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The changes of left ventricular longitudinal systolic function depending on hypertension and its control: analysis in a population

Aim	To evaluate changes in left ventricular (LV) systolic function by LV myocardial global longitudinal strain (GLS) and global strain rate (GSR) in patients with arterial hypertension (AH) and based on the effectiveness of blood pressure (BP) control in a Russian population sample of individuals older than 55 years.
Materials and methods	This cross-sectional study was a population-based cohort study (HAPIEE, Novosibirsk). LV myocardial GLS and GSR were studied by echocardiography in a random sample (n=1004, 55–84 years). Statistical analysis was performed with multivariate models of logistic regression.
Results	AH prevalence in the study sample was 78.4%. Mean GLS was 19.1% (SD, 4.07), which was less for men than for women (p=0.001). Mean GSR was 0.86 s^{-1} (SD, 0.19) and was not different between men and women. In individuals with AH, the GLS absolute value was lower than in normotensive people (18.8%; SD, 4.04 vs. 20.2%; SD, 4.03, p<0.001); these differences remained irrespective of the age, gender, body weight index (BWI) (p=0.027), and LV mass index (p=0.05). When people with AH were divided into groups, the lowest GLS absolute values were observed among «ineffectively treated» or not receiving any therapy individuals (p<0.001 vs. normotensive group). AH 1.6 times increased the risk of LV GLS decrease. In individuals with AH, the GSR absolute value was lower than in normotensive people (– 0.85 s^{-1} (SD, 0.19) vs. – 0.92 s^{-1} (SD, 0.18), p<0.001); this difference remained in multivariate models. The lowest GSR absolute values were observed in the «ineffectively treated» group irrespective of the gender, age, and BWI (p=0.036 vs. normotensive group). AH doubled the risk of LV GSR decrease, which could be partially explained by the contribution of BWI and myocardial mass index.
Conclusion	In this population sample, LV GLS and GSR were independently associated with AH. The lowest GLS and GSR values were observed for ineffectively treated» individuals with AH, which may reflect an early decline of LV systolic function with inadequate control of AH.

Keywords	Arterial hypertension; blood pressure control; left ventricular strain; strain rate; echocardiography
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Introduction

Ultrasound imaging of systolic myocardial strain is used to assess myocardial contractility and identify early stages of heart failure, including in preserved ventricular ejection fraction. The longitudinal strain of the left ventricle (LV) was shown to decrease in hypertension with LV hypertrophy. However, these results were mainly obtained in the clinical groups of patients with symptomatic hypertension [1, 2]. In a non-selective population-based sample, the variability of blood pressure (BP) parameters is much higher, and the severity of hypertension varies from initial to symptomatic stages. Identifying pre-hypertrophic structural and functional changes of the heart in elevated BP would allow a fresh look at the prevention of the progression of hypertension and the development of its complications.

There are sporadic data on changes in LV systolic global longitudinal strain (GLS) associated with hypertension in the general population [3–5]. No population-based echocardiographic study of LV strain parameters has been previously conducted in the Russian Federation. Moreover, there is a known prognostic phenomenon of a decrease in GLS and a simultaneous increase in the population risk of cardiovascular complications. However, its mechanisms are not clear [6, 7].

A pilot analysis of LV GLS was carried out in a subsample of the population of Novosibirsk residents. The results were published earlier [8]. This is the second phase of the LV

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GLS study in the population-based sample of more than 1000 persons using multivariate analysis.

The objective of the study was to assess changes in LV systolic function by GLS and global strain rate (GSR) in patients with hypertension and depending on the effectiveness of BP control in subjects of the population-based sample at the age of more than 55 years old.

Materials and methods

The study was carried out in the population cohort (HAPIE project, Novosibirsk). The re-examination stage was supported by a grant from the Russian Foundation for Basic Research. This study was performed in a random sample of male and female patients at the age of 55–84 years (n=1004) examined with a response of 85%. Echocardiography was performed with the assessment of LV GLS, and digital records were saved. The analysis excluded persons in whom the assessment of myocardial strain was technically impossible and who did not have complete screening data for any of the parameters used in this analysis (43 persons; 4.2%). A total of 961 (415 male and 546 female) patients were included in the analysis. The study design was cross-sectional. The study protocol was approved by the local ethics committee of the Research Institute for Internal and Preventive Medicine. All subjects signed informed consent.

The echocardiographic examination was performed on a Vivid 7 Dimension/Vivid q scanner (GE Healthcare) with a 1.5–3.7 MHz sector sensor. Data were analyzed off-line by one person. We assessed LV GLS using 2D speckle tracking imaging at the rate of at least 60 frames/sec. After the manual correction of endocardial borders at end-systole, segmental (17-sec) and global measures of GLS and GSR of the subendocardial layers were determined in the three-, four-, and two-chamber apical views. Subgroup (n=34) evaluation of reproducibility was carried out by two-fold measurements made by the main operator and the blind comparison of the operator/supervisor measurements. The Bland – Altman reproducibility index for subendocardial GLS was 2.9% (r=0.85) in the intra-operator series and 5.8% (r=0,67) in the operator/supervisor series.

The study protocol also included the assessment of the history of hypertension, cardiovascular diseases (CVDs), type 2 diabetes mellitus (DM), and corresponding treatment, three-time measurement of office BP followed by averaging, anthropometry, estimation of other cardiovascular risk factors, and social demographic profile. BP was measured on the right arm in a sitting position after 5-minute rest. The measurement was accurate to 2 mmHg, and the mean of three measurements was calculated. Hypertension was established according to standard epidemiological criteria: the mean office BP ≥140/90 mmHg [9] and/or the use of antihypertensive treatment in the two preceding weeks.

The following epidemiological categories of hypertension were used: (1) patients with hypertension who were treated with antihypertensive drugs and effectively controlled BP (n=156); (2) patients with hypertension who were treated with antihypertensive drugs and failed to effectively control BP (n=406); (3) patients with hypertension who were not treated with antihypertensive drugs (n=72); (4) patients with newly detected hypertension who are not informed about increased BP (n=120). The control group (0) comprised persons with normal BP (n=207). The mean levels of office systolic BP (SBP) <140 mmHg and diastolic BP (DBP) <90 mmHg during antihypertensive therapy were used as the criteria for effective BP control. SBP ≥140 or DBP ≥90 mmHg during the administration of any antihypertensive drug in the past two weeks was the criterion of ineffective treatment.

Coronary artery disease (CAD) was established by epidemiological criteria in exertional angina (Rose), ischemic changes in the electrocardiogram (MC classes 1, 4, 5), or a history of myocardial infarction, acute coronary syndrome, coronary revascularization (confirmed by hospitalization). The category of CVDs was established in CAD according to the specified criteria or a history of cerebral stroke (confirmed by hospitalization). Type 2 DM was established with a known history of treated type 2 SD or fasting glucose ≥7 mmol/L.

Statistical processing was performed using the SPSS v.13.0 software package. The hypothesis on normal distribution was verified using the Kolmogorov-Smirnov test. The data are expressed as the mean and the standard deviation (M, SD). The distribution of GLS and GSR was non-normal ($p<0.01$), and the parametric statistics were further calculated using logarithmic values.

The study groups differed in several parameters, which was taken into account in multivariate analysis when selecting covariates. In the first stage, the associations of GLS and GSR with hypertension and BP control were evaluated using ANOVA (GLM) and Fisher's exact test. The analysis was performed in a non-standardized model (Model 1) and in multivariate models standardized by age and sex (Model 2), age, sex, and BMI (Model 3), age, sex, and LV mass index (LVMI) to body surface area [10] (Model 4).

In the second stage, the logistic regression analysis was used to calculate the odds ratio (OR) of the reduced measures LV strain depending on the presence of hypertension and its control. Dichotomized GLS and GSR (the 4th quartile of distribution was considered as a decrease) were the dependent variables. The independent variables included four groups of hypertension (normal BP as a refe-

rence group) and potentially related covariates in multivariate Models 2–4 (similar to ANOVA), and Model 5 standardized by age, sex, BMI, myocardial mass, smoking status, and the presence of significant CVDs and type 2 DM. The critical p-value was <0.05 in all analyzes.

Results

The descriptive characteristics of the sample are given in Table 1.

The prevalence of hypertension was 78.5%. Mean GLS was 19.1% (SD 4.07) and was lower in male patients – 18.6% (SD 4.05) versus female patients – 19.5% (SD 4.04); p=0.001. Mean GSR was 0.86 s – 1 (SD 0.19) and did not differ between sexes. Clinical and ultrasound features observed in hypertension groups are provided in Table 2. The groups differed by sex, age, BP, BMI (all p<0.001), blood levels of glucose (p=0.003) and triglycerides (p=0.002), the prevalence of type 2 DM (p<0.001), CAD (p=0.012), main CVDs (p<0.001), and some echocardiographic parameters.

According to ANOVA, patients with hypertension had lower absolute GLS than that in persons with normal BP: – 18.8% (SD 4.04) versus – 20.2% (SD 4.03), p<0.001; the difference did not depend on age, sex (p<0.001), BMI (p=0.027), and LVMI (p=0.05). Among patients with hypertension divided into subgroups according to the treatment and BP control status, the lowest GLS were reported in those who did not control BP («ineffectively treated» or in newly detected hypertension), which were significantly lower than in the normal BP population irrespective of age and sex (Model 2; p<0.001). The significance of associations decreased when BMI or mass index was included in the model (p=0.165 and p=0.239, respectively), table 3.

Patients with hypertension had lower absolute GSR than that in persons with normal BP: – 0.85 s – 1 (SD 0.19) versus 0.92 s^{-1} (SD 0.18), p<0.001. The difference did not disappear in multivariate models irrespective of sex, age, BMI, but decreased when the mass index was taken into account. Among patients with hypertension divided into subgroups according to the treatment and BP control status, GSR was significantly lower in ineffectively treated patients than that in the normal BP population irrespective of sex, age, and BMI (p=0.036). With the additional standardization by LVMI (Model 4), the significance of the associations of GSR with BP control decreased (Table 4).

The risk of reduced GLS was shown in the multivariate regression analysis (Table 5) to increase 1.6-fold (95% confidence interval (CI) 1.02–2.59) in hypertension irrespective of other factors, including type 2 DM, CAD, or a complex of CVDs (p=0.042, Model 5). In the hypertension groups, the odds of reduced GLS were independently increased in ineffectively treated (OR=1.66, 95% CI 1.01–2.72) and non-treated patients (OR=1.86, 95% CI 1.02–3.37). The risk of reduced GSR in hypertension (Table 6) increased 2.0-fold (95% CI 1.29–3.18) irrespective of sex and age (Model 2), but the significance of the relationship was decreased for other factors. In the hypertension groups, the odds of reduced GSR were increased independently of other factors only in ineffectively treated patients (OR=1.71, 95% CI 1.03–2.83).

Discussion

The decrease in LV GLS and GSR was found to be associated in the study population-based sample (55–84 years old) with hypertension irrespective of other factors.

Our findings are consistent with the results of several previous trials [11, 12]. For example, Chen et al. (2007) observed early local systolic dysfunction in hypertension

Table 1. Clinical population characteristics of the population-based study sample (n=1004, male/female patients, 55-84 years old, Novosibirsk)

Clinical population characteristics	Mean values and rate, M (SD), n (%)
Total number of subjects	1004
Male/female, n (%)	439 (43.7)/565 (56.3)
Age, years	68.2 (6.8)
SBP, mm Hg	145.7 (21.6)
DBP, mm Hg	84.1 (11.4)
BMI, kg/m2	29.1 (5.28)
TC, mmol/L	5.57 (1.17)
HDL-C, mmol/L	1.3 (0.35)
TG, mmol/L	1.48 (0.84)
LDL-C, mmol/L	3.6 (1.05)
Glucose, mmol/L	6.38 (1.76)
Smoking, n (%)	
Nonsmoker	658 (65.5)
Former smoker	199 (19.8)
Active smoker	147 (14.6)
Hypertension, n (%)	787 (78.4)
Treatment of hypertension (in patients with hypertension), n (%)	584 (74.2)
Type 2 DM, n (%)	195 (19.4)
Treatment of type 2 DM (in patients with type 2 DM), n (%)	99 (50.7)
CAD, n (%)	128 (12.8)
CVDs, n (%)	188 (18.8)

SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI, body mass index; TC, total cholesterol; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; TG, triglycerides; DM, diabetes mellitus; CAD, coronary artery disease; CVDs, cardiovascular diseases.

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Table 2. Characteristics of the normal BP and hypertension subgroups (n=961, male/female, 55–84 years old, Novosibirsk)

Characteristics	Groups Mean values and rate, M (SD); n (%)					p, inter-group comparison
	(0) Normal BP	(1) Hypertension: BP control	(2) Hypertension: ineffective therapy	(3) Hypertension: no therapy	(4) Hypertension: not informed, no therapy	
Total number of subjects	207	156	406	72	120	
Male/female, n (%)	96 (46.4)/ 111 (53.6)	46 (29.5)/ 110 (70.5)	149 (36.7)/ 257 (63.3)	41 (56.9)/ 31 (43.1)	83 (69.2)/ 37 (30.8)	< 0.001
Age, years	65.3 (6.2)	68.9 (6.63)	69.2 (6.82)	67.6 (6.64)	68.6 (6.78)	< 0.001
SBP, mm Hg	123.3 (10.3)	126.8 (9.24)	160.3 (16.5)	159.3 (16.2)	153.7 (13.1)	< 0.001
DBP, mm Hg	75.7 (7.03)	75.8 (6.9)	88.9 (10.8)	90.6 (9.68)	88.7 (9.75)	< 0.001
BMI, kg/m^2	26.6 (4.68)	29.1 (4.68)	30.8 (5.38)	29.1 (4.96)	28.0 (4.43)	< 0.001
BSA, m^2	1.78 (0.18)	1.78 (0.19)	1.84 (0.2)	1.84 (0.18)	1.85 (0.18)	< 0.001
TC, mg/dL	217.6 (45.5)	209.4 (46.8)	217.0 (45.7)	220.9 (40.3)	213.5 (45.1)	0.292
HDL-C, mg/dL	52.3 (12.6)	49.6 (13.9)	49.6 (14.5)	50.1 (14.1)	49.1 (12.0)	0.147
TG, mg/dL	113.1 (58.2)	130.9 (75.6)	139.6 (79.4)	125.4 (57.7)	124.0 (64.7)	0.001
LDL-C, mg/dL	142.5 (42.8)	133.5 (41.5)	139.3 (41.5)	145.6 (36.7)	139.5 (36.6)	0.195
Glucose, mmol/L	6.01 (1.24)	6.4 (1.6)	6.59 (1.93)	6.33 (1.79)	6.28 (1.73)	0.003
Smoking, n (%)						
Nonsmoker	123 (59.9)	112 (71.8)	293 (72.2)	42 (58.3)	62 (51.7)	<0.001
Former smoker	40 (19.3)	30 (19.2)	76 (18.7)	15 (20.8)	28 (23.3)	
Active smoker	43 (20.8)	14 (9)	37 (9.1)	15 (20.8)	30 (25)	
Type 2 DM, n (%)	14 (6.8)	42 (26.9)	102 (25.1)	13 (18.1)	16 (13.3)	< 0.001
Treatment of type 2 DM (in patients with type 2 DM), n (%)	5 (35.7)	24 (57.1)	59 (57.8)	3 (23.1)	4 (25.0)	0.016
CAD, n (%)	16 (7.8)	25 (16)	62 (15.3)	5 (7)	10 (8.3)	0.012
CVDs, n (%)	20 (9.7)	38 (24.4)	96 (23.7)	7 (9.9)	15 (12.5)	< 0.001
LV mass, g	171.9 (51.1)	186.2 (55.5)	200.9 (57.3)	203.6 (71.4)	196.0 (48.8)	< 0.001
LVMI, g/m^2	95.5 (22.5)	103.6 (27.1)	108.6 (25.7)	109.4 (34.5)	104.9 (22.0)	< 0.001
LVEF (Simpson), %	52.7 (7.63)	52.2 (8.36)	51.6 (8.48)	51.6 (7.51)	51.8 (7.51)	0.545
LAVI, mL/m^2	22.7 (8.16)	25.6 (10.2)	28.1 (11.2)	26.7 (12.4)	23.7 (9.29)	< 0.001
E/A, units	0.90 (0.23)	0.88 (0.27)	0.87 (0.32)	0.83 (0.27)	0.82 (0.25)	0.127
GLS, %	–20.2 (3.82)	–19.4 (4.02)	–18.6 (4.19)	–18.8 (3.92)	–18.7 (3.88)	< 0.001
GSR, s^{-1}	–0.92 (0.18)	–0.87 (0.19)	–0.83 (0.19)	–0.87 (0.19)	–0.87 (0.17)	< 0.001

SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI, body mass index; BSA, body surface area; TC, total cholesterol; HDL-C, high-density lipoprotein cholesterol; TG, triglycerides; LDL-C, low-density lipoprotein cholesterol; DM, diabetes mellitus; CAD, coronary artery disease; CVDs, cardiovascular diseases; LV, left ventricle; LVMI, left ventricular mass index; LVEF, left ventricular ejection fraction; LAVI, left atrial volume index; E/A, the ratio of peak LV filling velocities; GLS, global longitudinal strain; GSR, global strain rate.

Table 3. Mean values of LV systolic GLS depending on hypertension and BP control in the population-based sample (n=961, male/female patients, 55–84 years old, Novosibirsk)

Category of hypertension / normal BP	n	Mean GLS, M (SD) %			
		Model 1*	Model 2*	Model 3*	Model 4*
(0) Normal BP	207	–20.2 (4.03)	–20.2 (4.09)	–19.6 (4.08)	–19.5 (4.06)
(1) Hypertension	754	–18.8 (4.04)	–18.7 (4.06)	–18.8 (3.95)	–18.9 (3.98)
p	-	< 0.001	< 0.001	0.027	0.050
(0) Normal BP	207	–20.2 (4.03)	–20.2 (4.09)	–19.6 (4.07)	–19.5 (4.06)
(1) Hypertension: BP control	156	–19.3 (4.03)	–18.9 (4.39)	–18.8 (4.24)	–18.9 (4.23)
(2) Hypertension: ineffective therapy	406	–18.6 (4.04)	–18.5 (4.16)	–18.8 (4.08)	–18.8 (4.11)
(3) Hypertension: no therapy	72	–18.7 (4.03)	–18.7 (4.03)	–18.7 (3.89)	–18.8 (3.89)
(4) Hypertension: not informed, no therapy	120	–18.7 (4.03)	–18.7 (4.33)	–18.6 (4.19)	–18.6 (4.18)
p, inter-group comparison	–	< 0.001	< 0.001	0.165	0.239
p_{0-1}**	–	0.414	0.052	0.999	0.999
p_{0-2}**	–	< 0.001	< 0.001	0.242	0.498
p_{0-3}**	–	0.078	0.091	0.999	0.999
p_{0-4}**	–	0.015	0.038	0.462	0.470

*, ANOVA, Model 1 – non-standardized, Model 2 – standardized by age and sex, Model 3 – standardized by age, sex, and body mass index, Model 4 – standardized by age, sex, and LV mass index. **, p for the pairwise comparison with the normal BP group.

with LV hypertrophy [11]. Kouzu et al. (2011) showed that patients with hypertension had lower GLS than those in the control group [12]. Thus, the role of increased myocardial mass in the decrease of LV GLS in patients with hypertension and LV hypertrophy was consistently demonstrated [1, 2, 11, 12]. In multicenter project EPOGH [13], BP was independently associated with the parameters of LV strain and rate of strain, although the authors did not take into account the role of myocardial mass. The population-based analysis allowed us to identify, in the large sample, a decrease

Table 4. Mean values of LV GSR depending on hypertension and BP control in the population-based sample (n=961, male/female patients, 55–84 years old, Novosibirsk)

Category of hypertension / normal BP	n	Mean GSR, M (SD), s^{-1}			
		Model 1*	Model 2*	Model 3*	Model 4*
(0) Normal BP	207	–0.92 (0.18)	–0.92 (0.2)	–0.89 (0.2)	–0.89 (0.19)
(1) Hypertension	754	–0.85 (0.19)	–0.85 (0.19)	–0.85 (0.19)	–0.86 (0.19)
p	–	< 0.001	< 0.001	0.013	0.029
(0) Normal BP	207	–0.92 (0.18)	–0.92 (0.18)	–0.9 (0.20)	–0.89 (0.20)
(1) Hypertension: BP control	156	–0.87 (0.19)	–0.87 (0.21)	–0.86 (0.21)	–0.87 (0.21)
(2) Hypertension: ineffective therapy	406	–0.83 (0.20)	–0.83 (0.20)	–0.84 (0.20)	–0.85 (0.20)
(3) Hypertension: no therapy	72	–0.87 (0.19)	–0.86 (0.19)	–0.86 (0.19)	–0.87 (0.19)
(4) Hypertension: not informed, no therapy	120	–0.87 (0.19)	–0.86 (0.20)	–0.86 (0.20)	–0.86 (0.20)
p, inter-group comparison	–	< 0.001	< 0.001	0.074	0.151
p_{0-1}**	–	0.135	0.252	0.999	0.999
p_{0-2}**	–	< 0.001	< 0.001	0.036	0.103
p_{0-3}**	–	0.584	0.520	0.999	0.999
p_{0-4}**	–	0.189	0.324	0.999	0.999

* – ANOVA, модель 1 – нестандартизованная; модель 2 – стандартизация по возрасту и полу; модель 3 – стандартизация по возрасту, полу и индексу массы тела; модель 4 – стандартизация по возрасту, полу и индексу массы миокарда ЛЖ.
** – p при попарном сравнении с группой нормотензии.

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Table 5. Logistic regression analysis of the associations of GLS with hypertension and BP control (n=961, male/female patients, 55–84 years old, Novosibirsk)

Independent variables	Model 1*, OR (95% CI)	Model 2*, OR (95% CI)	Model 3*, OR (95% CI)	Model 4*, OR (95% CI)	Model 5*, OR (95% CI)
Normal BP	1.0	1.0	1.0	1.0	1.0
Hypertension	2.35 (1.538–3.589), p<0.001	2.497 (1.621–3.847), p<0.001	1.771 (1.13–2.775), p=0.013	1.75 (1.107–2.768), p=0.017	1.623 (1.018–2.589), p=0.042
(1) Hypertension: BP control	1.581 (0.926–2.698), p=0.093	1.769 (1.026–3.052), p=0.040	1.404 (0.801–2.459), p=0.236	1.37 (0.776–2.419), p=0.278	1.243 (0.688–2.247), p=0.472
(2) Hypertension: ineffective therapy	2.4 (1.561–3.705), p<0.001	2.617 (1.681–4.074), p<0.001	1.714 (1.077–2.728), p=0.023	1.665 (1.038–2.672), p=0.035	1.66 (1.014–2.719), p=0.044
(3) Hypertension: no therapy	2.25 (1.186–4.269), p=0.013	2.219 (1.163–4.234), p=0.016	1.667 (0.857–3.244), p=0.133	1.62 (0.822–3.193), p=0.163	1.791 (0.896–3.581), p=0.099
(4) Hypertension: not informed, no therapy	2.134 (1.232–3.696), p=0.007	1.999 (1.142–3.498), p=0.015	1.633 (0.921–2.897), p=0.093	1.707 (0.955–3.052), p=0.071	1.857 (1.023–3.37), p=0.042

*, Model 1 – non-standardized, Model 2 – standardized by age and sex, Model 3 – standardized by age, sex, and BMI, Model 4 – standardized by age, sex, and myocardial mass index, Model 5 – standardized by age, sex, BMI, myocardial mass, type 2 DM, CAD, and smoking status.

Table 6. Logistic regression analysis of the associations of GSR with hypertension and BP control (n=961, male/female patients, 55–84 years old, Novosibirsk)

Independent variables	Model 1*, OR (95% CI)	Model 2*, OR (95% CI)	Model 3*, OR (95% CI)	Model 4*, OR (95% CI)	Model 5*, OR (95% CI)
Normal BP	1.0	1.0	1.0	1.0	1.0
Hypertension	2.195 (1.408–3.421), p=0.001	2.029 (1.292–3.184), p=0.002	1.56 (0.979–2.486), p=0.061	1.54 (0.958–2.475), p=0.075	1.43 (0.883–2.317), p=0.146
(1) Hypertension: BP control	1.586 (0.903–2.784), p=0.108	1.489 (0.841–2.637), p=0.172	1.26 (0.705–2.254), p=0.435	1.229 (0.682–2.217), p=0.492	1.098 (0.597–2.02), p=0.763
(2) Hypertension: ineffective therapy	2.629 (1.672–4.133), p<0.001	2.446 (1.542–3.878), p<0.001	1.826 (1.13–2.95), p=0.014	1.774 (1.09–2.888), p=0.021	1.709 (1.032–2.832), p=0.037
(3) Hypertension: no therapy	1.652 (0.814–3.352), p=0.165	1.552 (0.762–3.161), p=0.226	1.261 (0.612–2.6), p=0.529	1.222 (0.586–2.55), p=0.592	1.298 (0.614–2.748), p=0.495
(4) Hypertension: not informed, no therapy	1.402 (0.757–2.595), p=0.283	1.27 (0.679–2.374), p=0.455	1.093 (0.58–2.058), p=0.783	1.144 (0.603–2.169), p=0.681	1.193 (0.622–2.288), p=0.596

*, Model 1 – non-standardized, Model 2 – standardized by age and sex, Model 3 – standardized by age, sex, and BMI, Model 4 – standardized by age, sex, and myocardial mass index, Model 5 – standardized by age, sex, BMI, myocardial mass, type 2 DM, CAD, and smoking status.

in LV strain associated with hypertension irrespective of sex, age, BMI, LVMI, CAD, and type 2 DM. GSR also decreased in hypertension, but the association was more dependent on weight and myocardial mass.

Ineffectively treated and non-treated patients with hypertension had the lowest LV GLS and GSR values. Similar results were obtained in a small cross-sectional study by Reza et al. (2018) [14]. The authors demonstrated statistically significant differences in GLS between the groups with and without control of hypertension. GSR was shown in our study to be associated with a degree of hypertension control irrespective of several factors. This parameter is considered by a proxy indicator of such fundamental properties of the myocardium as compliance and dp/dt [15].

The development of subendocardial fibrosis in hypertensive myocardial damage may be a possible mechanism of a decrease in absolute LV strain and GSR in hypertension, as well as LV hypertrophy. It is confirmed by the findings of the new 3D-STI ultrasound technology on the decrease of endocardial GSR, rather than epicardial measures, in patients with hypertension [16]. In untreated patients with hypertension, a decrease in GLS was also correlated with levels of tissue inhibitor of matrix metalloproteinase-1, which is a marker of collagen metabolism of myocardial fibrosis [17]. In our study, the group of «ineffective hypertension control» differed in terms of clinical characteristics from other hypertension groups by the longer history of hypertension, higher

mean BP levels, values of LVMI and left atrial volume index (LAVI), and the lowest rates of LV relaxation (tissue Doppler of the mitral annulus), which is indicative of more severe damage of the myocardium as a target organ.

The study had several limitations. Only office measurement of BP was used, i.e., masked or white-coat hypertension was not taken into account. However, the standardized three-time measurement of BP and duplicate questions about treatment minimize this limitation in identifying hypertension. The study design is cross-sectional, i.e., the prognostic significance of the decrease in LV strain can not be estimated. The follow-up in our sample will allow us to analyze the contribution of LV strain, taking into account other myocardial phenotypes (myocardial mass, atrial remodeling) to cardiovascular risk to clarify the role of the decrease in myocardial strain in the determination of cardiovascular risk.

Conclusion

1. In the population-based sample (55–84 years old, Novosibirsk), the presence of hypertension increased the risk of a 1.6-fold decrease in left ventricular global systolic longitudinal strain by times, irrespective of sex, age, body mass index and myocardial mass index, and other cardiometabolic diseases.
2. The odds of a decrease in the rate of systolic myocardial strain associated with hypertension increased 2-fold, which was partly due to body weight and LV hypertrophy.
3. Ineffectively treated or non-treated patients with hypertension had the lowest rates of GLS and GSR irrespective of other factors.
4. The decrease in left ventricular systolic longitudinal strain in insufficient blood pressure control reflects the initial decrease in left ventricular systolic function and can be a potential mechanism of the population risk of cardiovascular complications in hypertension.

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