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Dysfunctional hemodynamic types in healthy young people: functional condition of blood vessels and central hemodynamics

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Summary

Objective

To investigate the functional condition of the blood vessels (endothelium-dependent vasodilatation and pulse wave velocity) and the central hemodynamics (CH) in healthy young people, depending on the type of circulation, defined by linear regression of blood pressure (BP) parameters.

Materials and methods

A total of 120 outpatient healthy young adults and 45 hypertensive patients aged 24.5 ± 0.3 and 29.1 ± 0.7 years respectively were investigated as outpatients before the beginning of treatment. Daily measurements of BP were made several times, the BP set of each patient was used for linear regression, and the hemodynamic types were determined on its coefficients; endothelium-dependent vasodilatation, pulse wave velocity and CH parameters were investigated as well. For statistical processing we used Statistica. 10.0 software.

Results

Regression analysis revealed dysfunctional hemodynamic types in 55.5% of hypertensive patients and in 25.8% of healthy young people, the diastolic dysfunctional type was the most frequent one, and it was found in 20.0% of healthy individuals and in 51.1% of hypertensive patients. Diastolic dysfunctional type in clinically healthy persons represents a latent hemodynamic disorder related to functional vascular disturbances due to increased vascular stiffness. Unlike the harmonic one, this type of dysfunction is characterized with more frequent disturbances of the vasomotor endothelial function (moderate and expressed) and with increased pulse wave velocity (11.4 m/s and 8.1 m/s, respectively, p = 0.00), and there were no differences between normotensive and hypertensive patients (whereas for the harmonic type these differences were significant). Patients with firstly diagnosed AH and different hemodynamic types had similar characteristics of vascular function inside their groups that indicated

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the existence of different pathogenetic mechanisms responsible for development of these abnormalities. Thus hemodynamic types defined by linear regression of BP parameters and the types of central hemodynamics represent different characteristics of the blood circulation and do not exclude each other.

Conclusion

Linear regression analysis of blood pressure parameters expands the possibilities for diagnosis of clinically latent hemodynamic disorders in normotensive individuals, such as dysfunctional types of the blood circulation, which are associated with functional vascular disorders and to a lesser extent – with disturbances of the central hemodynamics.

Keywords

Blood pressure, linear regression, circulatory types.

Introduction

Wide prevalence, high medical and social significance of arterial hypertension (AH) as the key element of cardiovascular pathology is well-known nowadays. Various aspects of this disease like pathogenesis, endothelial dysfunction and vascular stiffness, inflammation, individual AH phenotypes, blood pressure (BP) measurement techniques, and treatment represent a great interest for researchers [1-5]. At the same time, a period of latent functional cardiovascular abnormalities precedes clinical manifestations of AH, and it explains the necessity of detection of these problems at early stages. BP value as the integral characteristic of cardiovascular system (CVS) function is a promising parameter of early detection of preclinical circulation disorders. Development of modern informational technologies and methods of statistical analysis promotes discovery of new diagnostic possibilities even in this routine technique. In particular, we developed and patented the method of quantitative analysis of BP parameters' connection (QABPC) that represents an elementary regression model of circulation built on random values of patient's BP acquired within some period of time. It is represented as a system of linear equations describing circulation within time interval of observation as interaction between heart and vessels during blood movement:

$$S=Q+a_1W; \quad D=Q+a_2W,$$

where S – systolic BP, D –diastolic BP,

W – pulse BP ($W=S-D$).

After simple algebraic modifications a_1 coefficient can be expressed like $a_2=a_1-1$. In this case the regression model of circulation is based on two individual numeric parameters (a and Q) that have distinct physical meaning:

$S=Q+aW$; $D=Q+(a-1)W$, where $a = a_1$.

The coefficient Q reflects the value of BP in the area of descendent pulse wave measured in mm Hg (the characteristic of circulation in distal part of arterioles); the ratio between pressor (a) and depressor (a-1) coefficients defines a QABPC type. We proved the borderline values of a coefficient of the regression model and developed the classification of functional hemodynamic types [6]. It includes the following QABPC types: harmonic one (H), two dysfunctional ones (diastolic – DD and systolic – SD), and borderline harmonic with corresponding dysfunctional trend: borderline diastolic (BD) and borderline systolic (BS) types.

For creation of regression model it is necessary to perform several routine BP measurements within a distinct interval of time (optimal number is 20–25 measurements, if BP variability is low 7 measurements could be enough) and to use PC with appropriate software. Regression parameters characterize CVS function and in particular they describe cardiovascular interaction during blood movement and reflect homeostasis and environmental adaptation of organism. The existence of such hemodynamic types is proven by outpatient BP measurement performed on representative population samples of different gender, age, and health condition. It has been identified that dysfunctional and borderline hemodynamic types are the most frequent in patients with cardiovascular pathology (≥65%), at the same time they can be found in almost healthy individuals with normal BP. In this case it becomes relevant to find out which characteristics of heart and vessels define various circulation types, especially dysfunctional ones, and which is their clinical composition, in particular, in normal individuals?

Correlation between cardio-vascular interaction during blood movement, functional condition of vessels and central hemodynamic parameters are extremely poorly studied.

The objective of this study was to investigate the functional condition of blood vessels (endothelium-dependent vasodilatation and pulse wave velocity) and the central hemodynamics (CH) in healthy young people, depending on the type of circulation (QABPC type), defined by linear regression of blood pressure (BP) parameters.

Materials and methods

120 healthy young individuals (dispenser groups I and II, 56 males and 64 females) underwent outpatient observation and were included in the Group I (main group), and 45 patients (22 males and 23 females) aged 21–34 years with firstly diagnosed AH (1–2 grade, risk 2–3 before the start of therapy) were included in the Group 2 (comparison group). The average age of patients of the Group I and Group II was 24.5±0.3 and 29.1±0.7 years, respectively.

Patients of both groups underwent daily routine BP measurement during 7–10 days, and obtained BP values were elaborated using the above-described QABPC model that resulted in individual regression models of circulation defining QABPC circulation types and BP values in the area of decreasing pulsation.

Endothelium-dependent vasodilatation (EDV), pulse wave velocity (PWV), and CH parameters were evaluated within the same time interval using rheological techniques and "Impecard-M" equipment.

Brachial artery EDV was defined using reactive hyperemia test after 5 minutes of compression of the arm with a cuff and measurement of rheographic parameters at rest and 1, 2 or 3 minutes after cuff removal (Test 1). After it the second similar test was performed in order to evaluate EDV reserve (Test 2). Relative change of maximal volume flow rate Δ(dz/dt)% was quantified in both cases for each minute of decompression. EDV condition was evaluated in qualitative way on base of Δ(dz/dt)% value: no disturbances, moderate disturbance, evident disturbance, significant disturbance [7]. Time of pulse wave distribution and PWV were quantified according to the technique described at [7], and PWV values below 10.2 m/s were considered normal.

To evaluate CH parameters we performed impedance cardiography with consequent analysis of quantifiable parameters: stroke volume (SV, mL), cardiac output (CO, L/min), cardiac index (CI, L/(min*m^2)), total peripheral resistance (TPR, din*s*cm^{-5}), average BP (ABP, mm Hg), left ventricular filling pressure (LVFP, mm Hg) and evaluated CH type (normokinetic, eukinetic, hypokinetic, hyperkinetic ones) [8].

Statistical analysis was performed using Statistica 10.0 software. All obtained values were checked for normality using Shapiro-Wilk test. Quantitative parameters are present as median values (Me) and inter-quartile interval (25%–75%) in case of not-normal distribution. The significance of differences between relative and absolute values was estimated using χ^2 test and Mann-Whitney U-test, respectively. $p<0.05$ was considered significant.

Results and discussion

The distribution of QABPC types according to BP measurement in observation groups is present in Figure 1. It can be observed that harmonic hemodynamics prevailed in almost healthy young people, whereas dysfunctional types like DD one are more frequent in case of AH (the differences in H, SD, and DD types between groups are statistically significant). These results go along with our previous studies that indicated that DD type prevailed in patients with AH [1]. At the same time 25.8% of healthy individuals of the Group I had dysfunctional hemodynamics with prevalence of DD-type (20.0% of patients of this group), and 35.6% of patients with AH had harmonic type of hemodynamics.

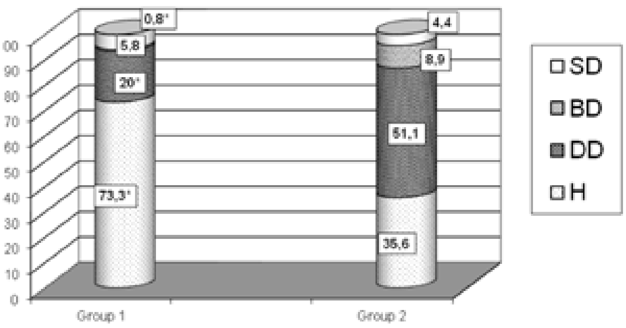

Figure 1. QABPC hemodynamic types in observation groups, % of individuals
Comment - *- statistically significant differences (p<0,05) comparing with the Group 2 (patients with AH).

In this regression model adequately defined relation between BP values D<Q<S corresponds to H type (0<*a*<1). Reduction of pressure coefficient to *a*<0 in SD type reflects the reduction of myocardial contractile function in blood movement that is compensated with increased function of so-called "peripheral heart" made of vessels and muscles (*D<S<Q*). Another inequation D<S<Q is fair, whereas *a*>1 indicates increased role of systolic component in circulation and decreased role of diastolic (vascular) component, in this case *Q<D<S* inequation is feasible (DD type). This interpretation of types and borders between them that can be concluded from the logic of regression is well-compatible with modern conceptions of interaction between the left ventricle (LV) and arterial system

Table 1. **Parameters of regression models (*a*, *Q*), BP and HR values in observation groups for different QABPC types (Me, 25%–75%)**

Group	Type	n	*A*	*Q*, mm Hg	SBP, mm Hg	DBP, mm Hg	PBP, mm Hg	HR, beats per minute
1	DD	24	1.28*^ 1.17–1.46	64.0^ 53.1–69.1	119.8^ 112.6–128.4	75.2^ 71.4–78.4	42.9^ 39.9–50.0	75.5 66.0–82.0
	BD	1	0.96	79.9	124.0	77.9	46.1	66.0
	SD	7	–0.16* –0.57…–0.07	132.3^ 121.2–154.9	120.8^ 118.0–139.3	74.7^ 71.4–77.7	45.0^ 40.3–49.3	74.0 66.0–82.0
	H	88	0.58^ 0.42–0.74	94.77 85.6–103.7	122.1^ 115.0–128.0	74.9^ 70.9–78.4	46.0^ 41.7–50.3	73.5 63.0–82.0
	Total	120	0.63^ 0.42–0.86	90.1 80.4–102.1	121.0^ 115.0–128.1	75.2^ 71.0–78.3	45.2^ 41.1–50.0	74.0 64.5–82.0
2	DD	23	1.27* 1.20–1.54	75.2 65.0–81.2	138.7 135.0–143.4	89.0 83.0–91.5	49.7 46.7–54.7	72.0 62.0–80.0
	BD	4	1.02* 1.01–1.04	88.3 87.2–90.0	145.2 138.3–149.3	88.8 87.8–91.2	53.9 49.6–59.0	73.0 69.0–83.0
	SD	2	–0.54* –0.7…–0.37	177.9 170.0–185.7	148.4 146.4–150.3	94.0 90.7–97.4	54.4 53.0–55.7	59.0* 50.0–68.0
	H	16	0.62 0.50–0.72	110.5 102.4–117.4	140.91 133.2–144.0	91.3 84.6–93.2	48.90 44.7–54.7	75.5 71.0–91.0
	Total	45	1.06 0.68–1.27	86.36 75.25–107.7	14000 135.0–146.4	89.9 84.80–92.5	50.00 46.8–54.7	73.0 65.0–82.0

Comments:
1 — Differences inside groups with H type (p<0,05); ^— differences with the Group 2 (p<0,05)
2 — Q and a – regression coefficients, SBP, DBP, and PBP – systolic, diastolic, and pulse blood pressure, respectively, HR – heart rate

represented as "pressure-volume" loop, and optimal ratio between arterial elastance and end-systolic LV elastance of healthy individuals stays in the interval of 0.7-1.0 [9, 10].

Measured BP values within the time interval in the Group 1 were significantly different from the ones in the Group 2 that corresponded to diagnosed AH. At the same time these values did not differ between different QABPC types within one group, whereas regression model parameters were significantly different for above-described types (Table 1).

60.8% of almost healthy individuals (n=73) had no disorders of vasomotor endothelial function, and this value was significantly higher than in the Group 2 (7 individuals, 15.5%). EDV disturbances were more frequently detected in the group of patients (84.4%) with AH and varied from moderate to evident and significant ones (p=0.000).

During each minute there were significant differences of relative change of maximal volume flow rate Δdz/dt% between comparison groups as for the first test as for the second one (Figure 2).

The investigation of the frequency of ADV disorders in relation to their QABPC type demonstrated that dysfunctional types and in particular the DD one from the Group 1 were significantly different from the H type being characterized with a higher percentage of people with moderate and evident ADV disorders and, consequently, with a lower proportion of individuals with normal ADV. SD type was enough rare in both groups, but normotensive people belonging to SD type had normal vasomotor function significantly less frequently comparing with the H type. At the same time, there were no significant differences in EDV condition depending on QABPC type in the Group 2 (Table 2). BD type was present just in 1 patient of the

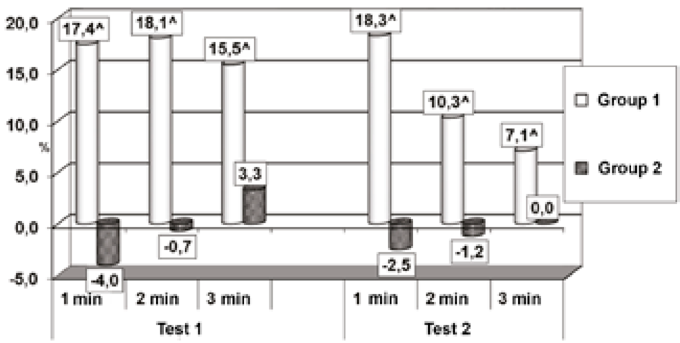

Figure 2. Δdz/dt% values (relative change of maximal volume flow rate, %, Me) in observation groups after reactive hyperemia test. Comment: ^ - the differences comparing with the Group 2 (p<0.05).

Table 2. **Condition of EDV in different QABPC types in observation group after reactive hyperemia test % (n)**

Test	Type	Healthy individuals (Group 1)					Patients with AH (Group 2)				
		EDV condition					EDV condition				
		n	1	2	3	4	n	1	2	3	4
1	DD	24	37.5*^# (9)	25.0* (6)	37.5* (9)	0^# (0)	24	8.7 (2)	26.1 (6)	43.5 (10)	21.7 (5)
	H	88	69.3^# (61)	5.7^ (5)	15.9^# (14)	9.1^ (8)	16	25.0 (4)	12.5 (2)	43.7 (7)	18.7 (3)
	SD	7	28.6* (2)	28.6 (2)	42.8 (3)		2	50.0 (1)		50.0 (1)	
2	DD	24	45.8* (11)	12.5 (3)	37.5* (9)	4.2# (1)	23	21.7 (5)	21.7 (5)	26.1 (6)	30.4 (7)
	H	88	68.2^# (60)	10.2 (9)	10.2^# (9)	11.4 (10)	16	37.5 (6)	18.8 (3)	37.5 (6)	6.2 (1)
	SD	7	28.6 (2)	28.6 (2)	42.8* (3)		2	50.0 (1)		50.0 (1)	

Comment:
EVD condition: 1 — no disturbance, 2 — moderate disturbance, 3 — evident disturbance, 4 — significant disturbance.
* — difference with H-type of the corresponding group (p<0,05),
^ — difference with the Group 2 in general (p<0,05),
# — difference with the corresponding type of the Group 2 (p<0,05).

Group 1 and in 4 patients of the Group 2, so it is not present in the Table 2.

Probably, in case of already developed AH not only vascular but also other pathogenetic mechanisms contribute in formation of hemodynamic types, whereas clinically latent hemodynamic shifts that manifest as dysfunctional hemodynamic types in normotensive people are related to functional vascular disturbances as impaired EDV. At the same time the majority of normotensive people with dysfunctional hemodynamic types have initial and expressed stages of EDV disorders, similar with the ones observed in patients with AH. The absence of significant differences in the frequency of moderate and evident EDV between dysfunctional types of normotensive people (Group 1) and patients with AH (in general and for corresponding types) is notable, it allows considering normotensive individuals with dysfunctional hemodynamics as the group of high risk of AH development.

Evaluation of endothelial reserve (Test 2) revealed similar percentage of individuals with different EDV condition in groups in general and depending on their type (Table 2).

Δdz/dt% values did not differ significantly within each group, apart from DD and H types in test1: healthy individuals had significantly lower Δdz/dt values measured after 3 minute comparing with the H type (10.8% and 20.7%, respectively, $p<0.05$); and the same differences were detected in the group of patients with AH after 2 minutes (-1.4% and 13.6%, respectively, $p<0.05$). Probably, dysfunctional hemodynamic types like the DD one are characterized with delayed and less evident vascular reaction on stress test and reserve capacity of endothelium, in particular in case of AH, is reduced. At the same time healthy individuals with H-type were significantly different from patients with AH for every minute of the study, and healthy individuals with dysfunctional types DD and SD had no such differences. These results indicate pathological origin of these types due to their hemodynamic similarity with AH.

Endothelial disbalance leads to increased stiffness of vascular wall and impaired damping capacity that shortens the time of pulse wave distribution (PWT) and increases PWV. High frequency of EDV in dysfunctional hemodynamic types affects these characteristics. In particular, PWT of DD type was significantly shorter and PWV was significantly higher than the ones of H type (11.4 m/s and 8.1 m/s, respectively, $p=0.001$) and did not differ from PWV of patients with AH ($p<0.05$), whereas the differences of this parameter between H type of normotensive individuals and patients with AH were statistically significant (Table 3). Patients with AH had no significant differences of PWT and PWV for different QABPC types that goes along with the above-mentioned absence of differences in frequency and expression of endothelial vasomotor function disturbances between different types.

Increase of PWV and the frequency of EDV abnormalities registered in DD-type of healthy individuals has been previously demonstrated by our group in the study where we performed QABPC analysis of BP values after 24h BP monitoring. It perfectly corresponds to the results of this study [8].

Thus, dysfunctional QABPC types reflect clinically latent hemodynamic disturbances in normotensive people, and impaired vasomotor function of the vessels (EDV) and increased PVW belong to them. In its

Table 3. **Time and PWV in different QABPC types in observation groups (Me, Q 25%–Q 75%)**

Group	Type	n	PWT, c			PWV, m/c		
			Me	Q 25%	Q 75%	Me	Q 25%	Q 75%
1	DD	24	50.0*	40.0	65.0	11.4*	8.1	13.7
	BD	1	160.0	160.0	160.0	3.3	3.3	3.3
	SD	7	60.0	50.0	70.0	9.0	7.7	9.6
	H	88	70.0^	60.0	80.0	8.1#	7.0	9.5
	Total	120	60.0^	50.0	80.0	8.5#	7.1	9.6
2	DD	23	50.0	40.0	70.0	11.4	8.0	13.5
	BD	4	45.0	30.0	140.0	12.6	6.7	21.4
	SD	2	50.0	40.0	60.0	12.6	10.8	14.3
	H	16	75.0	40.0	130.0	7.5	4.1	14.6
	Total	45	50.0	40.0	80.0	11.0	7.0	14.3

Comment:
* — difference with H-type of the corresponding group, p<0,05;
# — comparison with the Group 2 in general, p<0,05

Table 4. **Characteristics and types of CH in observation groups, Me/25%–75%**

Parameters, CH types		Group 1, n=120	Group 2, n=45
CH parameters	Initial SV, mL	68.0 / 55.5–80.5 *	56.1 / 36.9–66.2
	Initial CO, L/min	5.0 / 4.0–6.0 *	4.0 / 3.1–5.2
	Initial CI, L/min×m^2	2.8 / 2.2–3.4 *	2.0 / 1.6–2.7
	Initial TPR, din×s×cm^{-5}	1537.6 /1237.0–1892.8 *	2158.1 / 1567.2–2902.2
	Initial ABP, mm Hg.	92.5/85.0–99.3*	105.3/ 93.0–114.0
	Initial LVFP, mm Hg	16.9 / 15.9–18.0	17.6 / 16.4–18.3
CH types	Normokinetic, % (n)	50.0% (60)*	28.9% (13)
	Eukinetic, % (n)	6.7% (8)	4.4% (2)
	Hyperkinetic, % (n)	20.0% (24)*	6.7% (3)
	Hypokinetic, % (n)	23.3% (28)*	60.0% (27)

Comment:
*— p<0,05 comparing with the Group 2.

turn, it can become the background for future AH development. There were no significant differences of LVFP in both groups that may be explained by relatively young age of the participants and early stages of AH in the majority of patients of the Group 2. The percentage of patients with pathological hypokinetic type of CH was significantly higher in case of AH, whereas normokinetic and hyperkinetic types prevailed in normotensive patients. SV, CO, CI, and LVFP after stress test (ergometric stress testing) and at rest differed significantly between groups. The same differences were observed for all initial values of these parameters apart from LVFP.

Figure 3 demonstrates the distribution of CH types in different QABPC types in observation groups.

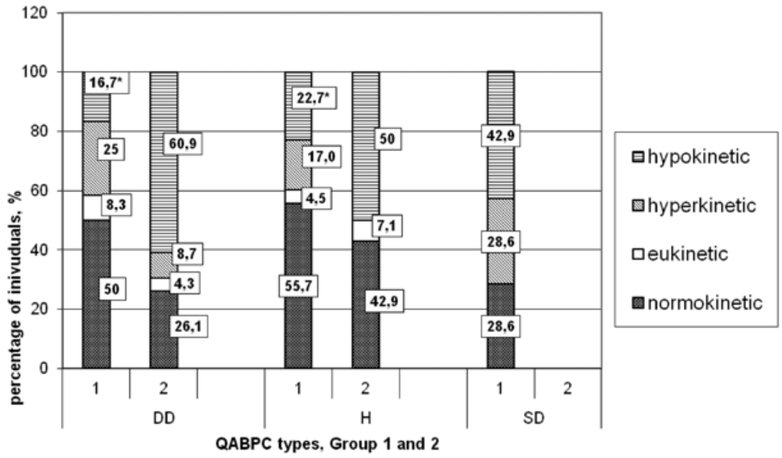

Figure 3. CH types distribution for different QABPC types, %
Comment. * — difference with the corresponding type of the Group 2, p<0.05.

Statistically significant differences of CH parameters and types between different QABPC types within each group have not been found. It may indicate that hemodynamic types identified according to regression analysis (QABPC-types) and CH types defined after rheographic assays represent different characteristics of circulation and do not substitute but complete each other for diagnostic purposes. In particular, it is possible to hypothesize that QABPC mostly reflects the circulation in distal parts of circulatory system (terminal parts of arterioles). At the same time, the lack of differences between different QABPC types within each of observation groups may be explained by small number of patients with DD and SD types, in particular with the SD one (7 persons from the Group 1, 1 person from the Group 2), that makes it favorable to perform other studies in this direction.

CH parameters (apart from initial LVfP and LVfP at rest) of healthy young individuals with H-type were significantly different from the ones of hypertensive patients, but SW and CI of SD type did not differ significantly from the values of these parameters in normotensive patients, and these values were lower than the corresponding ones for H-type of each group (p>0.05). More than that, there was the tendency for TPR increase (p>0.05) in particular after stress test (Table 5).

These results allow considering the reduction of heart's pumping function observed in SD-type and go along with the explanation of this type using the regression model that gives the leading role in heart pumping to the "peripheral heart". At the same time, taking into account small number of patients with this QABPC type as in the current study as in population in general [1], it is necessary to increase the number of patients to obtain more confident results.

Regression analysis of BP parameters (QABPC) demonstrated dysfunctional hemodynamic types in 55.5% of young patients with AH before the start of the treatment and in 25.8% of healthy young individuals with normal BP. DD type prevailed between dysfunctional types in both groups: it was present in 20.0% of healthy individuals and in 51.1% of patients with AH. This type is characterized with increased pressor parameter of regression (coefficient a(a>1)) that indicates the increased role of systolic component (cardiac output) for blood movement and decreased role of the diastolic (vascular) component. In this case the pressure of pulseless blood flow becomes less than diastolic one, whereas the H type keeps this value equal to diastolic BP. Thus, this regression doesn't correspond to normal physiological parameters characterizing the interplay between "cardiac" and "vascular" components of the blood flow. This hemodynamic type is pathological, and its presence in healthy individuals indicates the presence of latent hemodynamic disturbances.

Our study demonstrated that normotensive young people with DD-type had functional vascular abnormalities. In particular, this type is associated with abnormal endothelial vasomotor function (moderate and evident), increased PWV (that indicates increased vascular stiffness). Parameters of vascular function

Table 5. **Several parameters of CH in studied groups depending on individuals' QABPC type, Me/25%-75%**

Parameters	Group 1, QABPC type				Group 2, QABPC type			
	DD	BD	H	SD	DD	BD	H	SD
Initial SV, mL	67.2*/ 55.4–77.6	34.2	68.0*/ 56.2–80.6	73.7* / 54.2–102.1	54.9/ 29.0–68.7	59.2/ 54.8–69.7	55.4/ 47.2–60.4	54.2/ 32.1–76.3
Stress SV, mL	63.2/ 52.4–76.0	26.1	62.6*/ 52.4–81.4	76.1/ 55.5–77.2	51.9/ 36.9–65.3	59.0/ 53.6–65.8	55.2/ 47.1–78.0	47.5/ 33.2–61.7
SV at rest, mL	63.4*/ 56.2–78.1	24.2	68.4*/ 59.6–84.1	69.6*/ 55.2–87.6	55.4/ 32.8–65.1	64.8/ 51.6–71.8	50.6/ 45.2–63.0	56.2/ 34.8–77.5
Initial CO, L/min	5.1 */ 4.2–6.6	2.6	5.0*/ 4.1–5.9	4.4/ 4.0–6.9	3.9/ 2.3–5.2	4.8/ 3.8–5.8	4.1/ 3.3–5.4	3.1/ 2.2–4.0
Stress CO, L/min	5.3/ 4.1–7.2	2.2	5.7*/ 4.4–7.0	5.0/ 4.5–6.6	4.4/ 3.1–6.1	6.7/ 5.5–8.3	4.1/ 3.6–7.1	5.0/ 4.4–5.5
CO at rest, L/min	5.0 */ 4.2–6.4	1.8	5.2*/ 4.1–6.2	4.7/ 4.3–6.0	3.7/ 2.5–5.7	5.1/ 3.8–5.9	3.7/ 3.2–5.5	3.2/ 2.3–4.0
Initial CI, L/min*m^2	3.2/ 2.4–3.9*	1.2	2.8*/ 2.2–3.4	2.6/ 2.1–4.0	2.1/ 1.2–2.7	2.4/ 1.8–3.2	2.0/ 1.6–3.0	1.4/ 1.0–1.9
Stress CI, L/min*m^2	3.4*/ 2.4–4.0	1.1	3.3*/ 2.5–4.2	2.7/ 2.3–3.8	2.4/ 1.5–3.1	3.7/ 2.9–4.2	2.3/ 1.7–3.6	2.2/ 2.1–2.4
CI at rest, L/min*m^2	3.0*/ 2.4–3.8	0.9	2.9*/ 2.3–3.4	2.5/ 2.2–3.5	2.0/ 1.5–2.9	2.7/ 1.8–3.2	2.0/ 1.5–3.0	1.4/ 1.0–1.9

Comment.
* — p<0,05 comparing with the Group 2

measured in healthy individuals with DD type had no statistical differences comparing with patients with firstly diagnosed AH, whereas the differences with H-type healthy individuals were significant. These functional vascular disorders in DD-type prove the accuracy of the above-mentioned interpretation of this regression model characterizing this type as a functional disturbance of vascular (diastolic) circulation component.

Patients with firstly diagnosed AH had worsened parameters of vascular function (EDV, PWV, PWT) comparing with healthy individuals of comparable age. At the same time these parameters did not differ significantly between different QABPC types within one group, as it was described for the group of healthy individuals. It may indicate the involvement of other mechanisms into formation of dynamic QABPC types in AH.

QABPC types identified with linear regression of BP parameters and CH types (assessed with rheographic examination) represent different characteristics of hemodynamics and do not substitute but complete each other for diagnostic purposes.

Conclusion

Regression model of circulation built on BP parameters (QABPC) widens diagnostic resources for such clinically latent hemodynamic disorders as dysfunctional circulation types related to functional disturbances of vessels and CH. Additional examination and dynamic observation are required in almost healthy patients with dysfunctional circulation.

Conflict of interest: None declared

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