FEATURES OF HEMODYNAMICS OF PERSONS WITH HEARING LOSS

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Abstract. Regular monitoring of the cardiovascular system is necessary not only for individuals predisposed to heart and vascular diseases, but is also of particular importance for persons with congenital diseases of other systems. One of the factors that could affect the normal development of the cardiovascular system may be congenital or early acquired hearing pathology. It should be noted that the age-related physiological characteristics of hemodynamic parameters may differ in individuals with varying degrees of hearing loss. Measurement of hemodynamic parameters in real time in young people with varying degrees of hearing loss in two age groups revealed deviations from the indicators of the control group, as well as between the indicators in different age groups. A number of hemodynamic parameters were analyzed, such as: blood pressure, heart rate, stroke volume, stroke volume index, cardiac output, cardiac index, systemic vascular resistance, systemic vascular resistance index, blood flow integral, ejection time, etc. We obtained significantly higher values of hemodynamic parameters and low values of systemic vascular resistance in individuals with mild and moderate degree of hearing loss. The effect of arterial stiffness on hemodynamic parameters in patients with severe hearing loss was noted. These studies can be used for medical examinations of students, persons with disabilities; primary admission by a cardiologist of persons with concomitant diseases; functional diagnostics in sports medicine (among professional athletes, amateurs, participants of the Paralympic Games).
Keywords: Diagnosis, cardiovascular system, hemodynamics, cardiac output, ultrasound methods.

1. Introduction: More than 5% of the world's population - 466 million people (432 million adults and 34 million children) suffer from hearing loss (data of the World Health Organization). This disease means hearing impairment in a better hearing ear, exceeding 40 dB in adults and 30 dB in children [1]. Hearing impairment significantly affects the quality of life. In addition, a congenital or early acquired pathology of hearing can have a negative impact on the development of other body systems. In particular, the literature provides data on the relationship of hearing loss and clinical manifestations of coronary heart disease [2]. Studies were also conducted to identify the risk of cardiovascular diseases in individuals with various hearing impairments [3]. We previously discovered the effect of severe hearing pathology on cardiac output and stroke volume of individuals in the age group of 20-25 years [4]. However, to clarify the situation, it is necessary to study the dependence of other hemodynamic parameters, in particular, systemic vascular resistance, integral of blood flow velocity, time of blood ejection, if there is a pathology of the auditory analyzer in the age aspect. Analysis of both cardiac output and vascular resistance will provide a more complete characterization of the state of hemodynamics, and it will be possible to draw conclusions about parameters such as preload, afterload and integral rigidity of the arterial system.

According to some authors [5], cardiac output, systemic vascular resistance and stiffness of the arterial system are the main factors affecting the level of blood pressure, which changes must be recorded to assess the development of the risk of cardiovascular diseases.

The available literature presents data on the analysis of cardiac output and vascular resistance in healthy people, as well as those with hypertension, however, there is not enough information about the studied hemodynamic parameters for hearing impairment in different age groups, which is highly important.

Objective of our research was to study the hemodynamic parameters in individuals with varying degrees of hearing loss in different age groups.

2. Materials and methods. The study of hemodynamic parameters involved young people of two age groups (the total number of subjects - 90 people). 1st age group - forty-one 17-19-years-old persons (average age - 18.4±0.7 years (M±σ), average height - 168.3±7.4 cm (M±σ), average weight - 60.3±12.2 kg (M±σ), average body mass index (BMI) - 21.2±3.9 kg/m² (M±σ), average body surface area (BSA) - 1.68±0.19 m² (M±σ)). 25 young people of this age group who took part in the study had hearing pathology of varying degrees and etiology. The 2nd age group - forty-nine 20-22-years-old persons (average age - 20.8±0.8 (M±σ) years, average height - 167.3±8.9 cm (M±σ), average weight - 59.2±11.6 kg (M±σ), average BMI - 21.9±6.8 kg/m² (M ± σ), average BSA - 1.66±0.19 m² (M± σ)). 20 young people of this age group who took part in the study had hearing pathology of varying degrees and etiology. Based on the above information, during the study, young people with disabilities were divided into four groups according to their age and degree of hearing impairment. In addition, young people who do not have a hearing pathology participating in the study were divided into two groups according to their age. Thus, 6 groups of subjects were formed. Group 1a included 15 people aged 17–19 years, capable of hearing sounds over 70 dB (average age was 18.5±0.64 years (M±σ), average height - 166.6±9.12 cm (M±σ), average weight - 57.1±11.13 kg (M±σ), average BMI - 20.5±3.43 kg/m² (M±σ), average BSA - 1.62±0.19 m² (M±σ)). Group 1b consisted of 10 people of the same age with a hearing threshold of 40 dB (average age was 17.8±0.92 years (M±σ), average height - 173.4±5.62 cm (M±σ), average weight - 65.4±8.92 kg (M±σ), average BMI - 21.8±3.15 kg/m² (M±σ), average BSA - 1.77±0.13 m² (M±σ)). Group 2a was formed of persons aged 20–22 years able of hearing sounds above 70 dB (average age was 20.3±0.82 years (M±σ), average height - 165.6±10.42 cm (M±σ), average weight - 60.2±15.82 kg (M±σ), average BMI - 21.7±3.75 kg/m² (M±σ), average BSA - 1.66±0.26 m² (M±σ)). Group 2b included young people aged 20–22 years (n=10) with a hearing threshold of 40 dB (average age was 20.7±0.82 years (M±σ), average height - 170.4±12.55 cm (M±σ), average weight - 65.0±12.33 kg (M±σ), average BMI - 22.2±2.51 kg/m² (M±σ), average BSA - 1.76±0.22 m² (M±σ)). The hearing threshold was determined in accordance with audiometry data conducted by an otorhinolaryngologist. The hearing test was carried out twice a year, the last of which was carried out no later than 2 months before the start of the study. Etiological ranking was not carried out, however, it should be noted that the subjects of groups 1a and 2a in the overwhelming majority had congenital, and 2a and 2b - acquired pathology of hearing. The subjects of group 1c (n=16; average age - 18.8±0.4 years (M±σ), average height - 166.8±5.21 cm (M±σ), average weight - 60.0±14 , 36 kg (M±σ), average BMI - 21.5±4.79 kg/m² (M±σ), average BSA - 1.67±0.21 m² (M±σ)) and 2c (n=29; the average age - 20.9±0.65 years (M±σ), the average height - 166.8±6.85 cm (M±σ), the average weight - 56.8±9.0 kg (M±σ), average BMI - 20.4±2.57 kg/m² (M±σ), average BSA - 1.63±0.15 m² (M±σ)) participated in the study as a control. The selection criterion for the control group was the absence of deviations in auditory analyzer functioning. Persons with a history of pronounced deviations in the cardiovascular system were excluded from the study.

We measured the parameters of systolic ejection from the left ventricle into the lumen of the aortic valve using an ultrasound (US) cardiac output monitor (USCOM 1-A, Ultrasound Cardiac Output Monitor, Australia) equipped with a 2.2 MHz transducer in AV mode (aortic valve). All measurements were carried out at rest, in the supine position, before measurements the subjects were in a horizontal position for 5 minutes. Also, prior to the beginning of measurements of hemodynamic parameters, the diameter of the aortic valve opening was determined. For this, height and weight were measured, the values of which, together with the age and sex data, were entered into the case record of the subject. The diameter of the aortic valve opening was calculated automatically on the basis of the input data, which casts doubt on the accuracy of the values obtained. However, some literary sources [6,7,8,9,10] provide data on acceptable measurement accuracy using this method in comparison with transesophageal echocardiography and even invasive methods for studying cardiac output. In addition, systolic (BPsys) and diastolic (BPdia) pressure was measured using a sphygmomanometer, the values of which were also entered into the monitor's memory. To measure hemodynamic parameters in the AV mode, the sensor was positioned in the suprasternal position. After adjusting the sensor and obtaining the desired image on the monitor screen, we continued the measurements for the first minute with a choice of practically identical amplitudes of 5 to 8 peaks with an equal interval between them. The average values of hemodynamic parameters were obtained and analyzed: heart rate (HR); systolic (BPsys), diastolic (BPdia) and mean (MBP) blood pressure; pulse pressure (BPp); peak flow rate (Vpk); mean pressure gradient (Pmn); integral of blood flow velocity (vti); distance per minute (MD); ejection time in percent (ET%); flow time (FT); stroke volume change (SVV); stroke blood volume (SV); stroke volume index (SVI); cardiac output (CO); cardiac index (CI); systemic vascular resistance (SVR); systemic vascular resistance index (SVRI).

Statistical processing of the results was performed by using a Biostat computer program with Student's t-test. All mean values in the text are presented as M±σ. Differences were considered statistically significant at $p<0.05$.

3. Results and discussion. The mean values of some hemodynamic parameters differed among themselves in different age groups, as well as depending on the degree of hearing impairment (see Table).

Table. Hemodynamic parameters in patients with hearing impairment

Indicators of hemodynamics	Groups of persons surveyed (M±σ)					
	group 1a (n=15)	group 2a (n=10)	group 1b (n=10)	group 2b (n=10)	group 1c (n=16)	group 2c (n=29)
BPsys, mmHg	120.5±11.14	121.3±19.00	123.5±12.63	121.1±11.3	114.6±11.1	118.7±10.1
	p=0.543	p¹=0.977	p*=0.071	p²=0.533	p**=0.151	p³=0.584
	p°=0.895		p°°=0.660			
BPdia, mmHg	64.1±6.19	63.2±7.28	64.5±8.40	64.5±6.7	67.8±5.9	70.5±6.3
	p=0.892	p¹=0.683	p*=0.250	p²=0.015	p**=0.099	p³=0.004
	p°=0.743		p°°=1.0			
BPp, mmHg	56.5±11.03	58.1±15.61	59.0±7.20	56.6±10.4	46.8±8.1	48.2±9.7
	p=0.535	p¹=0.803	p*<0.001	p²=0.026	p**=0.009	p³=0.023
	p°=0.766		p°°=0.556			
MAP, mmHg	82.8±6.33	82.6±9.96	84.3±9.42	83.5±6.8	83.4±7.0	86.6±6.4
	p=0.637	p¹=0.816	p*=0.782	p²=0.201	p**=0.805	p³=0.150
	p°=0,		p°°=0.830			
Vpk, m/s	1.7±0.30	1.6±0.27	1.7±0.25	1.4±0.2	1.5±0.3	1.4±0.2
	p=1.0	p¹=0.076	p*=0.092	p²=1.0	p**=0.074	p³=0.017

	p°=0.405		p°°=0.008			
Pmn, mmHg	5.5±1.85	4.6±1.57	5.3±1.47	3.8±0.9	4.2±1.4	3.5±0.8
	p=0.777	p^1=0.179	p*=0.068	p^2=0.328	p**=0.035	p^3=0.007
	p°=0.219		p°°=0.013			
vti, cm	34.5±5.94	31.2±5.61	34.2±4.21	28.9±4.6	31.3±4.8	27.6±3.5
	p=0.892	p^1=0.329	p*=0.130	p^2=0.357	p**=0.109	p^3=0.022
	p°=0.178		p°°=0.015			
HR, bpm	75.9±14.28	77.5±19.46	72.9±17.97	66.7±9.7	74.1±10.9	75.7±11.2
	p=0.647	p^1=0.134	p*=0.833	p^2=0.030	p**=0.695	p^3=0.722
	p°=0.814		p°°=0.346			
MD, m/min	25.6±4.36	23.8±6.25	24.8±6.71	19.1±2.8	23.3±5.4	20.8±4.0
	p=0.720	p^1=0.044	p*=0.536	p^2=0.223	p**=0.204	p^3=0.087
	p°=0.404		p°°=0.023			
ET, %	39.4±6.27	39.8±9.54	38.2±7.79	35.1±4.9	40.1±4.2	39.6±5.6
	p=0.674	p^1=0.183	p*=0.425	p^2=0.030	p**=0.716	p^3=0.936
	p°=0.900		p°°=0.301			
FT, ms	315.9±19.66	309.2±9.82	319.0±21.43	317.2±22.3	326.8±24.0	316.4±25.3
	p=0.712	p^1=0.313	p*=0.410	p^2=0.930	p**=0.179	p^3=0.389
	p°=0.330		p°°=0.856			
SV, ml	99.5±20.29	90.0±24.40	105.6±15.25	86.7±13.7	90.1±13.2	79.4±10.1
	p=0.427	p^1=0.714	p*=0.011	p^2=0.081	p**=0.135	p^3=0.060
	p°=0.301		p°°=0.009			
SVI, ml/m^2	61.3±9.56	53.9±10.41	59.6±6.95	49.5±7.6	54.6±8.9	49.2±7.2
	p=0.634	p^1=0.295	p*=0.145	p^2=0,	p**=0.053	p^3=0.122
	p°=0.080		p°°=0.006			
CO, l/min	7.4±1.48	6.8±1.79	7.6±1.87	5.7±1.0	6.7±1.4	6.0±1.0
	p=0.768	p^1=0.107	p*=0.174	p^2=0.419	p**=0.186	p^3=0.087
	p°=0.370		p°°=0.011			
CI, l/min/m^2	4.6±0.86	4.2±1.27	4.3±0.87	3.3±0.5	4.1±1.0	5.2±8.1
	p=0.404	p^1=0.052	p*=0.608	p^2=0.467	p**=0.146	p^3=0.702
	p°=0.356		p°°=0.006			
SVR,d*s/cm^{-5}	951.2±170.02	1086.1±355.93	982.0±211.16	1267.8±240.0	1038.2±195.8	1238.4±239.8
	p=0.691	p^1=0.197	p*=0.496	p^2=0.740	p**=0.198	p^3=0.136
	p°=0.215		p°°=0.011			
SVRI, d*s/cm$^-$ /m^2	1535.8±290.95	1813.3±633.43	1730.0±331.84	2213.6±432.9	1728.8±371.8	2017.9±481.5
	p=0.136	p^1=0.116	p*=0.993	p^2=0.264	p**=0.120	p^3=0.293
	p°=0.150		p°°=0.012			
SVV, %	18.0±4.35	21.6±5.97	18.0±3.40	17.5±6.0	19.7±4.8	22.4±10.5
	p=1.0	p^1=0.143	p*=0.340	p^2=0.172	p**=0.311	p^3=0.821
	p°=0.094		p°°=0.821			

Notes: p - significance of differences in hemodynamic parameters between groups 1a and 1b;
p* - significance of differences in hemodynamic parameters between groups 1b and 1c;
p** - significance of differences in hemodynamic parameters between groups 1a and 1c;
p^1 - significance of differences in hemodynamic parameters between groups 2a and 2b;
p^2 - significance of differences in hemodynamic parameters between groups 2b and 2c;
p^3 - significance of differences in hemodynamic parameters between groups 2a and 2c;
p° - significance of differences in hemodynamic parameters between groups 1a and 2a;
p°° - significance of differences in hemodynamic parameters between groups 1b and 2b.

As the table shows, BPdia values significantly differed from each other in groups 2b and 2c, 2a and 2c. The same can be stated in the same groups for the BPp. Higher BPp rates with lower BPdia may indicate the existing rigidity of the arterial system in people with hearing impairments, indicating an increased risk of cardiovascular disease. The maximum flow rates (Vpk) were highest in groups 1a and 1b (1.7±0.3 m/s and 1.7±0.25 m/s, respectively). However, significantly higher than in the control group, there were only Vpk values in group 2a. The same was recorded for Pmn and vti. HR, ET (in group 2b) were also significantly higher compared to controls; MD score in group 2a compared with group 2b. All of the above was observed in the age group of 20-22 years, which can be attributed to age-related changes. These data are consistent with those of our previous studies [4], which provided the significantly higher values of indicators characterizing systolic ejection in young people over 20 years old. It should be noted that no significant differences were found in SV, SVI, CO, CI, SVR, SVRI, depending on the degree of hearing impairment in each of the studied age groups. However, these figures differed significantly in groups 1b and 2b, which indicates the severity of changes in hemodynamic parameters in the age aspect in individuals with mild and moderate degree of hearing loss (40 dB hearing threshold). We previously noted almost equal values of SV, SVI, CO, CI, SVR, SVRI in persons of 20–25 years old with mild and moderate degree of hearing loss compared with the control group, while there was a significant difference with indicators in individuals with severe hearing impairment (threshold of hearing 70 dB) in the same age category. Based on the obtained new data, it should be noted that in the age group of 17-19 years, the values of the above parameters in persons with mild and moderate degree of hearing loss are higher (SVR and SVRI lower) compared to those in people with severe hearing impairment. In accordance with the new data, we can assume that there are adaptive mechanisms in the development of the cardiovascular system in persons with mild and moderate degree of hearing loss, which can be confirmed by studying the hemodynamic parameters in the age aspect.

4. Summary. Thus, we found significantly higher BPp values in both age groups in individuals with hearing impairments compared with those in the control group, which indicates the presence of arterial stiffness. The values of Vpk, MD, HR, Pmn, vti, ET were significantly higher in persons with hearing impairment in the age group of 20-22 years. High rates of systolic ejection - SV, SVI, CO, CI with low values of systemic vascular resistance were observed in people with mild and moderate degree of hearing loss in the age group of 17-19 years.

5. Conclusion. Based on the data obtained in the course of our research, we can conclude that people with hearing loss shall undergo a more thorough hemodynamic monitoring with a certain frequency. Particular attention should be paid to the examination of hemodynamic parameters in early adolescence. These studies can be used for: medical examinations of persons with disabilities; primary admission by a cardiologist of persons with concomitant diseases; functional diagnostics in athletes, participants of the Paralympic Games.

Conflict of interests. The author declares that the provided information has no conflicts of interest.

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