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Original Research Article

Impedance plethysmography as an alternative method for the diagnosis of peripheral arterial disease

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ARTICLE INFO

Article history:
Received 11 April 2014
Accepted 21 November 2014
Available online 27 November 2014

Keywords:
Impedance plethysmography
Ankle-brachial index
Peripheral arterial disease

ABSTRACT

Background and objective: In the diagnosis of peripheral artery disease (PAD), the ankle-brachial index (ABI) is considered as the standard, and other noninvasive methods have received too little attention. Therefore, the aim of the study was to determine the diagnostic accuracy of impedance plethysmography in diagnosing PAD and to compare this method with other methods.

Materials and methods: A total of 66 patients with a mean age of 76.1 ± 9.6 years who had been treated for various cardiovascular diseases at Kaunas Clinical Hospital during 2011–2012 were enrolled into the study. All the patients were screened for PAD. Impedance plethysmography was performed with a new-generation Niccomo™ device. The receiver operating characteristic analysis was employed to determine the diagnostic accuracy of 4 parameters of impedance plethysmography: crest time (CT), crest width (CW), pulse amplitude (P_{ampl}), and alternating blood flow (ABF).

Results: There were a significant correlation between the ABI and the CT ($r = -0.699$, $P < 0.001$), between the ABI and the ABF ($r = 0.552$; $P < 0.001$), and between the ABI and the P_{ampl} only among men ($r = 0.652$; $P < 0001$). No correlation was found between the ABI and the CW. Among all the parameters, the CT had the highest sensitivity and specificity (73.2% and 96.0%, respectively). Other parameters had the following sensitivities and specificities: ABF, 61.0% and 96.0%; and P_{ampl}, 90.0% and 20.0%, respectively.

Conclusions: Impedance plethysmography, especially its parameter CT, is an alternative non-invasive method in diagnosing PAD and could be used for the screening of patients with PAD.

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Peer review under the responsibility of Lithuanian University of Health Sciences.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.medici.2014.11.007

1. Introduction

Peripheral artery disease (PAD) is a common pathological condition. It is estimated that the disease affects 10% and 20% of the general population [1]. The typical symptoms of intermittent claudication are experienced only by one-third of the patients, whereas in the majority (around 50%) of cases, the course of the disease remains asymptomatic [2,3].

Every clinic should have noninvasive diagnostic tools that would allow making rapid, simple, sufficiently accurate, time- and cost-effective screening of patients in order to early detect the disorders of the peripheral artery system. The measurement of the brachial index (ABI)/Doppler test is the most widely used test. It is rather simple to perform and is reported to have a sensitivity of around 95% and a specificity of almost 100% for the diagnosis of PAD [4]. Moreover, the ABI is an indicator of atherosclerosis at other vascular sites and recognized as a prognostic marker for future cardiovascular events and functional impairment [5,6].

To date, the diagnostics of PAD by different noninvasive methods has received too little attention over the world. Though the ABI is assumed as the standard for the screening of patients with PAD [4,5], our analysis has shown that it is applied rather rarely [7]. In medical practice across the world, impedance plethysmography is used for the assessment of blood flow in the lungs, heart, and aorta [8,9]. The first studies and publications about impedance plethysmography appeared in 1988–1993. Impedance plethysmography was successfully used to register periodic, heart activity-dependent pulse-wave velocity in limbs [10]. Limb impedance shows peripheral vascular response to the quantity and velocity of circulating blood [11] and peripheral vascular resistance. In 1990, a study by Jindal et al. investigated patients with the diagnosis of PAD who underwent impedance plethysmography, and the results obtained were compared with arteriographic findings. The results of impedance plethysmography were found to correlate very well with arteriographic findings [11]. However, there are no comparative studies that also examined the patients without the symptoms of PAD, when the ABI >0.9, as well as the patients without any symptoms.

Having reviewed the PubMed database of 2001–2011, we failed to find any articles describing diagnostics of PAD by the noninvasive diagnostic method of impedance plethysmography. Therefore, the aim of this study was to evaluate the diagnostic accuracy of impedance plethysmography in diagnosing arterial circulation disorders in the legs and to compare the sensitivity and specificity of this method with those of other noninvasive and invasive diagnostic methods.

2. Materials and methods

The study was conducted at Kaunas Clinical Hospital during 2011–2012. A total of 66 patients who had been treated for various cardiovascular diseases were enrolled into the study. Clinical data and data of medical history were collected from medical records and patients' interviews. The patients with cardiovascular diseases (CVD) were screened for PAD. The diagnosis of permanent atrial fibrillation (AF) was made based on subject's ECG or a history of rhythm disorders documented in medical records. Permanent AF was diagnosed according to the American College of Cardiology/American Heart Association/European Society of Cardiology definitions [12]. Previous ischemic stroke was documented in medical records, or the diagnosis of ischemic stroke was established by a neurologist and confirmed by computed tomography findings. The diagnosis of arterial hypertension (AH) was made based on the mean arterial pressure (MAP) of >140/90 mm Hg or o history of AH documented in medical records.

The ABI was recorded by using a 5-MHz Doppler ultrasound device (Elite model No. 100, Nicolet Vascular Inc., USA) in both the legs of all subjects. It was measured in the supine position after 10-min rest. Systolic blood pressure was measured at the level of the brachial artery of each arm and the posterior tibial and/or dorsalis pedis arteries of each leg. The measurements were performed 3 times, and the mean ABI was assessed. PAD was diagnosed in subjects with the ABI of <0.9 at least in one leg. Arterial circulation was assessed by using impedance plethysmography in the supine position to avoid interference caused by the venous blood influx.

The findings were recorded by using a new-generation Niccomo™ device, which is a tool for the noninvasive monitoring of hemodynamic parameters using the methods of impedance cardiography and impedance plethysmography. The 4 parameters of impedance plethysmography with the reference values defined in the manual of Niccomo™ software were analyzed [13]: crest time (CT) (reference value, <180 ms), crest width (CW) (reference value, <80 ms), pulse amplitude (P_{ampl}) (reference value, >0.7‰), and alternating blood flow (ABF) (reference value, >2.2%/min). While evaluating the associations between the ABI and parameters of impedance plethysmography, the severity of PAD according to Lawall and Diehm matched to those proposed by the manufacturer [14].

A device with a Doppler and color Doppler function, and a 5–10-Hz frequency linear transducer were used for the ultrasound examination of the arteries of the legs. During the examination, atherosclerotic plaques, changes in blood flow velocity, and changes in the Doppler spectrum were assessed. Blood flow velocity was measured at the groin and popliteal levels. If arteries were occluded, patients were referred to a vascular surgeon for consultation. In case of nonhealing wounds, necrosis, and pain at rest, angiography was performed.

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS), version 19.0. The following clinical parameters were analyzed: age, body mass index, hypertension, coronary artery disease, atrial fibrillation, and blood pressure. Continuous variables were expressed as a mean and standard deviation. The samples of continuous variables were checked for normality using the Kolmogorov–Smirnov test. Associations between continuous variables were tested by the Student *t*-test and the ANOVA method for variables with normal distribution and the Mann–Whitney and Kruskal–Wallis tests for nonnormally distributed variables. The chi-square test was employed to analyze associations between categorical variables.

In the study, the receiver operating characteristic (ROC) analysis was used. Spearman correlation was used for analysis of qualitative variables. The difference was considered to be statistically significant when a *P* value was less than 0.05.