AZJCVS
AZerbaijan Journal of CardioVascular Surgery

AZJCVS 2023;4(2):37-41
DOI: 10.5455/azjcvs.2023.06.09

Original Article

Hakan Guven[1], Askin Keskin Kaplan[2], Temmuz Taner[3]

[1]Hearth and Arrhythmia Hospital, Department of Cardiovascular Surgery, Bursa, Türkiye
[2]Maltepe University, Faculty of Medicine, Department of Family Medicine, İstanbul, Türkiye
[3]Bursa City Hospital, Department of Cardiovascular Surgery, Bursa, Türkiye

Received: 21 June, 2023
Accepted: 12 July, 2023
Published: 17 July, 2023

Corresponding Author: Hakan Guven
Hearth and Arrhythmia Hospital, Department of Cardiovascular Surgery, Bursa, Türkiye
Email: hakanguven@hotmail.com

CITATION
Guven H, Kaplan AK, Taner T. Diagnostic value of arteriel stiffness index and reflection index measurements in peripheral arterial disease: a comparative study. AZJCVS 2023;4(2):37-41.

Diagnostic value of arteriel stiffness index and reflection index measurements in peripheral arterial disease: A comparative study

Abstract
Aim: Atherosclerosis is undoubtedly a chronic, progressive, inflammatory and long asymptomatic disease. Therefore, early diagnosis is important in the long process. There are many methods used for early diagnosis. Among them, reliable, easily applicable, reproducible, inexpensive and easily accessible ones come to the fore. Digital Pulse Volume, which we obtained with Optical Pulse Oscillography, which is one of the digital plethysmographic methods that can be used in the early diagnosis and follow-up of peripheral arterial disease. In this study, we investigated the variability of these two parameters in patients diagnosed with peripheral artery disease.
Material and Methods: This single-center retrospective study was conducted between January 2019 and August 2020 in Bursa Heart and Arrhythmia Hospital Cardiovascular Surgery Outpatient Clinic. Ankle Brachial Index measurement was performed in 76 of the patients who applied to the outpatient clinic with the complaint of walking pain. Patients with an ankle brachial index below 0.9 and diagnosed with Peripheral Artery Disease and patients with an ankle brachial index of 0.9 and above were divided into 2 groups. Arterial Stiffness Index and Reflection Index measurements were made in patients in both groups. The difference between the two groups was compared.
Results: ASI values of group 1 patients were 7.18±1.41m/sec. while in Group 2 it was 11.08±0.90 m/sec. and it was found to be statistically significantly lower and within normal ranges in Group 1 ($p<0.001$), similarly, RI was found to be 16.61±3.44% in Group 1 and 33.16±10.71% in Group 2, and statistically significantly lower in Group 1 and in the normal range ($p<0.001$).
Conclusion: Assessment of arterial stiffness index and reflection index is believed to be useful in the prevention of CVD. By identifying people who are at risk of developing arterial stiffness, interventions can be targeted to reduce their risk of developing CVD.

Keywords: Ankle brachial index, arteriel stiffness index, reflection index, optical pulse oscillography, peripheral arterial disease

INTRODUCTION

Deaths due to cardiovascular diseases all over the world are in the first place, especially in developed countries (1). In a study by Balakumar et al. in 2016, they showed that cardiovascular diseases caused by atherosclerosis are responsible for more than half of the non-communicable causes of death worldwide each year (2). It is seen that cardiovascular diseases are an increasing trend, regardless of the development levels of countries and the socioeconomic status of people (3). Therefore, measures should be continued worldwide (3). It also creates an economic burden. Cardiovascular Diseases are at the top of the expenditures made by countries in the field of health. In Gögen S.'s study titled European Union and Turkey's heart health policies, 57% of the overall economic burden due to cardiovascular diseases is due to healthcare expenditures, 22% to unregistered expenditures of patients and 21% to productivity losses. It has been determined that expenditures are formed (4). According to WHO, it is estimated that more than 22 million deaths will occur due to cardiovascular diseases by 2030(5). This data further increases the value of studies for the early detection of atherosclerosis.

Atherosclerosis is undoubtedly a chronic, progressive, inflammatory and long asymptomatic disease (6). In this long subclinical process, the determination of atherosclerosis is important for the prevention of many cardiovascular diseases such as possible heart attack, stroke, and claudication (7). Today, many invasive and non-invasive methods are used for this purpose. Coronary and peripheral angiography, intravascular ultrasound invasive examinations, B-mode ultrasound, magnetic resonance imaging, electron-beam computed tomography can be counted among the noninvasive tests (6). However, these examinations are far from being a screening tool. Non-invasive examinations such as Pulse Wave Velocity (PWV), Arterial Stiffness Index (ASI), Ankle Brachial Index (ABI), Digital Volume Pulse (DVP) and carotid intima-media thickness (cIMT) offer easier and more widespread screening (7).

Arterial stiffness is determined by the smooth muscle tone of the vessel wall and the elastin/collagen structure it contains (8). When this structure is healthy, like young people, the wave velocity is slow and the return of the wave to the heart is late in diastole (9). When the structure is disrupted, in other words, when the artery hardens, wave motion accelerates and causes high pressure in systole and low pressure in diastole (9). These phases can be recorded by measuring Digital Pulse Volume (DPV) and Pulse-wave velocity (PWV) (10). Some calculations in the graphical breakdown of these phases have been proposed to measure the effects of arterial pressure on the vessel wall (11). Earlier, in 1922 Nachev et al. also measured arterial wave propagation velocity as an index of atherosclerosis and vascular health (12). In Japan, Takazawa et al. have used PWV extensively to evaluate the effects of vasoactive drugs and to characterize vascular aging (13).

ABI is measured by the systolic pressure in the ankle to the systolic pressure in the arm, it can be used as a screening test because it is quick and easy and has been used for many years to confirm the diagnosis in vascular practice and to evaluate the severity of peripheral arterial disease in the legs (14). At the same time, ABI is an indicator of atherosclerosis (15). It has been associated with coronary and cerebrovascular diseases and the presence of cardiovascular risk factors (15). In addition, low ABI has been demonstrated to be associated with increased mortality, myocardial infarction and stroke incidence in population cohort studies in the USA (16-19) and Europe (20-23). The ABI is calculated by dividing the systolic blood pressure obtained from the ankle by the systolic blood pressure obtained in the brachial artery while the patient is lying down (24). A ratio less than 1 (typically defined as <0.9) is considered abnormal (24).

In this study, we investigated the changes in Arterial Stiffness Index (ASI) and Reflection Index (RI) measurements in patients with peripheral arterial disease as determined by Ankle Brachial Index (ABI).

MATERIAL AND METHODS

Regional Ethics Committee approval was obtained for this retrospective study (Uludağ University Research Ethics Committee; number 2022-18/36).

This single-center retrospective study was conducted between January 2019 and August 2020 in Bursa Heart and Arrhythmia Hospital Cardiovascular Surgery Outpatient Clinic, with written informed consent from each patient.

Patients over 30 years of age, non-smokers, without known hypertension, coronary artery disease, renal failure, hyperlipidemia, and patients with a body mass index below 30 were included in the study. The remaining patients were not included in the study.

A total of 76 consecutive patients who applied to our outpatient clinic due to walking and leg pain were included in the study. Ankle Brachial Index (ABI), Arterial Stiffness Index (ASI) and Reflection Index (RI) measurements were made after taking the anamnesis and general examination of the all patients. Patients with a normal ABI of 0.9 and above in terms of peripheral arterial disease (PAH) were divided into Group 1 (n:37), and patients below 0.9, which were accepted as peripheral artery disease data, were divided into Group 2 (n:39). ASI and RI results were evaluated according to the presence of PAH.

DPV was recorded from the fingertip with an oscillograph, and Reflection index and SI measurements were made. Measurements were taken at room temperature, after the patients had rested for 15 minutes, in the supine position. Oscillography device: Vasolab 5000, (manufacturer ELCAT GmbH, Germany). Data analyzes were provided by the Microsoft Windows-based Vasolab 5000 software. All patients were measured by the same technician.

Statistical Analysis

All data were analyzed by saving them to the SPSS (statistical package for social sciences) for Windows 22 program on the computer. In order to decide which tests (parametric/nonparametric tests) will be applied first in the analysis of the data, the assumptions that must be met are tested. In order to decide the normality of the distribution, Kolmogorov-Smirnov, the other assumptions of the normal distribution, kurtosis and skewness values and histogram graph were used. T-test (Independent sample t-test) and Man Whitney-U test were used for the comparison of two independent groups. The significance level of 0.01 was used as a criterion in interpreting whether the obtained values were significant or not.

RESULTS

56 (74%) of the patients included in the study were male and 20 (36%) were female, and the mean age was 57.09 ± 17.59 years. There were 37 patients in Group 1 and 39 patients in Group 2. The mean ABI values of the patients in group 1 were 1.29±0.08, while in group 2 it was 0.8±0.05 (Table 1).

Table 1. Demografic information

		Group 1	Group 2	Age
Gender	Male (n)	26	30	57.09 ±17.59
	Female (n)	11	9	52.23±12.63
Ankle Brachial Index Mean±SD		1.29±0.08	0.8±0.05	

ASI values of group 1 patients were 7.18±1.41m/sec. while it was 11.08±0.90 m/sec in group 2. And it was found to be statistically significantly lower and within normal ranges in group 1 ($p<0.001$) (Figure 1) (Table 2).

Table 2. Comparation of arterial stiffness index and reflection index between peripheral arterial disease and non- peripheral arterial disease

Parameters	Peripheric arterial disease	Non-peripheric arterial disease	P-Value
Arteriel stiffness index (m/sec.) mean±SD	11,08±090	7.18±1.41	p<0.01
Reflection index (%) mean±SD	33.16±10.71	16.61±3.44	p<0.01

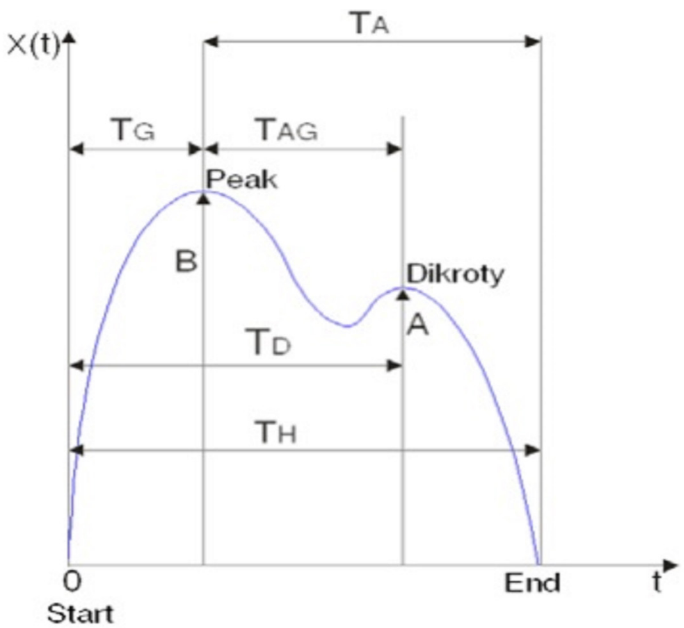

Figure 1. Nomenclature and evaluated parameters. TH: duration of cardiac cycle, P: pulse (beats/min), TG: peak concentration time, TD: dicrotic time, TA: decay time, TAG: basic arterial speed, TG/TA: standardized peak concentration time, TD/TA: standardized dicrotic time, RI: reflection index — RI=A/B (in%), SI: arterial stiffness — SI = Height/TAG (in m/s)

RI was found to be 16.61±3.44 % in Group 1 and 33.16±10.71% in Group 2, and it was statistically significantly low and within the normal range in Group 1 ($p<0.001$) (Figure 3) (Table 2).

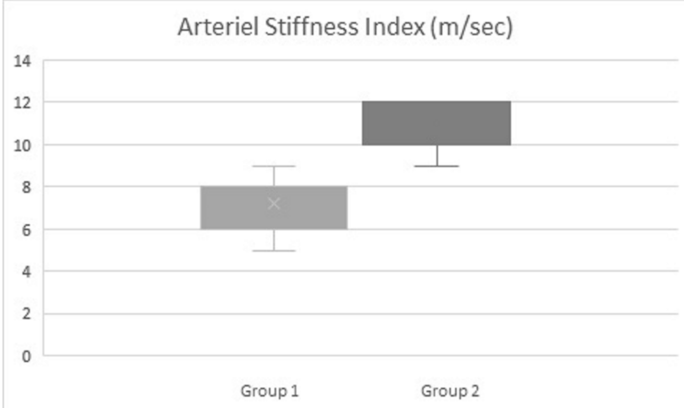

Figure 2. Arteriel stiffness index comparison by groups

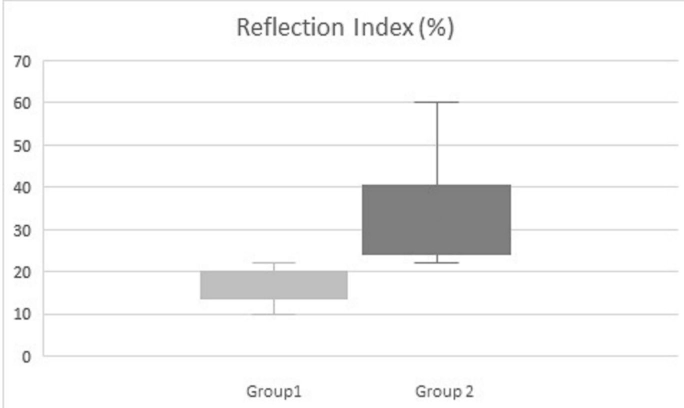

Figure 3. Reflection index comparison by groups

DISCUSSION

Peripheral arterial disease (PAD) which is one of the cardiovascular diseases is a prevalent manifestation of systemic atherosclerosis, predominantly affecting the arteries in the lower limbs (26). The global prevalence of PAD is estimated to be around 202 million individuals (27).

The presence of PAD substantially elevates the risk of cardiovascular events and overall mortality (28). Therefore, research focusing on the early stages of diagnosis assumes significant importance.

The ankle-brachial index (ABI) serves as a primary noninvasive diagnostic tool for lower extremity PAD (15,29). In individuals without PAD, the ABI value exceeds 1.0, while a value lower than 0.9 is commonly employed to diagnose PAD, demonstrating a diagnostic sensitivity of approximately 79% and specificity of 96% (30).

Pletysmographic principles form the foundation for the most widely used noninvasive methods in the field (31). Other techniques include computer oscillometry, ultrasonography, and applied tonometry. Pulse wave velocity, a well-established method, allows for the assessment of large artery stiffness (25). However, this method poses challenges in terms of complexity, time consumption, and cost. Consequently, there has been a drive toward the development of simplified approaches for measuring arterial stiffness. These alternative techniques offer the advantages of being noninvasive, cost-effective, and easily applicable. One such method involves obtaining Arterial Stiffness Index and Reflection Index from Digital Volume Pulse (DVP), which offers economic benefits, simplicity, minimal time requirements, and noninvasiveness. Hence, the present study aims to utilize Optical Pulse Oscillography (O-PO) to record Arterial Stiffness Index and Reflection Index, comparing the results between smokers and non-smokers.

Optical Pulse Oscillography (O-PO) is an economically feasible, non-invasive, and readily obtainable method used to acquire digital volume pulse (DVP) signals originating from peripheral pulse sites, including the ear lobe, fingertip, and toe. Several clinically significant parameters associated with O-PO signals include (a) pulse duration, (b) reflection index (RI), (c) pulse transit time (PTT), (d) pulse wave velocity (PWV) and (e) arterial stiffness index (ASI) (32).

In this study, we evaluated the differences in ASI and RI between those with (Group 2) and without PAH (Group 1). ASI values of group 1 patients were 7.18±1.41m/sec. while in Group 2 it was 11.08±0.90 m/sec. and it was found to be statistically significantly lower and within normal ranges in Group 1 ($p<0.001$), similarly, RI was found to be 16.61±3.44% in Group 1 and 33.16±10.71% in Group 2, and statistically significantly lower in Group 1 and in the normal range ($p<0.001$). As a result, we found that ASI and RI worsened statistically in patients with PAH.

Arterial stiffness (AS) and Reflection index (RI) are a reliable marker for changing in the structure and function of blood vessel walls, leading to the thickening of arterial walls, diminished flexibility, and increased rigidity (33). Several clinical studies have demonstrated that arterial stiffness is an early indicator of cardiovascular events (34). In our study, we showed that not only ASI and ABI, but also RI are closely related to the development of PAD or atherosclerosis. We believe that the evaluation of arterial stiffness index and reflection index are useful, together with other diagnostic methods, in the early diagnosis of atherosclerosis and therefore in the prevention of CVD.

Therefore, by evaluating both the arterial stiffness index and the reflectance index, healthcare professionals can gain a more comprehensive understanding of a patient's cardiovascular health and identify potential problems early on. This can help inform treatment decisions and lifestyle changes that can prevent the progression of atherosclerosis and reduce the risk of CVD. We recommend that this triad be followed carefully, especially in individuals with unmodifiable risk factors for atherosclerosis.

In this study, we did not aim to prove its superiority over ABI. Our main goal was to examine whether ASI and RI are also valuable in the diagnosis of atherosclerosis and PAD, and to evaluate their suitability for early diagnosis in future studies. We got results for some of them, but in order to be determined as a predictor, risk factors should be taken into account and long-term follow-up results should be seen in healthy individuals.

CONCLUSION

In conclusion, the evaluation of arterial stiffness index and reflection index are valuable in diagnosing PAD and could be useful in the early diagnosis of atherosclerosis and thus in the prevention of CVD.

Conflict of Interests: The authors declare that there are no conflict of interests.

Financial Disclosure: The authors declare that there is no financial support.

Ethics committee approval: Regional Ethics Committee approval was obtained for this retrospective study (Uludağ University Research Ethics Committee; number 2022-18/36).

Acknowledgment: We thank Abdullah Kınabaş for his technical support.

REFERENCES

1. Whitfield MD, Gillett M, Holmes M, Ogden E. Predicting the impact of population-level risk reduction in cardiovascular disease and stroke on acute hospital admission rates over a 5 year period—a pilot study. Public Health 2006;120:1140-8.
2. Balakumar P, Maung-U K, Jagadeesh G. Prevalence and prevention of cardiovascular disease and diabetes mellitus. Pharmacol Res 2016;113:600-9.
3. T.C. Sağlık Bakanlığı Temel Sağlık Hizmetleri Genel Müdürlüğü, Türkiye Kalp ve Damar Hastalıklarını Önleme ve Kontrol Programı, Basım 2010 Ankara. 2015.
4. Gögen S. Heart health policies of the European Union and Turkey. Arch Turk Soc Cardiol 2011;39:248-53.
5. Organization WH, edited. Global status report on noncommunicable diseases 2014. Geneva: World Health Organization.
6. Toth P. Subclinical atherosclerosis: what it is, what it means and what we can do about it. Int J Clin Pract 2008;62:1246-54.
7. Alizargar J, Bai C-H. Value of the arterial stiffness index and ankle-brachial index in subclinical atherosclerosis screening in healthy community-dwelling individuals. BMC Public Health 2019;19:65.
8. Van Bortel LM, Duprez D, Starmans-Kool MJ, Safar ME, Giannattasio C, Cockcroft J, et al. Clinical applications of arterial stiffness, Task Force III: recommendations for user procedures. Am J Hypertens 2002;15:445-52.
9. O'Rourke MF, Staessen JA, Vlachopoulos C, Duprez D, Plante GE. Clinical applications of arterial stiffness; definitions and reference values. Am J Hypertens 2002;15:426-44.
10. Oliver JJ, Webb DJ. Noninvasive assessment of arterial

DOI: 10.5455/azjcvs.2023.06.09

stiffness and risk of atherosclerotic events. Arterioscler Thromb Vasc Biol 2003;23:554-66.

11. Chowienczyk PJ, Kelly RP, MacCallum H, Millasseau SC, Andersson TL, Gosling RG, et al. Photoplethysmographic assessment of pulse wave reflection: blunted response to endothelium-dependent beta2-adrenergic vasodilation in type II diabetes mellitus. J Am Coll Cardiol 1999;34:2007-14.

12. Bramwell JC, Archibald VH. The velocity of the pulse wave in man. Proc R Soc Lond B Biol Sci 1922;93:298-306.

13. Takazawa K, Tanaka N, Fujita M, Matsuoka O, Saiki T, Aikawa M. Assessment of vasoactive agents and vascular ageing by the second derivative of photoplethysmograph waveform. Hypertension 1998;32:365–70.

14. Collaboration ABI; Fowkes FG, Murray GD, Butcher I, Heald CL, Lee RJ, Chambless LE et al. Ankle brachial index combined with framingham risk score to predict cardiovascular events and mortality: a meta-analysis. JAMA 2008;300:197-208.

15. Newman AB, Siscovick DS, Manolio TA, Polak J, Fried LP, Borhani NO, et al. Atherosclerosis: ankle-arm index as a marker of atherosclerosis in the cardiovascular health study. Circulation 1993;88:837-45.

16. Weatherley BD, Nelson JJ, Heiss G, Chambless LE, Sharrett AR, Nieto FJ, et al. The association of the ankle-brachial index with incident coronary heart disease: the Atherosclerosis Risk In Communities (ARIC) study, 1987–2001. BMC Cardiovasc Disord 2007;7:3.

17. Newman AB, Shemanski L, Manolio TA, Cushman M, Mittelmark M, Polak JF, et al. Ankle-arm index as a predictor of cardiovascular disease and mortality in the cardiovascular health study. Arterioscler Thromb Vasc Biol 1999;19:538-45.

18. Abbott RD, Petrovitch H, Rodriguez BL, Yano K, Schatz IJ, Popper JS, et al. Ankle/brachial blood pressure in men> 70 years of age and the risk of coronary heart disease. Am J Cardiol 2000;86:280-4.

19. Resnick HE, Lindsay RS, McDermott MM, Devereux RB, Jones KL, Fabsitz RR, et al. Relationship of high and low ankle brachial index to all-cause and cardiovascular disease mortality: the Strong Heart Study. Circulation 2004;109:733-9.

20. Leng G, Fowkes F, Lee A, Dunbar J, Housley E, Ruckley C. Use of ankle brachial pressure index to predict cardiovascular events and death: a cohort study. BMJ 1996;313:1440-4.

21. Hooi JD, Kester AD, Stoffers HE, Rinkens P, Knottnerus J, Van Ree J. Asymptomatic peripheral arterial occlusive disease predicted cardiovascular morbidity and mortality in a 7-year follow-up study. J Clin Epidemiol 2004;57:294-300.

22. Van der Meer IM, Bots ML, Hofman A, Iglesias del Sol A, van der Kuip DA, Witteman JC. Predictive value of noninvasive measures of atherosclerosis for incident myocardial infarction: the Rotterdam Study. Circulation 2004;109:1089-94.

23. Kornitzer M, Dramaix M, Sobolski J, Degre S, De Backer G. Ankle/arm pressure index in asymptomatic middle-aged males: an independent predictor of ten-year coronary heart disease mortality. Angiology 1995;46:211-9.

24. Curry SJ, Krist AH, Owens DK, Barry MJ, Caughey AB, Davidson KW, et al. Screening for peripheral artery disease and cardiovascular disease risk assessment with the ankle-brachial index: US preventive services task force recommendation statement. JAMA 2018;320:177-83.

25. Millasseau SC, Kelly RP, Ritter JM, Chowienczyk PJ. Determination of age-related increases in large artery stiffness by digital pulse contour analysis. Clin Sci (Lond) 2002;103:371-7.

26. Criqui MH, Aboyans V. Epidemiology of peripheral artery disease. Circ Res 2015;116:1509-26.

27. Fowkes FGR, Rudan D, Rudan I, Aboyans V, Denenberg JO, McDermott MM, et al. Comparison of global estimates of prevalence and risk factors for peripheral artery disease in 2000 and 2010: a systematic review and analysis. Lancet 2013;382:1329-40.

28. Agnelli G, Belch J, Baumgartner I, Giovas P, Hoffmann U. Morbidity and mortality associated with atherosclerotic peripheral artery disease. Atherosclerosis 2020;293:94-100.

29. Crawford F, Welch K, Andras A, Chappell FM. Ankle brachial index for the diagnosis of lower limb peripheral arterial disease. Cochrane Database of Systematic Reviews 2016;9:CD010680.

30. Lijmer JG, Hunink MG, van den Dungen JJ, Loonstra J, Smit AJ. ROC analysis of noninvasive tests for peripheral arterial disease. Ultrasound Med Biol 1996;22:391-8.

31. Binder S, Navratil K, Halek J. Chronic smoking and its effect on arterial stiffness. Biomed Pap Med Fac Univ Palacky Olomouc Czech Repub 2008;152:299-302.

32. Goswami D, Chaudhuri K, Mukherjee J. A new two-pulse synthesis model for digital volume pulse signal analysis. Cardiovasc Eng 2010;10:109-17.

33. Mozos I, Malainer C, Horbańczuk J, Gug C, Stoian D, Luca CT, et al. Inflammatory markers for arterial stiffness in cardiovascular diseases. Front Immunol 2017;8:1058.

34. Ben-Shlomo Y, Spears M, Boustred C, May M, Anderson SG, Benjamin EJ, et al. Aortic pulse wave velocity improves cardiovascular event prediction: an individual participant meta-analysis of prospective observational data from 17,635 subjects. J Am Coll Cardiol 2014;63:636-46.