), according to a regular daily use of tobacco products.

Venous blood samples were drawn after an overnight fast for the determination of serum lipid levels and all measurements of lipid levels were performed in duplicate in the same laboratory. To measurelevels of serum total cholesterol, triglycerides, and high-density lipoprotein cholesterol (HDL-C), standard enzymatic methods were used. Friedewald formula was used to calculate the low-density lipoprotein cholesterol (LDL-C) concentration. Details of these methods have been described previously [15].

2.3. Carotid ultrasound imaging

Ultrasound studies were performed by trained sonographers following the standardized protocol described previously [2]. Carotid artery imaging was performed using Sequoia512 ultrasound scanner (Acuson, Mountain View, Calif) equipped with a 14 MHz linear array transducer and the ECG signal (modified chest lead 5) was recorded and presented alongside with B-mode image sets.

A resolution box function was used to scan the left common carotid artery (CCA) to record a 25 mm wide and 15 mm high image, including the beginning of the carotid bifurcation and the distal CCA. For subsequent off-line analysis, a 5 s cine loop (25 frames per second) was digitally stored. To derive CIMT and Cdist as well as radial and longitudinal motions of artery wall, the same image set was used. Blood pressure was measured in the supine position with an automated sphygmomanometer (Omron M4, Omron Matsusaka Co., Ltd, Japan) immediately before and after ultrasound imaging, for the calculation of the distensibility parameters.

2.4. Longitudinal motion

Carotid artery wall motion analysis was performed using an inhouse motion tracking program developed by our research-group [16]. The software was written in Matlab (2007b, The MathWorks Inc., Natic, MA, USA). It is capable of reading the graphical ECG-information from the ultrasound recording and simultaneously tracking the longitudinal and radial motions of the arterial wall. The basic method used in the motion tracking was a two-dimensional cross-correlation (block matching) enhanced with a contrast optimization technique to reduce noise from the videos.

In the longitudinal motion analysis, regions of interest (ROIs) are drawn on the ultrasound image on the intima-media complex, on the adventitial layer and on the surrounding tissue outside the adventitia. When tracking the radial motion of the arterial wall, ROIs are drawn on the distal and proximal arterial wall. The motion tracking of the longitudinal motion was considered suitable for analysis if the tracking successfully recorded at least two heart cycles, otherwise the motion data was discarded. Details of the methods have been described earlier [7,16].

We measured two different longitudinal motion curves: between the intima-media complex and the adventitial layer (IA) and between the intima-media complex and the surrounding tissue (IO). The curves of the longitudinal motion have been previously shown to vary extensively between individuals [16]. We investigated the amplitude of the motion (ampl), the forward (ante) oriented, and backward (retro) oriented component of the motion between the different layers of the CCA wall. We evaluated also the main deviation of the longitudinal motion (dev) between the different arterial layers by computing the average of the motion curve over a cardiac cycle.

2.5. Conventional measurements of vascular health

CIMT was measured by focusing the image on the posterior wall of the left CCA and the best-quality end-diastolic frame was selected from the video. To derive the maximal CIMT, at least four measurements were taken from this image, approximately 10 mm proximal to the bifurcation. The method has been described previously in detail [2]. Cdist measures the ability of the arteries to expand in response to the pulse pressure caused by cardiac