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Původní sdělení | Original research article

Study of main arteries stiffness in patients with coronary heart disease depending on prevalence of atherosclerosis

U. I. Nizamov, F. M. Bekmetova, S. U. Khoshimov, A. B. Shek, R. D. Kurbanov

Republican Specialized Center of Cardiology, Tashkent, Uzbekistan

ARTICLE INFO

Article history:
Received: 6. 1. 2016
Received in revised form: 13. 4. 2016
Accepted: 14. 4. 2016
Available online: 18. 5. 2016

Klíčová slova:
Ischemická choroba srdeční
Koronární a multifokální ateroskleróza
Rychlost pulsové vlny

SOUHRN

Cíl: Studovat tuhost cévní stěny pacientů s ischemickou chorobou srdeční na základě prevalence aterosklerotických změn.

Materiál a metody: Do studie bylo zařazeno 90 pacientů s diagnózou nestabilní anginy pectoris třídy II B, kontrolní skupinu tvořilo 27 zdravých osob. Ukazatele tuhosti tepen jako rychlost pulsní vlny (pulse wave velocity, PWV) a index augmentace (augmentation index, AIx) byly hodnoceny metodou aplanační tonometrie s použitím přístroje SphygmoCor (AtCor Medical, Austrálie). Koronarografické vyšetření se provádělo přístrojem Allura CV-20 (Philips, Nizozemsko); stav karotid se posuzoval duplexní sonografií a postižení femorálních tepen se hodnotilo pomocí indexu kotník–paže < 0,9. V případě pochybností absolvoval pacient duplexní ultrazvukové vyšetření. Pacienti v hlavní skupině byli dále rozděleni do tří podskupin: podskupinu A tvořili pacienti s izolovanou koronární lézí; do podskupiny B byli zařazeni pacienti s bifokální aterosklerózou (kombinace změn na koronárních a karotických tepnách, nebo na koronárních a femorálních tepnách); podskupinu C zastupovali pacienti s multifokální aterosklerózou, která byla prokázána v třech cévních řečištích: karotickém, koronárním a femorálním.

Výsledky: Hodnoty PWV (11,2 ± 1,5 m/s) a AIx (19,8 ± 5,0 %) u pacientů s ischemickou chorobou srdeční byly 1,5× ($p < 0{,}001$), resp. 2,4× ($p < 0{,}001$) vyšší než u zdravých osob. Při analýze údajů jednotlivých podskupin bylo zaznamenáno zrychlení PWV ve všech třech podskupinách, přičemž maximálních hodnot bylo dosaženo v podskupině C (13,3 ± 1,5 m/s), což dostatečně spolehlivě překračuje hodnoty tohoto parametru v podskupině A (10,1 ± 0,6; $p < 0{,}01$) i B (11,0 ± 0,9; $p < 0{,}05$). I hodnota AIx byla byla vyšší v podskupině C (26,8 ± 6,4 %) než v podskupinách A (13,7 ± 2,9 %; $p < 0{,}001$) a B (18,9 ± 4,3 %; $p < 0{,}01$).

Závěr: U pacientů s ischemickou chorobou srdeční byla prokázána zvýšená tuhost cévních stěn projevující se vyšší rychlostí pulsové vlny ($p < 0{,}001$) a vyšším augmentačním indexem ($p < 0{,}001$) ve srovnání se zdravými jedinci, zatímco u pacientů s multifokální aterosklerózou (koronární, karotické a periferní tepny) byly nalezeny vyšší hodnoty AA ($p < 0{,}05$), AIx ($p < 0{,}001$), PWV ($p < 0{,}01$) a vyšší věk pacienta ($p < 0{,}01$). Na základě tohoto zjištění lze hodnocené parametry tuhosti cév považovat za zástupné (náhradní) markery při hodnocení prevalence a progrese aterosklerózy i účinnosti farmakologických intervencí.

ABSTRACT

Objective: To study the vascular wall stiffness in patients with coronary artery disease based on the prevalence of atherosclerotic lesion.

Materials and methods: The study involved 90 patients diagnosed with unstable angina class II B, the control group consisted of 27 healthy individuals. By using the SphygmoCor (AtCor Medical, Australia) apparatus, stiffness indicators, like pulse wave velocity (PWV) and augmentation index (AIx) were studied by means of the applanation tonometry method. Coronary angiography was performed on the Allura CV-20 (Philips, The

Address: Dr. Ulugbek Irgashevich Nizamov, MD, Republican Specialized Center of Cardiology, Tashkent, Uzbekistan, e-mail: ulugbek_nizamov@mail.ru
DOI: 10.1016/j.crvasa.2016.04.003

Please cite this article in press as: U.I. Nizamov, et al., Study of main arteries stiffness in patients with coronary heart disease depending on prevalence of atherosclerosis, Cor et Vasa 59 (2017) e114–e118 as published in the online version of *Cor et Vasa* available at http://www.sciencedirect.com/science/article/pii/S0010865016300352

Netherlands) unit, the state of the carotid arteries was studied by duplex ultrasonography, involvement of femoral arteries was evaluated based on ankle-brachial index < 0.9. In case of doubt, the patients underwent ultrasound duplex scanning. In the main group, patients were divided into 3 subgroups: subgroup A covered patients with isolated coronary lesion; subgroup B covered patients with bifocal atherosclerosis (combined lesion of coronary and carotid arteries or coronary and femoral arteries); subgroup C was represented by multifocal atherosclerosis patients who had atherosclerosis lesion in three vascular basins: carotid, coronary and femoral arteries.

Results: Values of PWV (11.2 ± 1.5 m/s) and AIx (19.8 ± 5.0%) in patients with coronary heart disease were 1.5 ($p < 0.001$) and 2.4 ($p < 0.001$) times higher than in those in healthy individuals. During the analysis carried out within the groups, the PWV in all three subgroups was accelerated with maximal values in the subgroup C (13.3 ± 1.5 m/s), which with sufficient level of confidence exceeds the value of this index in the subgroups A (10.1 ± 0.6, $p < 0.01$) and B (11.0 ± 0.9, $p < 0.05$). The value of AIx was also highest in the subgroup C (26.8 ± 6.4%), relative to the subgroups A (13.7 ± 2.9%, $p < 0.001$) and B (18.9 ± 4.3%, $p < 0.01$).

Conclusion: Patients with coronary heart disease, have demonstrated growing vascular wall stiffness, which is manifested in higher pulse wave velocity ($p < 0.001$) and augmentation index ($p < 0.001$) compared with healthy individuals. Whereas in the multifocal atherosclerosis (coronary, carotid and peripheral arteries) were higher AA ($p < 0.05$), AIx ($p < 0.001$), PWV ($p < 0.01$) and the age of patients ($p < 0.01$). That allows to consider the studied parameters of vascular stiffness as surrogate markers to assess prevalence and progression of atherosclerosis, as well as the effectiveness of pharmacological interventions.

Keywords:
Coronary and multifocal atherosclerosis
Coronary heart disease
Pulse wave velocity

Introduction

In recent years, scientific studies have revealed strong evidence for the role of increased stiffness of vascular wall in progression of hypertension and development of its major complications. For example, a correlation between increased vascular wall stiffness (measured based on the pulse wave velocity, PWV) and mortality rate was established in patients with hypertension in the REASON study [1]. The ASCOT-CAFE large-scale study [2] showed that the effect of antihypertensive therapy on the prognosis of patients with hypertension for a comparable decrease in brachial blood pressure (BP) depends on the degree of central aortic pressure reduction, which is modulated by elastic properties of large arteries.

According to the Framingham's criteria, PWV can be even stronger predictor of fatal and nonfatal cardiovascular complications than smoking, blood glucose, total cholesterol and other biological markers [3]. For the first time, in European (2007) and Russian (2008) recommendations on diagnosis and treatment of hypertension, vascular wall was identified as a "target organ" of the hypertensive process and increased PWV was included in the list of criteria for subclinical target organ damage in patients with hypertension. This indicator remained in the revised European recommendations on diagnosis and treatment of hypertension adopted in 2013 [4], where the carotid-femoral PWV was identified as an indicator influencing the prognosis of patients with hypertension.

However, the value of the vascular wall stiffness index in patients with coronary heart disease (CHD), depending on the severity of the disease and the intensity of atherosclerosis is the least studied topic.

Objective: to study stiffness of vascular wall in patients with CHD depending on the prevalence of atherosclerotic lesion.

Material and methods

The main group included 90 patients (54 men and 36 women) aged between 42 and 71 received by the coronary artery disease department of the Republican Specialized Center for Cardiology in 2015 with unstable angina (progressive angina II B class). The CHD diagnosis was confirmed by the results of veloergometry and coronary angiography (CAG). In addition, the study included 27 volunteers (15 men and 12 women) with the excluded cardiovascular disease, who were presented as a control group. The patients of the main group were divided into 3 subgroups: subgroup A included patients with isolated coronary artery disease; subgroup B – patients with bifocal atherosclerosis: a combined lesion in the coronary and carotid arteries, or coronary and femoral arteries; subgroup C represented patients with multifocal atherosclerotic process in which damage was detected in the three basins of the cardiovascular system (CVS): carotid, coronary and femoral arteries.

The vascular wall stiffness was studied based on the examination of the central systolic blood pressure (cSBP), central diastolic blood pressure (cDBP), central pulse pressure (cPP), aortic augmentation (AA), augmentation index (AIx), pulse wave velocity (PWV) by using the

Table 1 – Clinical and demographic characteristics of patients included in the study.

Index	Main group (n = 90)	Control group (n = 27)
Men	54 (60%)	15 (55.6%)
Women	36 (40%)	12 (44.4%)
Age	56.6 ± 11.7	53.1 ± 9.2
Duration of CHD	5.8 ± 3.1	–
Presence of myocardial infarction	27 (30%)	–
Essential hypertension	67 (74.4%)	–
Diabetes	17 (18.8%)	–
Smoking	51 (56.7%)	7 (25.9%)
Obesity	39 (43.3%)	10 (37.0%)

CHD – coronary heart disease.

applanation tonometry and by means of the SphygmoCor equipment (AtCor Medical, Australia).

Applanation tonometry was performed on a patient in the lying position after a 10-minute rest. The patient's passport data, anthropometric data, SBP and DBP measured manually by tonometry were entered into the computer software. The sensor of applanation tonometer was mounted on a radial artery and pulse wave was recorded to obtain high-quality recording with a minimal duration of 10 s, followed by automatic calculations to determine the parameters of central hemodynamics. In order to estimate the PWV, the distance (expressed in mm) from the pulse of the femoral artery to the clavicle (distal distance) and the distance (expressed in mm) from the pulse of the carotid artery to the clavicle (proximal distance) was measured. Consequently, three ECG electrodes were applied on the upper limbs and the left foot, pulse wave was consistently recorded at the carotid and femoral arteries with simultaneous ECG recording, and the PWVs were automatically calculated.

Ultrasonography of the carotid arteries was performed by means of the ALOKA – Multi View (Japan) ultrasound systems equipped with 7 MHz linear sensor (20 m) and SONOLINE VERSA PRO (SIEMENS, Germany). Images of the common carotid arteries (CCA) were obtained from the both sides in real time in synchronization with the R-wave of the ECG. During the sonography of the carotid arteries, thickness of the intima-media (IMT) posterior wall of the distal one-third of the CCA on both sides was estimated with the calculation of the maximal thickness of the IMT for 10-mm part proximal to the bifurcation, and size of atherosclerosis plaque with determination of stenosis percentage (%) by the diameter of the CCA.

Coronary angiography was performed on the Allura CV-20 (Philips, the Netherlands) unit. In order to assess the degree of arterial stenosis, the following characteristics, like: normal coronary artery, abnormal artery contouring without determining the degree of stenosis, stenosis of < 50%, stenosis of 51–75%, 76–95%, 95–99% (subtotal) and 100% (occlusion) were visually examined. Hemodynamically significant (> 50%) and non-significant coronary artery stenosis <50% cases were considered to be atherosclerotic lesions.

Femoral arteries involvement was evaluated based on the ankle-brachial index (ABI) of less than 0.9. In case of doubt, patients underwent ultrasound duplex scanning. According to recommendations of the European Society of Cardiology, ABI surpasses other methods such as history taking, questioning and checking pulse on peripheral arteries by palpation. The sensitivity and specificity of this indicator applied for peripheral arterial diseases detection reach up to 95% when the significant stenosis of the lower limbs arteries is angiographically verified [5].

The distribution of patients by clinical and demographic data is presented in Table. 1

Data obtained in this study was analyzed by using the methods of parametric and non-parametric variation statistics including calculations of the arithmetic mean values of the studied indicator (M), standard errors of the mean (σ), and the relative values (frequency, %). To compare the mean values, the statistical significance of the measurements was determined by the t-test (Student's t-distribution) with calculation of the error probability (*p*). For statistically significant changes the confidence level of $p < 0.05$ was used.

Results of the study

Based on the results of the test, the structure of the main group was as follows: subgroup A – 28 patients (31.1%), subgroup B – 45 patients (50%), subgroup C – 17 (18.9%).

All the patients were prescribed basic treatment, which included dual antiplatelet therapy (aspirin 75 mg and clopidogrel 75 mg), beta-blockers (bisoprolol) 2.5–10 mg/day, ACE inhibitors (perindopril, if the target blood pressure is not achieved), and statins (atorvastatin) (Table 2).

As can be seen from the table 2 in patients with multifocal atherosclerosis (subgroup C) were significantly higher the total cholesterol ($p < 0.05$), the triglycerides ($p < 0.01$), the cholesterol of low-density lipoproteins (LDL-C) ($p < 0.05$) and lower the cholesterol of high-density lipoproteins (HDL-C) ($p < 0.05$) than in the subgroup A.

Indicators of applanation tonometry were studied in each subgroup separately and the values were compared

Table 2 – Comparative characteristics of baseline lipid, carbohydrate metabolism, and initial treatment in the studied groups of patients with coronary heart disease.

Indicators	Main group (n = 90)	Subgroup A (n = 28)	Subgroup B (n = 45)	Subgroup C (n = 17)
Total cholesterol, mg/dL	246.7 ± 37.9	229.5 ± 30.8	253.3 ± 46.7	257.7 ± 31.9*
Triglyceride, mg/dL	215.0 ± 22.6	196.6 ± 14.0	215.6 ± 17.1	232.8 ± 36.7**
Cholesterol of HDL, mg/dL	37.5 ± 12.9	39.8 ± 15.4	36.0 ± 13.4	36.7 ± 9.9*
Cholesterol of VLDL, mg/dL	43.2 ± 15.8	39.3 ± 18.3	43.1 ± 15.1	46.6 ± 14.0*
Cholesterol of LDL, mg/dL	166.8 ± 22.2	150.4 ± 25.0	174.2 ± 21.1	174.4 ± 20.8*
Glucose, mmol/l	6.0 ± 1.2	6.0 ± 1.6	6.1 ± 0.9	6.2 ± 1.1
Bisoprolol, mg/day	6.6 ± 4.1	6.1 ± 4.4	6.5 ± 4.6	7.2 ± 3.3
Perindopril, mg/day	7.1 ± 3.7	4.7 ± 2.4	7.5 ± 4.1	8.3 ± 4.6
Atorvastatin, mg/day	32.4 ± 9.3	28.6 ± 7.2	29.3 ± 8.5	39.1 ± 10.1*

* $p < 0.05$, ** $p < 0.01$ – confidence level of differences between subgroup C with the subgroup A; HDL – high-density lipoproteins; LDL – low-density lipoproteins; VLDL – very low-density lipoproteins.

both within the subgroups and with the control group. Data is presented in Tables 3 and 4.

According to the applanation tonometry, in general, central hemodynamic parameters in patients with CHD during treatment corresponded to acceptable limits, although the mean values of the cSBP (p <0.05) and CPP (p <0.05) were somewhat higher than those values in healthy individuals, which could be probably explained by the fact that 67 (74.4%) patients had essential hypertension with controlled blood pressure values.

At the same time, in patients of the main group the values of PWV were 1.5 times (11.2 ± 1.5 m/s), and AIx – 2.4 times (19.8 ± 5.0 %) higher than those of the control group (p <0.001).

During the analysis carried out within the groups, the PWV in all three subgroups was accelerated with maximal values in the subgroup C (13.3 ± 1.5 m/s), which with sufficient level of confidence exceeded the value of this index in the subgroups A (10.1 ± 0.6, p < 0.01) and B (11.0 ± 0.9, p < 0.05). AIx augmentation index value was also highest in the subgroup C (26.8 ± 6.4) relative to subgroups A (13.7 ± 2.9, p < 0.001) and B (18.9 ± 4.3, p < 0 01).

Table 3 – Comparative evaluation of the parameters of central hemodynamics and pulse wave velocity in patients with ischemic heart disease and healthy individuals (M ± SD).

Indicators	Main group (n = 90)	Control group (n = 27)
cSBP, mmHg	123.9 ± 9.5*	117.6 ± 5.8
cDBP, mmHg	74.1 ± 5.8	73.6 ± 5.0
cPP, mmHg	49.8 ± 8.3*	44.0 ± 7.0
AA, mmHg	9.3 ± 1.3**	4.9 ± 0.9
AIx, %	19.8 ± 5.0***	8.1 ± 2.6
PWV, m/s	11.2 ± 1.5***	7.6 ± 0.7

* p < 0.05, ** p < 0.01, *** p < 0.001 – confidence level of differences relative to the control group; AA – aortic augmentation; AIx – augmentation index; cDBP – central diastolic blood pressure; cPP – central pulse pressure; cSBP – central systolic blood pressure; PWV – pulse wave velocity.

Discussion

Atherosclerosis is a dynamic process that develops over time determining remodeling of the arterial wall and does not clinically manifest itself, but its development often leads to acute clinical manifestations. Due to the complexity and inconvenience of invasive control methods (angiography, coronary angiography), reliable noninvasive surrogate markers are required to monitor the development and progression of atherosclerosis. These methods include ultrasound scanning of the main arteries to determine the ABI thickness and several indicators of the vascular wall stiffness, like: elasticity coefficient, distensibility coefficient, Peterson's elastic modulus, stiffness index, Young's modulus [6]. However, it is nowadays known that pulse wave velocity (PWV) evaluation is the «gold» standard for measurement of aortic stiffness.

It is known that PWV increases successively as the accumulation of atherosclerosis risk factors: hypertension [7], dyslipidemia [8], impaired glucose tolerance [9], and diabetes [10]. Carotid atherosclerosis becomes the next early and obvious link of this sequence [11]. Finally, in a sufficiently large number of longitudinal studies reported on the correlation PWV with cardiovascular and cerebrovascular complications of atherosclerosis [12,13].

Rotterdam study, for the first time, demonstrated a high correlation between increasing of pulse wave velocity (a marker of arterial stiffness) and presence of atherosclerosis, whereas the data obtained in that study made it possible to study this parameter as a predictor of prognosis for patients with CHD [14]. Independent studies based on angiography demonstrated that vascular wall stiffness increases proportionally to the number of atherosclerosis-impaired coronary arteries [15,16]. The results obtained in our study also confirm the correlation of the atherosclerosis prevalence with an increase of pulse wave velocity and augmentation index. The fact that patients with atherosclerotic vascular lesions of the three regions the average age was higher than in the subgroups with coronary atherosclerosis and bifocal, once again confirms its simultaneous impact on both the aging of blood vessels, and the prevalence of atherosclerosis [17].

Table 4 – Comparative evaluation of the parameters of central hemodynamics and pulse wave velocity in patients with coronary heart disease (M ± SD).

Indicators	Main group (n = 90)		
	Subgroup A, n = 28	Subgroup B, n = 45	Subgroup C, n = 17
Age, years	50.6 ± 10.0	52.7 ± 10.4	66.4 ± 14.7**
cSBP, mmHg	123.9 ± 11.4	121.8 ± 7.0	129.6 ± 9.8
cDBP, mmHg	73.4 ± 4.3	72.6 ± 3.8	79.3 ± 8.1
cPP, mmHg	43.9 ± 9.6	49.3 ± 5.0	50.3 ± 10.2*
AA, mmHg	8.3 ± 1.1	9.1 ± 1.3	10.5 ± 1.2*
AIx, %	13.7 ± 2.9	18.9 ± 4.3▲▲	26.8 ± 6.4***
PWV, m/s	10.1 ± 0.6	11.0 ± 0.9▲	13.3 ± 1.5**

* p < 0.05, ** p < 0.01, *** p < 0.001 – confidence level of differences between subgroup C with the subgroup A; ▲ p < 0.05, ▲▲ p < 0.01 – confidence level of differences between subgroup B with the subgroup C; AA – aortic augmentation; AIx – augmentation index; cDBP – central diastolic blood pressure; cPP – central pulse pressure; cSBP – central systolic blood pressure; PWV – pulse wave velocity.

Conclusion

Patients with coronary heart disease, have demonstrated growing vascular wall stiffness, which is manifested in higher pulse wave velocity ($p < 0{,}001$) and augmentation index ($p < 0{,}001$) compared with healthy individuals. Thus, in patients with vascular lesions of the two vascular beds (the coronary arteries and carotid) AIx ($p < 0.01$) and PWV ($p < 0.05$) were higher than in isolated coronary lesions. Whereas in the multifocal atherosclerosis (coronary, carotid and peripheral arteries) were higher AA ($p < 0.05$), AIx ($p < 0.001$), PWV ($p < 0.01$) and the age of patients ($p < 0.01$). That allows to consider the studied parameters of vascular stiffness as surrogate markers to assess prevalence and progression of atherosclerosis, as well as the effectiveness of pharmacological interventions.

Conflict of interest

No conflict of interest.

Ethical statement

The research was conducted according to Declaration of Helsinki.

Informed consent

Informed consent was obtained from all patients participating in this study.

References

[1] J. Blacher, A. Guerin, B. Pannier, et al., Impact of aortic stiffness on survival in end-stage renal disease, Circulation 99 (1999) 2434–2439.
[2] B. Williams, P.S. Lacy, S.M. Thom, et al., Differential impact of blood pressure-lowering drugs on central aortic pressure and clinical outcomes: principal results of the Conduit Artery Function Evaluation (CAFE) study, Circulation 113 (2006) 1213–1225.
[3] J. Blacher, R. Asmar, S. Djane, et al., Aortic pulse wave velocity as a marker of cardiovascular risk in hypertensive patients, Hypertension 33 (1999) 1111–1117.
[4] 2013 ESH/ESC Guidelines for the Management of Arterial Hypertension, The Task Force for the management of arterial hypertension of the European Society of Hypertension (ESH) and of the European Society of Cardiology (ESC), Heart Journal 10 (2013) 1093–1151.
[5] ESC Guidelines on the diagnosis and treatment of peripheral artery diseases, European Heart Journal 32 (2011) 2851–2906.
[6] S. Laurent, J. Cockroft, L. Van Bortel, et al., Expert consensus document on arterial stiffness: methodological issues and clinical applications, European Heart Journal 27 (2006) 2588–2605.
[7] A. Yamashina, H. Tomiyama, T. Arai, et al., Nomogram of the relation of brachial-ankle pulse wave velocity with blood pressure, Hypertension Research 26 (2003) 801–806.
[8] M.R. Razman, A.R. Jamaluddin, M.N. Ellyda, F.A. Seikh, Arterial and stiffness and its association with dyslipidemia, International Medical Journal of Malaysia 12 (2013) 59–66.
[9] H. Ohnishi, S. Saitoh, S. Takagi, et al., Pulse wave velocity as an indicator of atherosclerosis in impaired fasting glucose. The Tanno and Sobetsu Study, Diabetes Care 26 (2003) 437–440.
[10] K. Cruickshank, L. Riste, S.G. Anderson, et al., Aortic pulse-wave velocity and its relationship to mortality in diabetes and glucose intolerance: an integrated index of vascular function? Circulation 106 (2002) 2085–2090.
[11] M.J. Krantz, C.S. Long, P. Hosokawa, et al., Pulse wave velocity and carotid atherosclerosis in White and Latino patients with hypertension, BMC Cardiovascular Disorders 11 (2011) 15.
[12] K. Sutton-Tyrrell, S.S. Najjar, R.M. Boudreau, et al., Elevated aortic pulse wave velocity, a marker of arterial stiffness, predicts cardiovascular events in well-functioning older adults, Circulation 111 (2005) 3384–3390.
[13] F.U. Mattace-Raso, T.J. van der Cammen, A. Hofman, et al., Arterial stiffness and risk of coronary heart disease and stroke: the Rotterdam Study, Circulation 113 (2006) 657–663.
[14] N.E. Van Popele, D.E. Grobbee, M.L. Bots, et al., Association between arterial stiffness and atherosclerosis. The Rotterdam study, Stroke 32 (2011) 454–460.
[15] D. Drechsler, Assessment of carotid arteries and pulse wave velocity in patients with three-vessel coronary artery disease, Polish Heart Journal LVII (2002) 254–259.
[16] O. Satiroglu, M. Bostan, N. Bayar, et al., Relation between aortic stiffness and extension of coronary artery disease, Turkish Journal of Medical Sciences 42 (2012) 417–424.
[17] H. Smulyan, R.G. Asmar, A. Rudnichi, et al., Comparative effects of aging in men and women on the properties of the arterial tree, American College of Cardiology 37 (2001) 1374–1380.