

**T.V. Kolesnyk,
A.V. Nadiuk,
H.A. Kosova**

INFLUENCE OF AGE AND BODY MASS INDEX ON ARTERIAL STIFFNESS AND LEFT VENTRICULAR HYPERTROPHY IN PATIENTS WITH ARTERIAL HYPERTENSION II STAGE

SE «Dnipropetrovsk medical academy of Health Ministry of Ukraine»

Department of Propaedeutics of internal medicine

V. Vernadsky str., 9, Dnipro, 49044, Ukraine

ДЗ «Дніпропетровська медична академія МОЗ України»,

кафедра пропедевтики внутрішньої медицини

(зав. – д.мед.н., проф. Т.В. Колесник)

вул. В. Вернадського, 9, Дніпро, 49044, Україна

e-mail: dr.avnadiuk@gmail.com

Цитування: *Медичні перспективи. 2019. Т. 24, № 3. С. 22-32*

Cited: *Medicni perspektivi. 2019;24(3):22-32*

Key words: *arterial pressure, arterial hypertension, arterial stiffness, vascular aging, pulse wave velocity, central aortic pressure, amplification pressure, body mass index*

Ключові слова: *артеріальна гіпертензія, артеріальний тиск, судинна жорсткість, судинне старіння, швидкість розповсюдження пульсової хвилі, центральний аортальний тиск, ампліфікаційний тиск, індекс маси тіла*

Ключевые слова: *артериальная гипертензия, артериальное давление, сосудистая жесткость, сосудистое старение, скорость распространения пульсовой волны, центральное аортальное давление, амплификационное давление, индекс массы тела*

Abstract. Influence of age and body mass index on arterial stiffness and left ventricular hypertrophy in patients with arterial hypertension II stage. Kolesnyk T.V., Nadiuk A.V., Kosova H.A. *Based on the cumulative data of scientific research reference values for the central blood pressure and its amplification were proposed in patients with different cardiovascular risk factors. Still, the possibility of its practical implementation in patients of different age groups has not been fully studied. There were examined 132 untreated patients (23 females and 109 males) with uncomplicated essential hypertension, which were divided into 3 groups depending on age (WHO, 2012): I group included 47 patients of the young age, II group - 50 middle-aged patients and III group – 35 elderly patients. Measurements of central systolic blood pressure (cSBP), SBP amplification (SBP Amp), pulse wave velocity (PWV) were carried out by Arteriograph Tensioclinic (Tensiomed, Hungary). Target-organ damage included LVH which was determined by echocardiographic left ventricular mass index (LVMI), adjusted for body surface (g/m^2) or height ($\text{LVMI}^{2.7}$), aortic $\text{PWV} > 10$ m/s. It was established that the use of a personalized approach in the examination of patients with arterial hypertension makes it possible to increase the efficiency of diagnosis of hypertensive-mediated subclinical organ damage. So in order to identify impairment of the vascular wall in patients of a young age with hypertension, with overweight and obesity, the reference values of PWV and cSBP in accordance with the age norm should be taken into account. It was particularly in this cohort of patients that the greatest adverse effect of vascular stiffness and body mass index (BMI) on the formation of left ventricular hypertrophy was revealed, while in elderly people it is necessary to use the reference values of cSBP, depending on the degree of hypertension.*

Реферат. Вплив віку та індексу маси тіла на пружньо-еластичні властивості артеріальної стінки і гіпертрофію лівого шлуночка у хворих на артеріальну гіпертензію II стадії. Колесник Т.В., Надюк А.В., Косова Г.А. *За результатами чисельних досліджень було встановлено і запропоновано референтні нормативні значення для центрального артеріального тиску та його ампліфікації в пацієнтів з різним серцево-судинним ризиком. Проте можливість їх практичного застосування в пацієнтів різних вікових груп повністю не вивчена. Було обстежено 132 пацієнти з неускладненою есенціальною артеріальною гіпертензією, що не отримували антигіпертензивну терапію (23 жінки та 109 чоловіків), яких було розподілено на 3 групи залежно від віку (ВООЗ, 2012): I група включала 47 пацієнтів молодого віку, II група - 50 пацієнтів середнього віку та III група – 35 пацієнтів літнього віку. Вимірювання центрального систолічного артеріального тиску (цСАТ), ампліфікаційного САТ, швидкість розповсюдження пульсової хвилі (ШПХ) проводили за допомогою артеріографа Tensioclinic (Tensiomed, Hungary). Ураження органів-мішеней включало гіпертрофію лівого*

шлуночка (ГЛШ), яку визначали за ехокардіографічним індексом маси міокарда лівого шлуночка, скоригованим до поверхні тіла ($г/м^2$) або зросту (ГЛШ^{2.7}) і ШРПХ в аорті >10 м/с. Встановлено, що використання персоналізованого підходу при обстеженні хворих на артеріальну гіпертензію дозволяє підвищити ефективність діагностики зумовлених гіпертензією субклінічних уражень органів. Таким чином, для виявлення ураження судинної стінки у хворих молодого віку з артеріальною гіпертензією і надмірною масою тіла та ожирінням слід використовувати референтні значення ШРПХ і $цСАТ$ відповідно до вікової норми. Саме в цій групі пацієнтів виявлено найбільш несприятливий вплив судинної жорсткості та індексу маси тіла (ІМТ) на формування гіпертрофії лівого шлуночка. Разом з тим в осіб похилого віку необхідно використовувати референтні значення $цСАТ$ залежно від ступеня артеріальної гіпертензії.

According to WHO experts in 2013, cardiovascular mortality is 17 million people per year, which is one third of deaths worldwide. Almost 9.5 million deaths is result of arterial hypertension (AH) [8].

According to the results of the international epidemiological population survey aimed to assess cardiovascular risk factors among the urban population in Ukraine, carried out in Dnipro city (2009-2013), AH was detected in 45.7% of the subjects and a progressive increase in the prevalence of hypertension with age was found.

Thus, among respondents in the age group of 30-39 years, hypertension was detected in 31.5% of cases, at the age of 40-49 years – in 29.8% with a subsequent almost twofold increase, at the age of 50-59 years – in 55.6%, and at the age of 60-69 years the prevalence of hypertension reached 68.6% [6].

Obesity is an independent risk factor affecting the presence of hypertension. In a population-based study, M.R. Movahed et al., it was revealed that in 2002, AH was present in 50.7% of obese patients [19]. According to a population-based study conducted in Dnipro, only 29.3% of the population had normal body weight, and overweight and obesity of degree I-III were totally 70.7%. Of these: overweight was found in 39.18%, obesity of I degree - 22.75%, II degree - 7.78%, and III degree – 1.03% of the population [4].

Due to this, it is necessary to obtain reliable markers of damage of the vascular component and criteria for stratifying the risk of cardiovascular complications, already at an early stage of the development of the disease, available in real medical practice. It has been established that at the pre-clinical stages of the development of AH an increase in arterial wall stiffness has a high prognostic significance.

Arterial stiffness is the most important determinant of increased systolic blood pressure (SBP) and pulse blood pressure (PBP) and, therefore, the main cause of many cardiovascular complications and events, including left ventricular hypertrophy (LVH). Also, an increase in vascular stiffness is a leading component of the development of atherosclerotic vascular lesions and, therefore, stroke, heart

attack, renal failure [11]. Measurement of the pulse wave velocity (PWV) is the “gold standard” for determining the elastic characteristics of arteries [11].

Evaluation of PWV provides additional information about the elastic properties of the arterial system. Normally, it should not exceed 10 m/sec [13].

It has been established that an increase in PWV only by 1m/sec increases the risk of death by 15%, and therefore it is considered as an independent predictor of the development of cardiovascular diseases and cardiovascular mortality [23]. It was observed that the prognostic value of PWV is most important in the early stages of hypertension [3].

The European Association of Non-Invasive Studies of Large Arteries carried out joint work within the framework of the Arterial Stiffness' Collaboration in order to determine the reference values of PWV. The study included 11092 almost healthy individuals who were divided into age groups over decades (in the years <30 , 30-39, 40-49, 50-59, 60-69 and over 70), which were further stratified into groups according to the degree of blood pressure (BP) elevation. As a result, reference and normal values of PWV were proposed for different age groups in accordance with the degree of blood pressure elevation [12].

In France, Annie Herbert et al. [16] in the framework of The Reference Values for Arterial Measurements Collaboration analyzed data from 77 studies in 53 centers of 45,436 healthy individuals, who were not treated for hypertension, dyslipidemia, had no obvious cardiovascular diseases and diabetes. Using additional data about the level of brachial systolic and diastolic blood pressure, age, gender, smoking status, lipid profile parameters, glucose and creatinine level stratification of cardiovascular risk was carried out. The levels of central SBP (cSBP) were determined and its amplifications (AmpBP) were calculated as percentiles for the population: “Normal” indicators for individuals without cardiovascular risk (CVR) factors and “reference” values for individuals with any CVR factor. Normal and reference values of cSBP and AmpBP were proposed depending on the age category and, separately, on the degree of hypertension [16]. However,

the possibility of practical application of these indicators in patients of different age groups, taking into account the presence of increased body weight or obesity remains not fully understood.

Therefore, the main objective of our work was to define the features of central and peripheral blood pressure, the elastic properties of the arterial wall and left ventricular hypertrophy in patients with essential hypertension of stage II, depending on age and body mass index (BMI).

MATERIALS AND METHODS OF RESEARCH

We examined 132 patients (23 women and 109 men) with stage II AH, who were stratified into three groups according to the WHO 2012 classification. The first group consisted of 47 patients of young age (from 31 to 45 years), the second group consisted of 50 middle-aged people (from 46 to 60 years), and the third group – 35 elderly people (from 61 to 75 years).

The mean age in the first group was 38.00 (35.00; 41.00) years, in group II – 53.00 (50.00; 57.00) years and 66.00 (62.00; 68, 00) years in group III. All groups differed significantly in age ($p < 0.05$).

The stage and degree of arterial hypertension were established according to the guidelines for the diagnosis and treatment of arterial hypertension (Order of the Ministry of Health of Ukraine N 384 of 24.05.2012 and guidelines of ESH/ ESC 2013, 2018). In all examined groups, 1 degree hypertension was registered more often: in 32 patients (68.09%) from group I, in 30 patients (60.00%) from group II and in 22 (62.86%) patients in group III. Degree II AH was found in 10 (21.27%) patients in the first group, in 13 (26.00%) in group II, and in 7 (20.00%) in group III. Degree III hypertension was registered in 5 people (10.64%) in group I, 7 (14.00%) people in group II, and 6 (17.14%) in group III. By results of assessment of BP levels according to the degree of its elevation, it was found that the groups did not differ significantly ($p > 0.05$). The duration of hypertension was 5.00 (2.00; 13.00) years in the group of young patients, 9.00 (4.00, 13.00) years in the middle-aged group and 13.00 (10.00, 16.00) years in the group of elderly patients and was significantly higher in group III compared with groups I and II ($p < 0.05$).

Analysis of risk factors revealed that in the first group, the BMI was 29.98 (26.88; 33.95) kg/m^2 , in the second group – 32.07 (28.63; 35.98) kg/m^2 and was more than in third – 25.58 (27.34; 30.58) kg/m^2 ($p < 0.05$). Smoking as a risk factor was found in 20 (42.55%) persons in the first group, in 14 (28.00%) in group II and in 3 (8.57%) in group III. Younger patients smoked significantly more often than older patients ($p < 0.05$). Family history of hypertension was detected in 39 (82.99%) patients in

group I, 34 (68.00%) patients in group II, and 15 (42.85%) patients in group III.

Exclusion criteria included symptomatic hypertension, NYHA functional class III-IV heart failure with LV ejection fraction $< 40\%$, coronary heart disease, cardiac arrhythmias, diabetes mellitus and severe comorbid conditions.

Parameters of central (cSBP, cPBP, AmpBP) and peripheral hemodynamics (SBP and diastolic BP (DBP) and PBP and ankle-brachial index (ABI)), as well as the characteristics of the elastic properties of the arterial wall (PWV, pulse wave return time (RT) and augmentation index (AI)) were determined by arteriograph Tensioclinic (Tensiomed, Hungary) using the oscillometric method [22].

Additional analysis of the PWV according to the reference value adjusted for age and degree of hypertension proposed in the Arterial Stiffness' Collaboration study 2010, was made [12]. Analysis of the levels of cSBP and AmpBP was performed in accordance with reference values adjusted for age and the degree of hypertension determined in the The Reference Values for Arterial Measurements Collaboration study, 2014 [16].

Evaluation of LV structural remodeling was performed using transthoracic echocardiography (EchoCG) with assessment of anteroposterior size of the left atrium (LA), left ventricular end-diastolic internal dimension (LVIDd) and end-systolic ID (LVIDs) and right ventricle (RV), LV end-diastolic volume (LVEDV) and end-systolic volume (LVESV), LV ejection fraction (LV EF), stroke volume (SV), inter-ventricular septum wall thickness (IVST) and LV posterior wall thickness (LVPW). The LV myocardium mass (LVMM) was calculated using the formula of the American Echocardiographic Society. LV hypertrophy (LVH) was determined with indicators of LV myocardial mass index (LVMMI) by body surface area (g/m^2) and by indexation of LVMM to height^{2.7} (LVMMI^{2.7}), since this allows to analyze the actual degree of LVH excluding the influence of patient weight.

The study was approved by Biomedical Ethical Commission of the Dnipropetrovsk Medical Academy, Ukraine. Protocol N 1, 2016 Jan 20.

Statistical processing of the research results was carried out using Excel 2010, a software product STATISTICA 6.1. For quantitative parameters with asymmetric distribution, the average values were estimated in medians and interquartile range (25% and 75% percentiles), presented as Me (25%; 75%). The assessment of the reliability of the difference of the means for quantitative parameters with asymmetric distribution was carried out according to the Mann-Whitney U criteria. Correlative analysis was

performed using the Spearman's rank correlation coefficients [5]. Differences between the indicators were considered significant at $p < 0.05$.

RESULTS AND DISCUSSION

Analysis of level of SBP in groups (Table 1), revealed its elevation with age ($p > 0.05$), that corresponds to the data of J.G. Wang et al. which showed gradual increasing of SBP level with aging, whereas DBP increases till sixth decade, and then stabilizes or gradually decreases [21]. However, among the examined patients the level of the DBP was similar in all groups ($p > 0.05$). The level of PBP was the highest among the elderly persons and the difference

was significant compared with the middle-aged group ($p < 0.0045$). Comparing the PBP level in elderly and young patients showed a tendency toward significant difference ($p = 0.054$). Increased PBP in the arteries of small and large caliber leads to the early development of atherosclerosis [20]. The highest heart rate (HR) was found in young patients. Significantly higher HR was in younger patients compared with other groups ($p < 0.02$), and HR in patients of group II and III did not differ significantly ($p > 0.05$). The parameter of the ABI between groups did not differ statistically.

Table 1

Parameters of central and peripheral hemodynamics in the examined patients

Parameters	I group, young age, n=47	II група, middle age, n=50	III група, elderly, n=35
SBP. mm Hg.	145.5 (135.00; 162.00)	151.00 (136.00; 163.00)	153.00 (140.00; 172.00)
DBP. mm Hg.	89.50 (80.00; 101.00) ^{&}	95.00 (84.00; 102.00)	91.00 (86;00; 100.00)
PBP. mm Hg.	56.50 (48.00; 66.00)	56.50 (48.00; 61.00)	62.00 (55.00; 73.00) ^{&}
Heart rate. beats/min.	75.50 (62.00; 86.00)	66.00 (59.00; 75.00)	68.0 (58.00; 78.00) ^{s&}
cSBP. mm Hg.	134.15 (123.80; 151.60)	149.25 (135.40; 169.10)	151.20 (134.00; 179.50) ^{s&}
cSBP above norm adjusted to the age (number of the patient (%))	42 (89.36%)	48 (96.00%)	27 (77.14%)
cSBP above the norm adjusted to the degree of hypertension (number of the patients (%))	34 (72.34%)	45 (90.00%)	31 (88.57%)
AmpBP	11.05 (6.40; 15.20)	0.25 (-7.50; 8.70)	-5.90 (-8.00; 4.40)
AmpBP above the norm (number of the patients (%))	22 (46.81%)	38 (76.00%)	29 (82.86%)
ABI	1.28 (1.18; 1.35)	1.30 (1.20; 1.40)	1.30 (1.20; 1.40)

Notes: - $p < 0.05$ between the groups I and II; \$ - $p < 0.05$ between the groups I and III; & - $p < 0.05$ between the groups II and III.

The central pressure in the aorta is hemodynamically significant blood pressure, which is mean pressure in the aorta during one cardiac cycle [7]. Scientific evidence from the past 10 years suggests that central pressure is better associated with future cardiovascular events than the level of brachial blood pressure [7, 13, 22]. Many studies have shown that, compared to the SBP on the brachial artery, cSBP is more closely related to the thickness of the

intima-media complex, the mass of the left ventricle, and damage to other target organs in the general population and in hypertensive patients [7, 10, 20, 22].

According to the results of our study, it was established that the cSBP level in elderly people was significantly higher by 11.28% than in young patients and was not significantly different compared with middle-aged patients ($p = 0.002$). The level of cSBP in

patients of middle age was significantly higher (by 10.12%) than in the young ($p=0,002$).

For a more detailed analysis of central hemodynamics, an analysis of the levels of cSBP and AmpBP was performed in accordance with reference values adjusted for age and the degree of hypertension determined in the Reference Values for Arterial Measurements Collaboration study, 2014

[16]. Result of our study showed that among young and middle-aged patients, an increase in the level of cSBP is more commonly detected according to the reference values adjusted for age, however among elderly patients, increasing of cSBP level according to the reference values adjusted to the degree of hypertension is more significant. (Fig. 1).

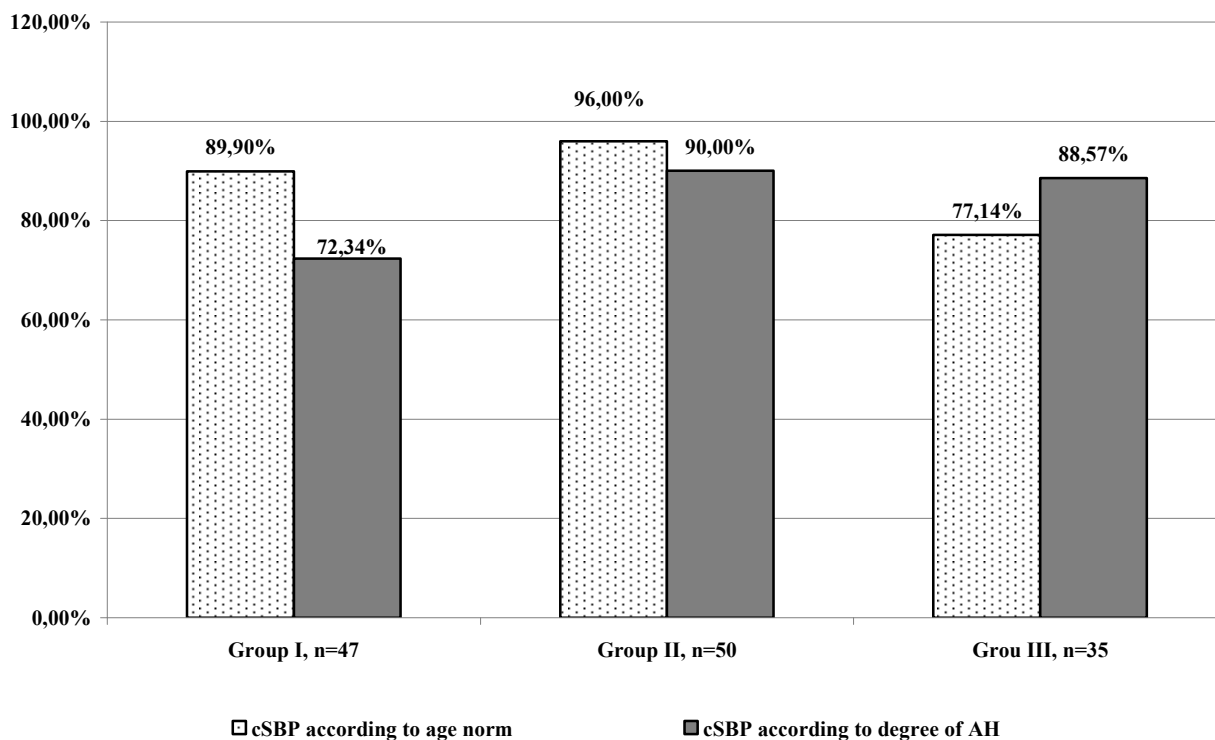


Fig. 1. The frequency of detection of elevated level of cSBP in accordance with reference values adjusted for age and the degree of hypertension (%)

The difference between cSBP in aorta and brachial SBP is called amplification blood pressure (AmpBP) [9]. This parameter reaches its maximum at a young age and decreases with age [1]. The AmpBP level reflects the stiffness of the aorta and normally the cSBP level is 10–12 mm lower than the SBP level in the brachial artery [22]. Studies have shown that low amplification of pulse BP among older age groups has received greater prognostic value than the level of brachial BP [3, 18].

According to the results of the study, it was determined that in young patients the AmpBP level (11.05 (6.40; 15.20) mm Hg) was the highest ($p<0.0001$) and corresponded to generally accepted norms (+10-12 mm). In middle-aged and elderly patients the AmpBP level (0.25 (-7.50; 8.70) and -5.90 (-8.00; 4.40) mm Hg, respectively) was significantly lower than in young patients ($p<0.0001$). In

groups the decrease in AmpBP was found in 82.86% of the elderly, in 76.00% – middle aged and in 44.81% of young patients with stage II hypertension.

Analysis of elastic characteristics of the arterial wall (Table 2) revealed that the level of PWV increases with the age. It was found that in elderly patients PWV was significantly higher by 11% than in young patients ($p<0.00001$) and 8.11% higher than in middle-aged patients ($p<0.005$). Pathological increase in PWV is registered more often among patients of group I – 77.14%, compared to 62.00% in group II and 51.06% in group III.

For a more precise diagnosis of the vascular wall damage as a target organ, there was made an analysis of the PWV according to the reference value adjusted for age and degree of hypertension proposed in the ArterialStiffness' Collaboration study 2010 [12].

Table 2

Elastic properties of the arterial wall in examined patients

Parameters	I group, young age, n=47	II group, middle age, n=50	III group, elderly, n=35
AI, %	-46.25 (-59.60; -28.60) ^{S&}	-9.25 (-33.90; 21.20)	8.7 (-22.7; 35.60)
PWV, m/sec	10.00 (8.20; 10.50) ^S	10.20 (9.30; 11.50) [*]	11.10 (10.00; 12.10)
PWV, m/sec above norm adjusted to the age (number of the patients (%))	42.56%	24.0%	20.86%
RT, msec	117.50 (108.00; 134.00) ^{S&}	104.50 (97.00; 121.00)	100.00 (92.00; 111.00)

Notes: * - p<0.05 between the groups I and II; S - p<0.05 between the groups I and III; & - p<0.05 between the groups II and III.

In the group of young patients, the percentage of the patients with increased PWV raised to 93.62%, due to exceeding the age norm in patients with PWV<10 m/sec (+42.56%). In the group of middle-aged patients 86.0% of individuals had an increase in PWV above the age norm (+24.0%) and among elderly patients - 80.00% (+20.86%). The need for a more personalized assessment of PWV value is extremely important. It was found that patients with PWV in the aorta >75th percentile compared with

the group of patients where the level of PWV corresponded to the value of <75th percentile are more often diagnosed with target organ damage, specifically: carotid atherosclerosis – almost 9 times more often, thickening of intima-media complex – 2 times more often (p<0.05). Moreover, all cases of microalbuminuria were diagnosed specifically among patients with PWV >75th percentile (32.40%) (p<0.01) [2].

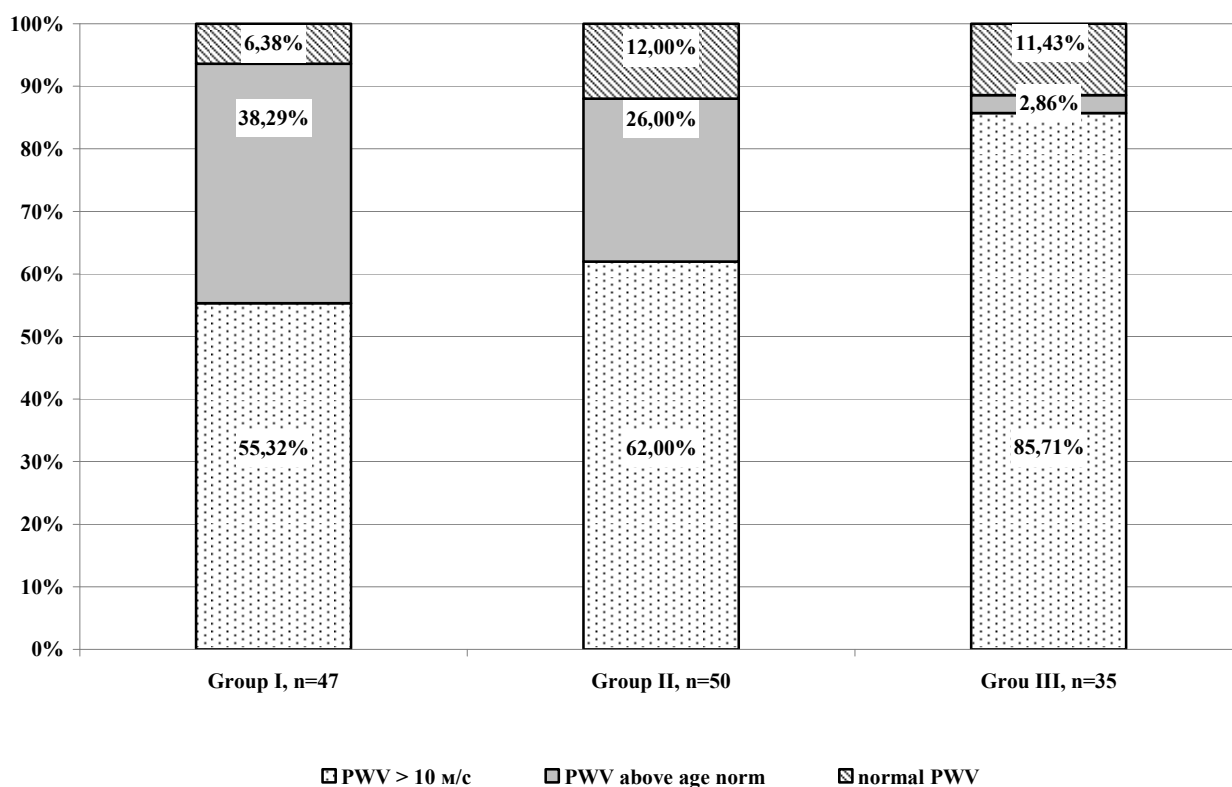


Fig. 2. Distribution of the surveyed groups depending on the PWV increasing (%)

The return time of the pulse wave (RT, ms) also reflects aortic stiffness, and the smaller it is, the higher the vascular stiffness. Normally, it is not less than 124 ms [22]. According to the results, the lowest RT level was registered in elderly persons. Among the examined patients in the first group, normal RT was detected in 17 (48.57%) patients, in group II – in 11 people (22.00%), in group III RT was increased in all patients.

Condition of the aorta and large arteries is also reflected by the augmentation index. The value of AI is the ratio of the maximum pressure during systole to the value of cPBP [7]. In healthy young people, AI has a negative value (-10% and below), but with aging or an increased risk of cardiovascular events, it becomes more positive [15]. We found that only among patients of group I, AI was normal and increased with age. It was established that in patients of a young age, AI was 6.31 times lower than in elderly people ($p < 0.000001$) and 5 times less than in middle-aged patients ($p < 0.00001$).

According to some authors, AI is also a predictor of cardiovascular events [14]. Data of a meta-analysis of Vachopoulos C. et al., 2010 showed that with an increasing of AI by every 10%, the risk of cardiovascular diseases rises by 32% [23]. Also in an epidemiological study in the population of Copenhagen (Denmark), Julie Hjorts Janner et al. in 2012 it was found that an increase in AI is an important predictor of cardiovascular events and mortality [17]. However, AI is not a direct parameter of stiffness but the result of interaction between several factors. The BP level and heart rate are the most important variables that affect the AI [14]. It was established that an increase in AI in patients with hypertension is a predictor of total mortality even in patients with end-stage kidney disease [3].

Assessment of structural and functional state of the heart according to the results of EchoCG has shown that the dimensions of the LV – LVIdD, LVIdS, as well as the volumes of the LV – LVEDV and LVESV corresponded to the standard values and did not differ significantly in groups ($p > 0.05$). The size of the LA was in the normal range in all groups of patients ($p > 0.05$). The LVEF was preserved and did not differ significantly between the groups ($p > 0.05$).

An increased thickness of the LVPW and IVS (Table 3) was revealed in all groups, specifically: in the I group – 1.00 (0.98; 1.16) and 1.30 (1.20; 1.40) cm, in group II – 1.00 (0.92; 1.11) and 1.35 (1.30; 1.50) cm, in group III 1.0 (0.95; 1.17) and 1.37 (1.20; 1.50) cm, respectively, which exceeded the standard values but did not differ significantly ($p > 0.05$).

The highest value of the LV myocardium mass index was found in group III – 110.50 (101.74;

129.49) g/m^2 , it decreased with age and was 108.8 (102.20; 120, 56) in group II and in group I – 100.75 (87.80; 118.91) g/m^2 . In elderly people, LVMMI was by 9.75 g/m^2 more than in young people ($p = 0.041$), and in group of middle-aged people, 8.1 g/m^2 more than in young people ($p = 0.036$).

The value of LVMMI^{2,7} exceeded the threshold in elderly patients (50.92 (46.41; 61.70) $\text{g}/\text{height}^{2,7}$) and middle age (52.75 (47.48; 58.13) $\text{g}/\text{height}^{2,7}$), and in young patients was normal (44.11 (37.02; 54.15) $\text{g}/\text{height}^{2,7}$). By LVMMI^{2,7} III and I groups differed significantly by 6.18 $\text{g}/\text{height}^{2,7}$, 13.37% ($p = 0.013$), and group II and I by 8.64 $\text{g}/\text{height}^{2,7}$, 16.38% ($p = 0.0008$).

It has been shown that a more sensitive indicator of LVH evaluation is LVMMI^{2,7}. Depending on the value of LVMMI, the frequency of LVH detection was 29.27% in group I patients, 51.06% in group II patients and 51.61% in group III. But the groups did not differ in the frequency of LVH diagnosis. And depending on the value of LVMMI^{2,7}, LVH (LVH^{2,7}) was diagnosed in 43.90%, 82.30% and 74.42% of cases in groups I, II and III, respectively and the difference was significant among patients of groups I and III, I and II ($p < 0.05$).

Results of multifactorial correlation analysis showed that there is a direct relationship between the age of the patients and the duration of hypertension in group I and II ($r = +0.32$; $p < 0.05$ and $r = +0.30$; $p < 0.05$, respectively). In the group I, an increase in age was also associated with a significant decrease in AmpBP ($r = -0.40$; $p < 0.05$) and parameter of RT ($r = -0.36$; $p < 0.05$). Increase in BMI correlated with the duration of hypertension in patients of group I ($r = +0.32$; $p < 0.05$) and in patients of group III, with an increase in ABI ($r = +0.52$; $p < 0.05$).

It was established that the decreasing of ABI in different age groups has its own interrelation features with the parameters of vascular stiffness. Thus, in the group of young persons, the ABI decreased in the presence of higher level of SBP and cSBP ($r = -0.44$ and $r = -0.36$, respectively; $p < 0.05$), and in the elderly, with an increase in PWV ($r = -0.57$; $p < 0.05$), as well with decrease of RT ($r = +0.64$; $p < 0.05$). While value of PWV in patients of group III associated with a longer history of hypertension ($r = +0.33$; $p < 0.05$).

Correlation analysis of the obtained data with the EchoCG parameters has showed that in group I an increase in BMI was associated with an increase in LVPW thickness and LVMMI^{2,7} ($r = +0.40$ and $r = +0.37$, respectively; $p < 0.05$). Decrease in LVEF was associated with age and increasing of BMI only in group II patients ($r = -0.31$ and $r = -0.33$; $p < 0.05$).

Table 3

The structural characteristics of the left ventricle by EchoCG data

Parameter	LVPWT, sm	IVST, Sm	LVMMI, g/m ²	LVMMI ^{2,7} , g/height ^{2,7}
I group	1.00 (0.98; 1.16)	1.30 (1.20; 1.40)	100.75 (87.80; 118.91)	44.11 (37.02; 54.15)
II group	1.00 (0.92; 1.11)	1.35 (1.30; 1.50)	108.8 (102.20; 120.56)*	52.75 (47.48; 58.13)*
III group	1.0 (0.95; 1.17)	1.37 (1.20; 1.50)	110.50 (101.74; 129.49)	50.92 (46.41; 61.70) [§]

Notes: * - p<0.05 between the groups I and II; § - p<0.05 between the groups I and III; & - p<0.05 between the groups II and III.

Analysis of correlations between the parameters of EchoCG and the characteristics of the elastic properties of the vascular wall revealed that only in group I LVMMI and LVMMI^{2,7} were associated with the level of SBP(r=+0.34 and r=+0.35 respectively;

p<0.05), DBP (r=+0.49 and r=+0.42 respectively; p<0.05), cSBP (r=+0.45 and r=+0.42 respectively; p<0.05), AmpBP (r=-0.39 and r=-0.31 respectively; p<0.05) and AI (r=+0.38; p<0.05 and r=+0.33; p<0.05 by groups respectively).

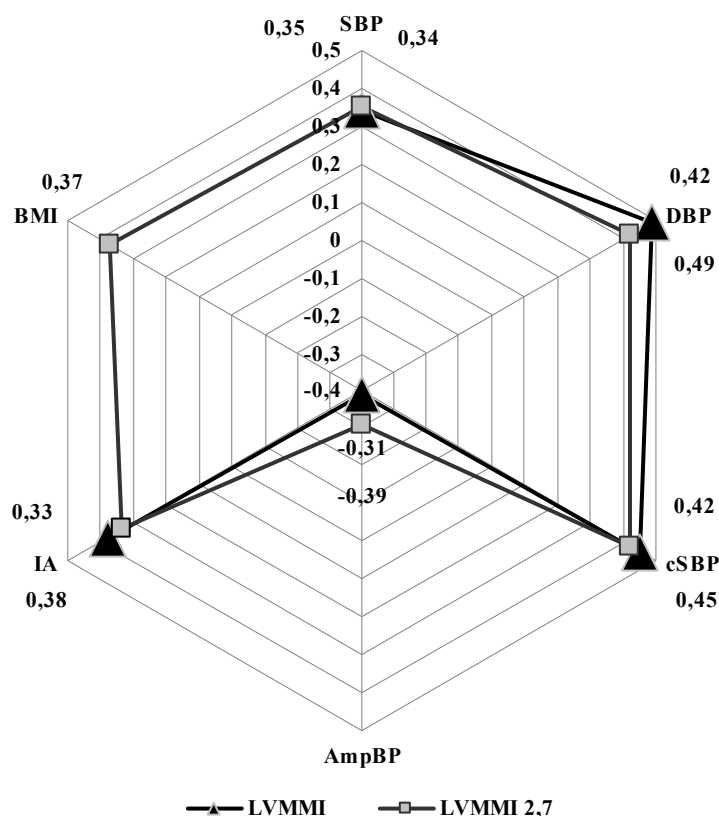


Fig. 3. Correlation between the parameters of LVMMI and LVMMI^{2,7}, indicators of central and peripheral hemodynamics and BMI among young patients

CONCLUSION

1. In the context of modern requirements for the personification management of each individual case of hypertension, relying on modern inter-

national guidelines and diagnostic possibilities in today's hypertensiology, it is necessary to take into

account the peculiarities of hypertension in patients of different age groups.

2. Thereby, among younger patients the AmpBP level and PWV value are more sensitive indicators of vascular stiffness and for the elderly – the cSBP level and ABI.

3. We have established that for a personalized approach in patients of young age with hypertension, reference values of cSBP adjusted for age should be taken into account, and in elderly people – reference values of cSBP adjusted for degree of hypertension. For the middle-aged group all indicators of the elastic properties of the vascular wall have the same diagnostic significance.

4. For the early detection of patients with a high risk of subclinical target organ damage, especially

among young patients, not only the pathologically increased level of PWV should be considered but also the age reference values of PWV.

5. Particular attention should be paid to young patients with overweight and obesity, because it is exactly this age category that has a relationship between the increase in PWV adjusted for age and an increase in BMI.

6. Not only elevated level of SBP and DBP, but also an increased cSBP level, AI value, and pathological decrease of AmpBP influenced the formation of LVH among young people.

7. Only in young patients with AH, the LVMMI_{2,7} increasing is associated with an increasing in BMI.

REFERENCES

1. Dzyak GV, Kolesnik TV, Kolesnik EL. [Central aortic pressure on the background of long-term combination antihypertensive therapy]. *Ukrainian Medical Chronicle*. 2012;90(4):89-93. Russian. Available from: <https://www.umj.com.ua/article/39559/centralnoe-aortalnoe-davlenie-na-fone-dlitelnoj-kombinirovannoj-antigipertenzivnoj-terapii>
2. Druzhilov MA, Druzhilova OYu, Otmakhov VV, Kuznetsova TYu. [The pulse wave velocity in the aorta as an additional prognostic criterion for abdominal obesity]. *Cardiovascular Therapy and Prevention*. 2015;3:5. Russian. doi: <https://doi.org/10.15829/1728-8800-2015-3-49-53>
3. Kniazkova II, Zhadan AV, Nesen AO. [Arterial stiffness as a risk factor and therapeutic target for arterial hypertension]. *Praktycal anhiology*. 2017;76(1):5-14. Ukrainian. Available from: <https://angiology.com.ua/ua-issue-article-666>
4. Mitchenko OI, Mamedov MN, Kolesnyk TV, Dieiev AD, Romanov VYu, Kulyk OYu, Shkroba AO. [Prevalence of arterial hypertension in the urban population of Ukraine depending on the degree and type of obesity]. *International Endocrinological Journal*. 2015;67(3):13-19. Ukrainian. doi: <https://doi.org/10.22141/2224-0721.3.67.2015.75265>
5. Rebrova OYu. [Statistical analysis of medical data. Application package STATISTICA]. Moskva: MediaSphere; 2002. Russian.
6. Mitchenko EI, Mamedov MN, Kolesnik TV, Deev AD. [The current profile of risk factors for cardiovascular diseases in the urban population of Ukraine]. *Ukrainian Kardiological Journal*. Collection of materials XIV Natsional Ukrainian cardiology congress. 2013;76-83. Russian. Available from: http://journal.ukrcardio.org/wp-content/uploads/2013/04/D5_4d_2013.pdf
7. Nedogoda SV, Ledyeva AA, Tsoma VV, Chumachok EV, Barykina IN. [Central pressure in the aorta as a target for antihypertensive therapy]. *Farmateka*. 2011;20:30-37. Russian. Available from: <https://lib.medvestnik.ru/apps/lib/assets/uploads/pharmateca/PDF/8313.pdf>
8. World Health Organization. A global brief on hypertension : silent killer, global public health crisis: world health day. 2013;39. Available from: https://www.who.int/cardiovascular_diseases/publications/global_brief_hypertension/en/
9. Cecelja M, Chowienczyk P. Role of arterial stiffness in cardiovascular disease. *RSM Cardiovascular Disease*. 2012;1(4):1-10. doi: <https://doi.org/10.1258/cvd.2012.012016>
10. McEniery CM, Cockcroft JR, Roman MJ, Franklin SS, Wilkinson IB. Central blood pressure: current evidence and clinical importance. *European Heart Journal*. 2014;35:1719-25. doi: <https://doi.org/10.1093/eurheartj/ehq565>
11. O'Rourke MF, Staessen Jan A, Vlachopoulos Ch, Duprez DI, Plantedoc GE. Clinical applications of arterial stiffness; definitions and reference values. *American Journal of Hypertension*. 2002;15(5):426-44. doi: [https://doi.org/10.1016/S0895-7061\(01\)02319-6](https://doi.org/10.1016/S0895-7061(01)02319-6)
12. Boutouyrie P, Mattace-Raso F, Hofman A, Verwoert GC, Wittemana JC, Wilkinson I, et al. Determinants of pulse wave velocity in health people and in the presence of cardiovascular risk factors: 'establishing normal and reference values'. The reference values for Arterial Stiffness' Collaboration. *European Heart Journal*. 2010;31:2338-50. doi: <https://doi.org/10.1093/eurheartj/ehq165>
13. Williams B, Mancia G, Spiering W, Agabiti Rosei E, Azizi M, Burnier M, Clement DL, Coca A, de Simone G, Dominiczak A, Kahan T, Mahfoud F, Redon J, Ruilope L, Zanchetti A, Kerins M, Kjeldsen SE, Kreutz R, Laurent S, Lip GYH, McManus R, Narkiewicz K, et al. ESC/ESH guidelines for the management of arterial hypertension. *European Heart Journal*. 2018;39(33):3021-104. doi: <https://doi.org/10.1093/eurheartj/ehy339>

14. Gismondi RA, Oigman W, Neves MF. Antihypertensive agents and arterial stiffness. *Journal of Thoracic Disease*. 2016;8(7):1386-87. doi: <https://doi.org/10.21037/jtd.2016.05.60>
15. Hanboly NH. Arterial stiffness in health and disease. *Nigerian Journal of Cardiology*. 2017;14(2):65-70. doi: https://doi.org/10.4103/njc.njc_3_17
16. Herbert A, Cruickshank JK, Laurent S, Bou-touyrie P. Reference Values for Arterial Measurements Collaboration. Establishing reference values for central blood pressure and its amplification in a general healthy population and according to cardiovascular risk factors. *Eur Heart J*. 2014;35:3122-33. doi: <https://doi.org/10.1093/eurheartj/ehu293>
17. Janner JH, Godtfredsen NS, Ladelund S, Vestbo J, Prescott E. High aortic augmentation index predicts mortality and cardiovascular events in men from a general population, but not in women. *European Journal of Preventive Cardiology*. 2013;20(6):1005-12 doi: <https://doi.org/10.1177/2047487312449588>.
18. Benetos A, Gautier S, Labat C, Salvi P, Valbusa F, Marino F, et al. Mortality and cardiovascular events are best predicted by low central/peripheral pulse pressure amplification but not by high blood pressure levels in elderly nursing home subjects: the partage (predictive values of blood pressure and arterial stiffness in institutionalized very aged population) study. *Journal of the American College of Cardiology*. 2012;60(16):1503-11. doi: <https://doi.org/10.1016/j.jacc.2012.04.055>
19. Movahed M, Lee J, Lim W, Hashemzadeh M, Hashemzadeh M. Strong independent association between obesity and essential hypertension. *Clinical Obesity*. 2016;6(3):189-92. doi: <https://doi.org/10.1111/cob.12139>
20. O'Rourke MF, Staessen Jan A, Vlachopoulos Ch, Duprez DI, Plantedoc GE. Consequences of arterial stiffening and increase in central blood pressure in hypertension. *Mediographia*. 2015;37(4):380-90. ISSN 0243-3397 Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4155427/>
21. Wang JG, Stassen JA, Franclin SS, Fagard R, Gueyffie F. Systolic and diastolic blood pressure lowering as determinants of cardiovascular outcome. *Hypertension*. 2005;45(5):907-13. doi: <https://doi.org/10.1161/01.HYP.0000165020.14745.79>
22. User's manual TensioClinic TensioMed Arterio-grafand TensioMed Program [Internet]. [cited 2017.10.19] Available from: http://www.tensioed.com/download/manual_arg_bt_en.pdf
23. Vlachopoulos C, Aznaouridis K, Stefanadis C. Prediction of cardiovascular events and all-cause mortality with arterial stiffness: a systematic review and meta-analysis. *Journal of the American College of Cardiology*. 2010;55(13):1318-27. doi: <https://doi.org/10.1016/j.jacc.2009.10.061>

СПИСОК ЛІТЕРАТУРИ

1. Дзяк Г. В., Колесник Т. В., Колесник Э. Л. Центральное аортальное давление на фоне длительной комбинированной антигипертензивной терапии. *Укр. мед. часопис*. 2012. Т. 90, № 4. С. 89-93. <https://www.umj.com.ua/article/39559/centralnoe-aortalnoe-davlenie-na-fone-dlitelnoj-kombinirovanoj-antigipertenzivnoj-terapii>
2. Дружилов М. А., Дружилова О. Ю., Отмахов В. В., Кузнецова Т. Ю. Скорость пульсовой волны в аорте как дополнительный прогностический критерий при абдоминальном ожирении. *Кардиоваскулярная терапия и профилактика*. 2015. № 3. С. 5 с. DOI: <https://doi.org/10.15829/1728-8800-2015-3-49-53>
3. Князькова І. І., Жадан А. В., Несен А. О. Артеріальна ригідність як чинник ризику і лікувальна мішень при артеріальній гіпертензії. *Практична ангіологія*. 2017. Т. 76, № 1. С. 5-14. URL: <https://angiologia.com.ua/ua-issue-article-666>
4. Поширеність артеріальної гіпертензії у міській популяції України залежно від ступеня та типу ожиріння / О. І. Митченко, та ін. *Міжнародний ендокринологічний журнал*. 2015. Т. 67, № 3. С. 13-19. DOI: <https://doi.org/10.22141/2224-0721.3.67.2015.75265>
5. Реброва О. Ю. Статистический анализ медицинских данных. Применение пакета прикладных программ STATISTICA. Москва: МедиаСфера, 2002.312с.
6. Современный профиль факторов риска сердечно-сосудистых заболеваний в городской популяции Украины / Е. И. Митченко и др. *Укр. кардиологический журнал: материалы XIV Нац. конгресса кардиологов Украины*. 2013. С. 76-83. URL: http://journal.ukrcardio.org/wp-content/uploads/2013/04D/5_4d_2013.pdf
7. Центральное давление в аорте как мишень для антигипертензивной терапии / С. В. Недогода и др. *Фарматека*. 2011. № 20. С. 30-37. URL: <https://lib.medvestnik.ru/apps/lib/assets/uploads/pharmateca/PDF/8313.pdf>
8. A global brief on hypertension: silent killer, global public health crisis: world health day 2013. *World Health Organization*. 2013. 39 p. URL: https://www.who.int/cardiovascular_diseases/publications/global_brief_hypertension/en/
9. Cecelja M., Chowienczyk P. Role of arterial stiffness in cardiovascular disease. *JRSM Cardiovascular Disease*. 2012. Vol. 1, No. 4. DOI: <https://doi.org/10.1258/cvd.2012.012016>
10. Central blood pressure: current evidence and clinical importance / С. М. McEniery et al. *Eur. Heart J*. 2014. No. 35. P. 1719-1725. DOI: <https://doi.org/10.1093/eurheartj/ehs565>
11. Clinical applications of arterial stiffness; definitions and reference values / V. F. O'Rourke et al. *Am. J. Hypertension*. 2002. Vol. 15., No. 5. P. 426-444. DOI: [https://doi.org/10.1016/S0895-7061\(01\)02319-6](https://doi.org/10.1016/S0895-7061(01)02319-6)
12. Determinants of pulse wave velocity in health people and in the presence of cardiovascular risk factors: 'establishing normal and reference values' / The reference

values for Arterial Stiffness' Collaboration / P. Boutouyrie et al. *Eur. Heart J.* 2010. No. 31. P. 2338-2350. DOI: <https://doi.org/10.1093/eurheartj/ehq165>

13. ESC/ESH guidelines for the management of arterial hypertension / B. Williams et al. *Eur. Heart J.* 2018. Vol. 39, No. 33. P. 3021-3104. DOI: <https://doi.org/10.1093/eurheartj/ehy339>

14. Gismondi R. A., Oigman W., Neves M. F. Anti-hypertensive agents and arterial stiffness. *J. Thoracic Disease.* 2016. Vol. 8, No. 7. P. 1386-1387. DOI: <https://doi.org/10.21037/jtd.2016.05.60>

15. Hanboly N. H. Arterial stiffness in health and disease. *Nigerian J. Cardiology.* 2017. Vol. 14, No. 2. P. 65-70. DOI: https://doi.org/10.4103/njc.njc_3_17

16. Herbert A., Cruickshank J. K., Laurent S., Boutouyrie P. Reference Values for Arterial Measurements Collaboration. Establishing reference values for central blood pressure and its amplification in a general healthy population and according to cardiovascular risk factors. *Eur. Heart J.* 2014. No. 35, p. 3122-33. DOI: <https://doi.org/10.1093/eurheartj/ehu293>

17. High aortic augmentation index predicts mortality and cardiovascular events in men from a general population, but not in women / J. H. Janner et al. *Eur. J. Preventive Cardiology.* Vol. 20, No. 6. P. 1005-1012. DOI: <https://doi.org/10.1177/2047487312449588>

18. Mortality and cardiovascular events are best predicted by low central/peripheral pulse pressure amplification but not by high blood pressure levels in elderly

nursing home subjects: the partage (predictive values of blood pressure and arterial stiffness in institutionalized very aged population) study / A. Benetos et al. *J. Am. College of Cardiology.* 2012. Vol. 60, No. 16. P. 1503-1511. DOI: <https://doi.org/10.1016/j.jacc.2012.04.055>

19. Movahed M. R., Lee J. Z., Lim W. Y. Hashmzaden Strong independent association between obesity and essential hypertension. *Clin Obes.* 2016. Vol. 6, No. 3. P. 189-192. DOI: <https://doi.org/10.1111/cob.12139>

20. O'Rourke M. F. Consequences of arterial stiffening and increase in central blood pressure in hypertension. *Mediographia.* 2015. Vol. 37, No. 4. P. 380-390. URL: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4155427/>

21. Systolic and diastolic blood pressure lowering as determinants of cardiovascular outcome / J. G. Wang et al. *Hypertension.* 2005. Vol. 45, No. 5. P. 907-913. DOI: <https://doi.org/10.1161/01.HYP.0000165020.14745.79>

22. User's manual TensioClinic TensioMed Arteriograf and TensioMed Program. URL: https://www.tensio-med.com/download/manual_arg_bt_en.pdf

23. Vlachopoulos C., Aznaouridis K., Stefanadis C. Prediction of cardiovascular events and all-cause mortality with arterial stiffness: a systematic review and meta-analysis. *J. Am. College of Cardiology.* 2010. Vol. 55, No. 13. P. 1318-1327. DOI: <https://doi.org/10.1016/j.jacc.2009.10.061>

The article was received
2019.06.20

