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The Relationship between the Parameters of Blood Pressure Variability and Arterial Wall Stiffness in Patients with Arterial Hypertension

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Abstract

The purpose of the research was to study the significance of blood pressure variability (BPV) in the assessment of arterial stiffness (AS) in patients with arterial hypertension (AH), and their possible relationship with the indicators of structural and functional remodeling of the myocardium, serum lipid spectrum, and homeostasis system.

Materials and Methods: A total of 138 patients (mean age of 56.7±12.8) with AH were examined. All patients were twice divided consecutively into two groups: one on the basis of age (the age groups ≥60 years and <60 years), and another on the basis of the presence or absence of isolated systolic hypertension (ISH). The age groups ≥60 years and <60 years did not differ in terms of blood pressure. The ISH and systolic-diastolic hypertension (SDH) subgroups did not significantly differ in sex composition and average 24-h SBP (131.2±8.6 mm Hg and 137.5±17.0 mmHg, respectively; P>0.05). In the ISH subgroup, average 24-h DBP was significantly lower than in the SDH subgroup: 74.5±4.8 mmHg and 87.4±10.9 mmHg, respectively (P=0.000). All patients underwent the following examinations: assessment of traditional risk factors, physical examination, clinical and biochemical laboratory methods, 12-lead ECG, echocardiography, 24-hour ABPM, assesment of the AS parameters, and measuring the carotid-femoral pulse wave velocity (PWVcf).

Results: The age group ≥60 years was characterized by a significant increase in AS compared to the age group <60 years. In the age group ≥60 years, the levels of daytime and nighttime pulse pressure (PP) and the variability of daytime SBP and PP were significantly higher than in the age group <60 years. The increase in AS was associated with an increase in the daytime and nighttime SBP and PP, with the variability of daytime SBP and PP. An increase in AS was also associated with an increase in the degree of the left ventricular myocardium remodeling. In ISH patients, compared to SDH patients, a significant increase in AS was found. ISH patients were characterized by a greater variability in the daily SBP and PP. The level of cardiovascular risk (CVR) in AH was associated with an increase in the daily variability of SBP, DBP and PP.

Conclusion: In a comprehensive examination of patients with AH, it is advisable to perform ABPM with simultaneous determination of AS parameters. The increased AS and BPV mark the patients belonging to a higher CVR group.(**International Journal of Biomedicine. 2019;9(3):197-201.**)

Key Words: arterial hypertension • ambulatory blood pressure monitoring • arterial stiffness • pulse wave velocity

Abbreviations

AH, arterial hypertension; **ABPM**, ambulatory blood pressure monitoring; **AIx**, augmentation index; **AS**, arterial stiffness; **BP**, blood pressure; **BPV**, blood pressure variability; **ISH**, isolated systolic hypertension; **LVESD**, left ventricular end-systolic dimension; **LVESV**, left ventricular end-systolic volume; **PP**, pulse pressure; **PWV**, pulse wave velocity; **RoR**, rate of rise; **SDH**, systolic-diastolic hypertension.

Introduction

In the 21st century, hypertension remains the major preventable cause of cardiovascular disease and all-cause death globally.[1,2] Large artery stiffening is the most important pathophysiological determinant of isolated systolic hypertension (ISH) and age-dependent increase in pulse pressure (PP).[3,4] The pulse wave velocity (PWV) and the changes in the pulse wave reflections, quantified as augmentation index (AIx), are parameters of arterial stiffness (AS).[5]

According to 2018 ESC/ESH guidelines for the management of AH, carotid-femoral PWV is the gold standard for measuring large AS.[3,6] A growing number of studies have demonstrated the association between AS and stroke, coronary artery disease, dissecting aortic aneurysms, and overall mortality from cardiovascular diseases.[7-9] The additive value of PWV above and beyond traditional risk factors, including SCORE and the Framingham risk score, has been suggested by several studies.[10] There are several devices available for the noninvasive measurement of the PWV and AIx.

In recent years, there has been a tendency to include AS determination algorithms in blood pressure monitoring devices, but the daily dynamics of AS has not been studied enough.[11] Controversial questions remain about the role of dyslipidemia in the genesis of AS, as well as the effect of vascular remodeling on the structural and functional state of the myocardium. Based on the foregoing, **the purpose** of the research was to study the significance of BPV in the assessment of AS in patients with AH, and their possible relationship with the indicators of structural and functional remodeling of the myocardium, serum lipid spectrum, and homeostasis system.

Materials and Methods

Patients for the study were recruited on the basis of the Republican Specialized Scientific-Practical Center for Cardiology in the departments of Coronary Heart Disease and Arterial Hypertension. A total of 138 patients were examined and 106(77%) were diagnosed with AH. The patients were aged from 36 to 82 years (mean age of 56.7±12.8). Among the surveyed, men accounted for 52%, women 48%.

The study protocol was reviewed and approved by the Ethics Committee of the Republican Specialized Centre of Cardiology. All participants provided the written informed consent.

Inclusion criteria were the presence of AH or suspicion of AH. Exclusion criteria were symptomatic hypertension; valvular heart disease, acute coronary syndrome, chronic heart failure (NYHA FC>III), cardiac arrhythmia, history of stroke and myocardial infarction within previous 12 months, occlusive peripheral arterial disease, renal impairment, diabetes mellitus, severe co-morbidities, orthostatic hypotension, conditions requiring hormone steroid therapy or the appointment of anticoagulants, cancer and other pathologies that can affect the state of peripheral arteries.

The structure of the diagnosis of patients with AH was as follows: AH Grades 1, 2 and 3 were found in 4.7%, 38%, and 57.3%, respectively. AH Stages 1, 2 and 3 were detected in 9%, 63% and 28% of cases, respectively. In 28% of patients with AH, stable angina functional class II was detected.

Cumulative risk (CR) of heart attacks, strokes and fatal cardiovascular complications was as follows: a low CR – in 0% of cases, a medium CR – in 19%, a high CR – in 21%, and a very high CR – in 60%.

The patients included in the study were twice divided consecutively into two groups: one on the basis of age (the age groups ≥60 years and <60 years), and another on the basis of the presence or absence of ISH.

The age groups ≥60 years and <60 years did not differ in terms of BP: average 24-h SBP was 129.3±14.7 mmHg and 136.5±18.9 mmHg, respectively, and average 24-h DBP was 81.9±11.5 mmHg and 81.0±10.3 mmHg, respectively, $P<0.05$ in both cases. In the age groups <60 years and >60 years, there were 56% and 41% men, respectively, and 44% and 59% women, respectively. Thus, the sex composition of the groups did not differ.

The ISH subgroup included 19 patients (58% women and 42% men) with mean age of 55.32±11.6 years, which was not statistically different from the SDH subgroup—56.9±9.9 years ($P>0.05$). The SDH subgroup included 87 patients (34% women and 66% men). The ISH and SDH subgroups did not significantly differ in sex composition and average 24-h SBP (131.2±8.6 mmHg and 137.5±17.0 mmHg, respectively; $P>0.05$). In the ISH subgroup, average 24-h DBP was significantly lower than in the SDH subgroup: 74.5±4.8 mmHg and 87.4±10.9 mmHg, respectively ($P=0.000$).

All patients underwent the following examinations: assessment of traditional risk factors, physical examination, clinical and biochemical laboratory methods, 12-lead ECG, echocardiography, and 24-hour ABPM. The 24-hour ABPM was performed by the oscillometric method using an XAI-MEDICA device and «Kardiosens» software (LLC KhDAVP, Ukraine). ABPM was performed according to the International recommendations.

We implemented the algorithm for analyzing the AS parameters using the SphygmoCor device (AtCor Medical, Australia), which sequentially records pulse waves with a high-precision applanation tonometer applied to the proximal artery (carotid artery) and with a short time interval to the distal artery (femoral artery), and simultaneously recorded an ECG.

The carotid-femoral pulse wave velocity (PWVcf) was calculated using the time of the wave passing between the registration points determined by the R wave on the ECG. To do this, we determined the time between the R wave on the ECG and the occurrence of pulsation.[12-14] In addition, such indicators as the central SBP (SBPc), central DBP (DBPc), central PP (PPc), aortic augmentation (AA), and AIx were taken into account.

Echocardiography was carried out according to the recommendations of the American Society of Echocardiography[15] in M- and B-modes using Philips EnVisor C Ultrasound Machine (the Netherlands). The following parameters were measured and calculated: IVST, PWT, LVEDD, LVESD, EF, LVEVD, LVESV, and LVM (LVM was calculated using the formula R. Devereux.[16] LVM was indexed to body surface area (LVMI). Left ventricular hypertrophy (LVH) was defined as LVMI of >95 g/m^2 (for women) and >115 g/m^2 (for men).[3]

Statistical analysis was performed using the statistical software «Statistica» (v6.0, StatSoft, USA). Baseline characteristics were summarized as frequencies and percentages for categorical variables and as mean± standard deviation (SD) for continuous variables. The Mann-Whitney U Test was used to compare the differences between the two independent groups (for nonparametric data). Spearman's rank correlation coefficient was calculated to measure the strength and direction of the relationship between two variables. We used the McNemar chi-square tests to compare discordance of two dichotomous data A probability value of $P \leq 0.05$ was considered statistically significant.

Results and Discussion

In the age group ≥60 years, an increase in the levels of SBPc, PPc and Aix was revealed. In this group, the levels of SBPc, PPc and Aix were 169.7±11.8 mmHg, 75.1±10.1 mmHg and 34.9±6.8% compared to 153.8±9.7 mmHg (P=0.001), 61.8±5.1 mmHg (P=0.05), and 27.6±4.3% (P=0.05) in age group <60 years, respectively. In addition, we found a significant increase in the index of PWV up to 13.7±1.64 m/s, compared to 11.2±1.46 m/s in the age group < 60 years (P=0.002). The detected increase in AS in the group of older patients fits well with literature data.[17-19]

The results of ABPM in the two age groups are presented in Table 1. In the age group ≥60 years, the levels of PP, daytime SBP variability and daytime PP variability were significantly higher than in the age group <60 years. The results of ABPM are consistent with the literature data, which also show an increased BPV in older patients.[20]

Table 1.
The results of ABPM in the two age groups

Indexes	≥60 years	<60 years	P
Daytime SBP variability, mmHg	15.84±5.43	10.97±2.11	0.008
Average PP, mmHg	59.15±11.4	45.94±7.63	0.003
Minimum daytime PP, mmHg	38.32±8.59	33.11±6.99	0.013
Average daytime PP, mmHg	56.09±12.11	47.53±7.75	0.002
Maximum daytime PP, mmHg	76.68±18.3	66.78±12.88	0.034
Average nighttime PP, mmHg	54.78±16.25	45.67±7.22	0.018
Maximum nighttime PP, mmHg	67.22±18.35	55.84±11.53	0.009
Daytime PP variability, mmHg	9.56±3.16	7.59±2.19	0.016

Table 2.
Correlations between AS and ABPM parameters

Indexes	R	P	Indexes	R	P
AIx and Average daytime SBP	0.56	0.000	PWV and Average daytime SBP	0.61	0.001
AIx and Minimum daytime SBP	0.42	0.000	PWV and Minimum daytime SBP	0.40	0.000
AIx and Maximum daytime SBP	0.52	0.000	PWV and Maximum daytime SBP	0.49	0.002
AIx and Daytime SBP variability	0.33	0.004	PWV and Daytime SBP variability	0.54	0.002
AIx and Average nighttime SBP	0.28	0.018	PWV and Average nighttime SBP	0.30	0.01
AIx and Minimum nighttime SBP	0.29	0.012	PWV and Minimum nighttime SBP	0.36	0.01
AIx and Maximum nighttime SBP	0.27	0.025	PWV and Maximum nighttime SBP	0.22	0.000
AIx and Average PP	0.78	0.000	PWV and Average PP	0.81	0.000
AIx and Minimum daytime PP	0.53	0.000	PWV and Average 24- h SBP	0.64	0.000
AIx and Maximum daytime PP	0.65	0.000	PWV and Minimum daytime PP	0.59	0.000
AIx and Minimum nighttime PP	0.48	0.000	PWV and Maximum daytime PP	0.66	0.000
AIx and Average nighttime PP	0.65	0.000	PWV and Minimum nighttime PP	0.54	0.000
AIx and Maximum nighttime PP	0.63	0.000	PWV and Average nighttime PP	0.61	0.000
AIx and Daytime PP variability	0.48	0.000	PWV and Maximum nighttime PP	0.68	0.000
AIx and Nighttime PP variability	0.35	0.003	PWV and Daytime PP variability	0.52	0.000
AIx and RoR in morning SBP	0.28	0.033	PWV and Nighttime PP variability	0.29	0.001
AIx and Average 24- h SBP	0.52	0.000	PWV and Morning SBP RoR	0.30	0.05

The results of the correlation analysis are presented in Table 2. AIx and PWV (indicators of AS) directly correlated with values of SBP and PP, as well as their variability, in ABPM.

In the age group ≥60 years, fractional shortening was significantly lower (31.7±1.9% and 35.5±2.6%, respectively, P=0.008) and LVESV significantly greater (70.2±18.3 ml and 54.7±8.0 ml, respectively, P=0.02) than in the age group <60 years. LVPWT also increases with age (R=0.40, P=0.02).

Analysis of the relationships between parameters of daily oscillometry and echocardiography data showed a significant correlation for PWV with IVST (R=0.41, P=0.02), LVPWT (R=0.46, P=0.009) and LVESV (R=0.51, P=0.003).

There were no significant correlations between the indices of AS and plasma lipid spectrum in the study groups.

In the group of patients with ISH, compared to patients with SDH, the PWV value was significantly greater (14.5±2.29 m/s and 12.7±2.9 m/s; P=0.001). In addition, a significant increase in AIx up to 39.9±4.81%, compared to 31.2±5.55%, was revealed (P=0.04). The results of ABPM in the groups of patients with ISH and SDH are presented in Table 3. The revealed patterns of the dynamics of SBP, DBP and PP in these groups are regular and follow from the definition of ISH. At the same time, the increase in the variability of the daytime SBP and PP in the ISH group, compared to the SDH subgroup, was poorly discussed in the literature.

Among the studied parameters of the coagulogram, the level of fibrinogen was significantly greater in the ISH subgroup, compared to the SDH subgroup: 4.3±1.1 g/l and 2.4±0.3 g/l, respectively (*P*=0.02).

Table 3.
The results of ABPM in the groups of patients with ISH and SDH

Indexes	ISH	SDH	P
Average daytime DBP, mmHg	76.54±5.78	87.29±11.15	0.001
Daytime DBP load, %	8.64±9.66	43.96±34.12	0.001
Daytime SBP variability, mmHg	15.00±4.75	11.83±3.76	0.013
Average nighttime SBP, mmHg	113.70±10.98	129.19±17.77	0.020
Average nighttime DBP, mmHg	63.21±5.68	79.83±10.63	0.000
Nighttime SBP load, %	20.80±28.38	58.54±37.33	0.007
Nighttime DBP load, %	11.60±14.46	66.09±30.86	0.000
Average PP, mmHg	56.64±5.26	50.13±10.45	0.003
Daytime PP variability, mmHg	10.67±3.36	8.06±2.31	0.012
Nocturnal SBP fall,%	13.20±5.55	6.32±4.66	0.013
Nocturnal DBP fall,%	15.60±7.69	9.04±8.35	0.043
Average 24- h DBP, mmHg	73.85±4.80	87.37±10.89	0.000

When analyzing the relationship between the degree of cardiovascular risk (CVR) and ABPM indices, a significant direct correlation was found with the daily variability of SBP (R=0.39, *P*=0.009), DBP (R=0.29, *P*=0.03) and PP (R=0.35; *P*=0.007). In addition, a direct correlation was found between the maximum daytime PP and the degree of CVR (R=O.38, *P*=0.004).

Conclusion

The age group ≥60 years is characterized by a significant increase in AS compared to the age group <60 years. In the age group ≥60 years, the levels of daytime and nighttime PP and the variability of daytime SBP and PP were significantly higher than in the age group <60 years. The increase in AS is associated with an increase in the daytime and *nighttime* SBP and PP, with the variability of daytime SBP and PP. The relationship between AS and the variability of SBP and PP, as well as the morning SBP RoR, was revealed. An increase in AS is also associated with an increase in the degree of the left ventricular myocardium remodeling (an increase in IVST, PWT, and LVESV). In ISH patients, compared to SDH patients, a significant increase in AS was found. ISH patients were characterized by a greater variability in the daily SBP and PP. In the SDH subgroup of patients, an increase in fibrinogen level was revealed. The level of CVR in AH is associated with an increase in the daily variability of SBP, DBP and PP.

Thus, in a comprehensive examination of patients with arterial hypertension, it is advisable to perform ABPM with simultaneous determination of AS parameters. The increased arterial stiffness and blood pressure variability mark the patients belonging to a higher CVR group.

Competing Interests

The authors declare that they have no competing interests.

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