Artery Research (2015) 9, 33–39

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/artres

Clinical utility of digital volume pulse analysis in prediction of cardiovascular risk and the presence of angiographic coronary artery disease

Konstantinos Vakalis [a], Aris Bechlioulis [a], Katerina K. Naka, Konstantinos Pappas, Christos S. Katsouras, Lampros K. Michalis*

Department of Cardiology and Michaelidion Cardiac Center, University of Ioannina, Ioannina, 45110, Greece

Received 15 September 2014; accepted 21 October 2014
Available online 6 December 2014

KEYWORDS
Digital pulse volume;
Arterial stiffness;
Stiffness index;
Pulse wave velocity;
Coronary artery disease;
Cardiovascular risk

Abstract *Background:* Stiffness Index (SI), assessed by finger photoplethysmography (digital volume pulse analysis), has been suggested as a simple and easy measure of arterial stiffness. However, its potential association with cardiovascular risk and coronary artery disease (CAD) has been little studied. The aims of the study were to investigate the relation of SI with classical risk factors and established arterial stiffness indices and its ability to predict cardiovascular risk and the presence of angiographic CAD.
Methods: We enrolled 126 consecutive patients (mean age 61 years, 74% males) with suspected stable CAD undergoing diagnostic coronary angiography. Cardiovascular risk was assessed using Framingham risk score (FRS) and the European Heart score. Carotid-femoral (PWVcf) and carotid-radial (PWVcr) pulse wave velocity and augmentation index, using applanation tonometry, and SI using finger photoplethysmography, were measured in all patients.
Results: SI was positively correlated with PWVcr ($p = 0.017$) but not with PWVcf. Increased SI (R^2 0.19, $p < 0.001$) was independently associated with higher diastolic blood pressure and male gender. Increased SI and PWVcf were associated with higher FRS and Heart score ($p < 0.05$ for all), while only higher PWVcf was associated with the presence of angiographic CAD ($p = 0.007$).
Conclusions: SI, easily derived using finger photoplethysmography, was related to classical risk factors and peripheral arterial rather than aortic stiffness. SI and PWVcf were the only vascular indices associated with cardiovascular risk, but only PWVcf was related to the presence of

* Corresponding author. Tel.: +30 26510 07710; fax: +30 26510 07865.
E-mail address: lmihalis@cc.uoi.gr (L.K. Michalis).
[a] These authors had equal contributions to the preparation of the manuscript.

http://dx.doi.org/10.1016/j.artres.2014.10.001

coronary atherosclerosis. Further research is needed to clarify the value of this useful index of arterial stiffness in risk stratification.

Introduction

Cardiovascular disease (CVD) is one of the most common causes of mortality and morbidity in the western world.[1] Atherosclerosis is the leading cause of CVD and the identification of individuals at high CVD risk has been an important priority of modern medicine. The assessment of CVD risk in clinical practice is currently based on the calculation of "risk scores" such as the Framingham Risk Score (FRS)[2] and the European Heart Score[3] that take into consideration the presence of various established cardiovascular risk factors i.e. age, gender, smoking, blood pressure, lipids and diabetes status. However, in several occasions the estimated risk may be misguiding[4] leading to the search of novel markers that could refine risk stratification. Indices of subclinical atherosclerosis have been suggested to improve prediction of cardiovascular events.[5]

Increased arterial stiffness is thought to occur early in the atherosclerotic process and established measures of arterial stiffness, such as aortic pulse wave velocity (PWV) and augmentation index (AIx), have been shown to be associated with cardiovascular prognosis in several studies and large meta-analyses.[6–11] Increased carotid-femoral PWV (PWVcf)[12–15] and central AIx[12,16] have also been associated with the presence of coronary atherosclerosis in patients undergoing coronary angiography. Digital volume pulse (DVP) analysis using finger photoplethysmography is a non-invasive method for evaluating arterial stiffness with high reproducibility and low inter-observer variability.[17] Stiffness index (SI), derived by contour analysis of the digital pulse, is considered to be a measure of arterial stiffness[17] and has been previously associated with aortic PWV.[18,19] However, very few data exists associating this index to cardiovascular risk scores,[20–22] while its usefulness for risk stratification and the prediction of the presence of coronary atherosclerosis, especially in comparison to established arterial stiffness indices, has not been previously studied.

The aims of the present study were to investigate the association of SI with i) classical risk factors, ii) established arterial stiffness indices such as PWV and AIx derived by arterial tonometry and iii) cardiovascular risk (as assessed by FRS and Heart Score) and the presence of significant angiographic coronary artery disease (CAD), in high risk patients with suspected stable CAD undergoing diagnostic coronary angiography.

Methods

Study patients and design

One hundred thirty seven consecutive subjects referred for diagnostic coronary angiography due to suspected stable CAD were enrolled in the current study. Anginal symptoms on exertion and/or a positive non-invasive stress test indicating a high risk for stable CAD were the main reasons for referral. Patients with suspected or documented acute coronary syndrome, any history of previously established cardiovascular disease (including CAD, cerebrovascular and symptomatic peripheral vascular disease), valvular heart disease, prosthetic valves, congenital heart disease, hypertrophic obstructive cardiomyopathy, atrial fibrillation, as well as those on hemodialysis were excluded from the study.

Upon enrollment all subjects were asked about their medical history, presence of cardiovascular risk factors and use of any medication. A complete physical examination was performed before coronary angiography. Blood samples were drawn from all patients early in the morning after an overnight fast and just before coronary angiography. Measurement of vascular indices was performed in the morning before coronary angiography. Subjects whose pulse wave recordings could not be adequately assessed ($n = 11$) were excluded from the final analysis.

The study protocol was approved by the Ethics Committee of the University Hospital of Ioannina, Greece. The study complied with the Declaration of Helsinki and all participants provided written informed consent.

Cardiovascular risk factor assessment

Body mass index (BMI) was calculated as weight (kg) divided by the square of height (m^2). The minimum waist circumference between the pelvic brim and the costal margin was measured. Smokers were defined as those who were smoking at the time of enrollment or those who had stopped for less than 12 months. Office blood pressure (BP) was measured in the sitting position after 5 min of rest using an automated brachial sphygmomanometer (Omron M7, Omron Healthcare Co, Kyoto, Japan) and the mean of three consecutive measurements by a trained operator was reported. Hypertension was defined as office measured systolic blood pressure (SBP) $>$ 140 mmHg and/or diastolic blood pressure (DBP) $>$ 90 mmHg or administration of anti-hypertensive medications. Hypercholesterolemia was defined as low density lipoprotein cholesterol (LDL-c) $>$ 115 mg/dl or administration of anti-cholesterolemic medications. Diabetes mellitus was defined as a fasting blood glucose concentration $\geq$ 126 mg/dl or administration of anti-hyperglycemic medications. Creatinine clearance was estimated using the Modification in Diet in Renal Disease (MDRD) formula.[23] Fasting plasma glucose, serum lipids and creatinine were measured using standard methodology.

FRS is a multivariate risk function that predicts 10-year risk of developing coronary events[2]; a risk score of $<$10%, 10–20% and $>$20% indicates low, intermediate and high risk respectively. The risk factors included in FRS are age, gender, smoking, blood pressure, total and high density