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Intrarenal hemodynamics in hypertensive patients

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Abstract

Objective. To investigate the doppler features of the blood flow in hypertensive patients. **Design and methods.** We examined 49 hypertensive patients (mean age 52.8 ± 12.9 years) and 20 healthy subjects (mean age 49.2 ± 17.6 years). The intrarenal blood flow was studied by the triplex scan. We also assessed creatinine levels, estimated glomerular filtration rate by MDRD formula and creatinine clearance by Cockroft-Gault formula, and albuminuria. **Results.** A decreased blood flow velocity parameters and the increase of the proximal renal artery segment were found (peak systolic velocity in right and left renal arteries — 78.4 ± 21.4 and 59.3 ± 11.4 cm/s in hypertensive group and 100.8 ± 34.3 and 88.7 ± 18.2 cm/s in control group, $p < 0.05$; resistant index in right and left renal arteries — 0.66 ± 0.05 and 0.67 ± 0.05 in hypertensives and 0.62 ± 0.06 and 0.63 ± 0.06 in controls, $p < 0.05$). There was no difference of blood flow velocities in the distal segment of the renal arteries between the groups. **Conclusions.** Different variants of the renal artery remodeling occur in proximal and distal segments of renal arteries in hypertensive patients. The most typical changes include the increase of the main renal artery trunk with the decreased blood flow velocity, while segment and interlobar renal arteries are characterized by narrowing that might result in nephroangiosclerosis.

Key words: arterial hypertension, intrarenal blood flow, hemodynamic parameters

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Особенности интраренальной гемодинамики у больных эссенциальной гипертензией

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Резюме

Цель исследования — изучить допплерографические особенности внутрипочечного кровотока у больных артериальной гипертензией (АГ). **Материалы и методы.** Обследовано 49 пациентов с эссенциальной АГ (средний возраст 52,8 ± 12,9 года) и 20 здоровых лиц (средний возраст 49,2 ± 17,6 года). Интраренальный кровоток исследовали с применением триплексного ультразвукового сканирования. Функциональное состояние почек оценивали путем определения уровня креатинина, расчетной скорости клубочковой фильтрации по формуле MDRD и клиренса креатинина по формуле Кокрофта-Гаулта; экскреции альбумина с мочой. **Результаты.** Установлено снижение скоростных показателей кровотока и увеличение диаметра просвета проксимального сегмента почечных артерий у лиц с эссенциальной гипертензией (пиковая систолическая скорость в устьях правой и левой почечных артерий 78,4 ± 21,4 и 59,3 ± 11,4 см/с в основной группе и 100,8 ± 34,3 и 88,7 ± 18,2 см/с в контрольной группе, $p < 0,05$; индекс резистентности в правой и левой почечных артериях 0,66 ± 0,05 и 0,67 ± 0,05 в основной группе и 0,62 ± 0,06 и 0,63 ± 0,06 в контрольной группе, $p < 0,05$); разницы скоростей кровотока в дистальном сегменте почечных артерий между группами выявлено не было. **Выводы.** При АГ в проксимальных и дистальных сегментах наблюдаются разные варианты ремоделирования почечных артерий. Для основного ствола почечной артерии характерно увеличение просвета, сопровождаемое снижением скоростных характеристик кровотока, а в сегментарных и междолевых артериях, напротив, диаметр просвета сужается, что может способствовать впоследствии развитию нефроангиосклероза.

Ключевые слова: артериальная гипертензия, внутрипочечный кровоток, гемодинамические показатели

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Introduction

Essential hypertension (HTN) leads to cardiovascular and renal complications. Its prevalence achieves 30–45 % in the general population in European countries [1], and in Russia it is about 40 % [2]. Kidneys are actively involved in the pathogenesis of HTN, and at the same time they are one of the target organs [3]. High blood pressure (BP) of considerable duration contributes to the development of nephroangiosclerosis and chronic renal failure [4–6]. Early detection of renal damage is one of the aims in cardiology. However, clinical manifestations are lacking at the early stages of kidney damage impeding timely diagnosis [7]. Elevated creatinine level, decreased glomerular filtration rate and microalbuminuria are characteristic for the primary glomerulosclerosis in HTN [1, 8], however, they manifest when kidney damage is irreversible. In recent years, renal vascular triplex scanning is considered the most important method for early detection of violations of intrarenal blood flow in HTN [7, 9, 10]. However, recent national and international studies of intrarenal hemodynamics in HTN are rather sparse and controversial. The dynamics of blood flow in different segments of renal arteries are not fully assessed.

The purpose of this research was to study intrarenal hemodynamics and characteristics of the renal arteries in patients with essential HTN.

Design and methods

The study group included 49 patients (24 men and 25 women) with essential HTN stage I–II (according to national clinical guidelines for the diagnosis and treatment of HTN, 2010) aged 41–64 years (mean age — 52.8 ± 12.9 years, mean HTN duration — 14.4 ± 9.7 years). HTN stage I was diagnosed in 23 (47 %) patients, and HTN stage II — in 26 (53 %) patients. There were 16.3 % (8 people) smokers in the study group, 55.1 % (27 people) had abdominal obesity, 36.7 % (18 people) — family history of early onset of cardiovascular disease. The control group consisted of 20 healthy subjects (8 men and 12 women) aged 31–67 (average age was 49.2 ± 17.6 years), including 20 % (4 people) smokers, 45 % (9 persons) patients with abdominal obesity, and 40 % (8 people) subjects with the family history of early onset of cardiovascular disease. The study was conducted after 3-day washout period. Previous treatment included a one or two component therapy. Patients took angiotensin-converting enzyme (ACE) inhibitors (enalapril, lisinopril), diuretics (indapamide). All patients signed informed consent form.

The inclusion criterion was the presence of essential HTN stage I–II. Exclusion criteria were unsatisfactory ultrasound imaging of the kidneys and renal arteries, secondary HTN, thyroid disease, diabetes mellitus, cardio- and cerebrovascular events in past, chronic heart failure II B stage and above.

All patients underwent office BP measurement, ambulatory blood pressure monitoring (ABPM), medical history was taken and medical outpatient records were studied. ABPM was performed by the device BPLab MnSDP-2 ("Pyotr Telegin", Nizhny Novgorod, Russia): the measurements were taken every 15 minutes in the daytime and every 30 minutes at night. The average 24-hour, average daytime, average nighttime systolic (SBP) and diastolic blood pressure (DBP) were assessed.

Brachial BP on both arms was measured by standard technique, after 10 minutes of rest immediately before ultrasound examination, and average SBP and DBP of two measurements were calculated.

Ultrasonography of the kidneys with renal blood flow analysis was carried out with the use of Vivid 7 Dimension device (USA). The length, thickness and width of the kidneys, as well as parenchymal layer thickness were estimated by standard technique.

Kidney volume (V) was calculated by the formula [11]:

Table 1

CLINICAL AND DEMOGRAPHIC CHARACTERISTICS OF THE STUDIED GROUPS

Index	HTN group (n = 49)	Control group (n = 20)
Gender (male / female), n	24/25	8/12
Mean age, years	52.8 ± 12.9	49.2 ± 17.6
Systolic BP, mmHg	162.7 ± 28.9	112.7 ± 16.4*
Diastolic BP, mmHg	95.9 ± 15.3	72.2 ± 12.0*
Body mass index, kg/m^2	28.6 ± 5.7	25.4 ± 4.1

Note: HTN — hypertension; BP — blood pressure; * — p <0.05 in comparison with the group of hypertensive patients.

Table 2

PARAMETERS OF INTRARENAL HEMODYNAMICS IN PATIENTS WITH ESSENTIAL HYPERTENSION AND HEALTHY INDIVIDUALS

Segments of renal artery	Parameter	Right kidney		Left kidney	
		HTN group (n = 49)	Control group (n = 20)	HTN group (n = 49)	Control group (n = 20)
Mouth	Vps, см/с	78.4 ± 21.4	100.8 ± 34.3*	59.3 ± 11.4	88.7 ± 18.2*
	Vd, см/с	27.1 ± 9.4	38.2 ± 18.1*	20.9 ± 5.3	32.5 ± 6.5*
	RI	0.66 ± 0.05	0.62 ± 0.06*	0.67 ± 0.05	0.63 ± 0.04*
Distal artery, I segment	Vps, см/с	60.7 ± 25.8	71 ± 28.5	51.6 ± 12.6	64.5 ± 17.3*
	Vd, см/с	21.8 ± 9.2	29.5 ± 11.8*	18.4 ± 5.6	25 ± 5.6*
	RI	0.64 ± 0.06	0.58 ± 0.04*	0.65 ± 0.06	0.6 ± 0.04*
Segmental artery	Vps, см/с	37.4 ± 10.2	38 ± 14.9	37.1 ± 8.2	39.3 ± 6.1
	Vd, см/с	15.7 ± 5.3	17.3 ± 8.4	14.2 ± 3.4	17.6 ± 2.5*
	RI	0.6 ± 0.06	0.55 ± 0.03*	0.6 ± 0.05	0.54 ± 0.05*
Interlobar artery	Vps, см/с	28.5 ± 8.1	28.7 ± 7.2	26.5 ± 6.2	26 ± 3.8
	Vd, см/с	12.8 ± 2.3	14.1 ± 3.0*	11.1 ± 2.4	13 ± 2.1*
		0.57 ± 0.05	0.51 ± 0.05*	0.57 ± 0.06	0.49 ± 0.03*

Note: HTN — hypertension; Vps — peak systolic velocity; Vd — end-diastolic velocity; RI — resistance index; * — $p < 0.05$ in comparison with the group of hypertensive patients.

$V = A \times B \times C \times 0.523$,

where A is the length (cm), B — the thickness (cm), and S — the width (cm).

Blood flow in the main renal arteries at the mouth and in the segmental and interlobar renal arteries was evaluated by triplex ultrasound. The following parameters were measured: the diameter of the renal artery in the first segment, and velocity characteristics including peak systolic flow velocity (Vps) and end diastolic velocity (Vd). Among peripheral resistance indices, resistance index (RI) was assessed due to the high significance for vessels with low peripheral resistance like renal arteries.

Serum creatinine was evaluated by Jaffe's method, and glomerular filtration rate was estimated by the MDRD formula [8]; creatinine clearance was calculated by Cockcroft-Gault formula [8]. Urea level was measured by enzyme assay, urinary albumin excretion — by immunochemical method.

Statistical analysis was performed using Statistica 6.0 ("StatSoft" Inc, USA) software package. The variable distribution was tested by Kolmogorov-Smirnov test showing normal distribution of the studied data. Therefore, the results are presented as M ± SD, where M is the arithmetic mean, and SD — standard deviation. Student t-test was used to compare the differences between the two independent samples. Differences were considered statistically significant at the p-level < 0.05.

Results

The groups were matching by sex and age (Table 1). However, the main renal artery blood flow differed significantly between patients with essential hypertension and the control group (Table 2). The peak systolic velocity in the mouths of the right (78.4 ± 21.4 cm/s) and the left (59.3 ± 11.4 cm/s) renal arteries was significantly lower than in the comparison group (100.8 ± 34.3 and 88.7 ± 18.2 cm/s, respectively). Similar differences were noted in the end diastolic velocity values. Resistance index in the proximal part of the right (0.66 ± 0.05) and the left (0.67 ± 0.05) renal arteries was significantly higher in hypertensive patients than in the control group (0.62 ± 0.06 and 0.63 ± 0.06, respectively).

Vps in the I segment of the left renal artery (51.6 ± 12.6 cm/s) was lower in hypertensive patients than in the comparison group ($p < 0.05$). RI in the distal main right (0.64 ± 0.06) and left (0.65 ± 0.06) renal arteries were higher than in the control group (0.62 ± 0.06 and 0.63 ± 0.04, respectively).

The segmental and interlobar arteries of the significant differences in the characteristics of

Table 3

RENAL FUNCTION IN THE STUDIED GROUPS

Index		HTN group (n = 49)	Control group (n = 20)	p
Urea, mmol/l		5.3 ± 1.3	4.2 ± 1.3	0.004
Creatinine, mcmol/l		83.6 ± 15.5	87.5 ± 15.6	0.34
eGFR, mL/min/1.73 m²		75.7 ± 14.1	99.8 ± 16.5	0.0001
Creatinine clearance, ml/min		107.4 ± 37.6	123.7 ± 35.7	0.1
Albumin urine excretion, mg/l		6.9 ± 3.4	5.2 ± 3.1	0.057
Right kidney	PTL, cm	1.55 ± 0.15	1.54 ± 0.13	0.73
	Volume, cm³	108.5 ± 21.5	116.7 ± 33.8	0.22
	Diameter of the renal artery, cm	0.55 ± 0.07	0.47 ± 0.04	0.0001
Left kidney	PTL, cm	1.56 ± 0.14	1.61 ± 0.15	0.2
	Volume, cm³	114.3 ± 29.5	102.2 ± 11.8	0.08
	Diameter of the renal artery, cm	0.54 ± 0.07	0.48 ± 0.04	0.003

Note: HTN — hypertension; eGFR — glomerular filtration rate; PTL — parenchymal thickness of the layer.

the peak systolic velocity between patients with essential hypertension and healthy subjects have been identified, the level of significance matched $p > 0.05$. However, the resistance index of intrarenal blood flow in patients with AH were significantly higher than in the comparison group ($p < 0.05$).

Interestingly, the diameters of the right (0.55 ± 0.07 cm) and left (0.54 ± 0.07 cm) renal arteries were greater in hypertensive patients as compared to the control group (0.47 ± 0.04 cm, p = 0.0001 and 0.52 ± 0.05 cm, p = 0.003, respectively) (Table. 3).

Urea levels and glomerular filtration rate differed significantly in hypertensive patients and the controls. The serum urea level (5.3 ± 1.3 mmol/l) was higher in hypertensives than in healthy individuals (4.2 ± 1.3 mmol/l, p = 0.004). The glomerular filtration rate (71.1 ± 8.5 ml/min/1.73 m²) was lower in patients with essential hypertension compared to the control group (99.8 ± 16.5 ml/min/1.73 m², p = 0.0001) (Table 3).

Discussion

Our analysis showed an increase in resistance index (reflecting peripheral resistance), in all segments of the renal arteries in hypertensive patients compared to healthy individuals. This is consistent with the results of earlier studies [7, 9, 10].

According to M. N. Nasrullaev (2010) [7], the velocity characteristics of blood flow in the segmental arteries are higher in hypertensive patients than in the control group. In our study, systolic blood flow velocity in the segmental and interlobar arteries was similar in the groups, while diastolic blood flow velocity was lower in hypertensive patients. We suggest that this caused the increase in the resistance indices due to the narrowing of the artery lumen [12].

To our knowledge, the variability in distribution of blood flow velocity in infrarenal proximal and distal renal arteries is demonstrated for the first time. In the main renal trunks, in the mouth, and at the renal portal, peak systolic and end-diastolic velocities were lower in hypertensive patients compared to the controls. However, the renal artery diameter was increased at the mouth in hypertensive subjects compared to the normotensive ones. G. H. Gibbons and coworkers (1994) distinguished several types of vascular remodeling in hypertension. One is characterized by an increase in vessel lumen and is observed in the elastic arteries and vessels of transition type (aorta, carotid artery). Second type is characterized by the hypertrophy of the vascular walls and narrowing of the lumen and can be seen in small resistance vessels [13]. Renal artery at the level of mouth can be defined as transition type vessels. Therefore, elevation of intravascular pressure in hypertension leads to an increase in both the outer and inner diameters with negligible changes in wall thickness due to the cellular and noncellular disorganization. An increase in resistance index in the segmental and interlobar renal arteries in hypertensive patients indicates the narrowing of the vascular lumen. Endothelial dysfunction, vasoconstriction of the intrarenal arteries and arterioles leading to the vascular proliferation and hyalinosis enhance the progression of nephroangiosclerosis [14].

Conclusions

Based on our results, renal artery remodeling varies in proximal and distal segments in hypertensive patients. The remodeling of the main renal trunk is characterized by an increase in the lumen accompanied by a decreased blood flow velocity, while the lumen diameter in the segmental and interlobar arteries increases, subsequently promoting the development of nephroangiosclerosis.

Conflict of interest

The authors declare no conflict of interest.

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