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Kidney ultrasound biometric data dynamics in women with gestational hypertension

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ABSTRACT

Introduction: The stable level of morbidity in the Russian Federation of pregnant women with gestational arterial hypertension (GAH) and as a consequence of the disability of women of working age and their offspring actualizes the search for early ultrasound markers of kidney damage as a target organ urgent.
Objectives: Despite the variety of publications on ultrasound semiotics of the kidneys, there are no specific biometric parameters of the kidneys in pregnant women without somatic pathology, which actualizes this study.
Patients and Methods: A comprehensive clinical examination of 183 outpatients and inpatients (mean age 27.9 ± 4.7 years) with gestational hypertension performed.
Results: There is a significant increase in the volume of the right kidney, the left kidney shape index, the diameter of the renal calyces and pelvis, the coefficient of asymmetry, the ratio of the diameter of the renal calyces to the volume of the right kidney with an increase in the degree of gestational hypertension.
Conclusion: Structural changes of kidneys are interconnected with hemodynamic parameters observed and can be expressed by mathematical model.

Implication for health policy/practice/research/medical education:
The development and application in clinical practice of adequate safe and accurate methods for assessing the biometric parameters of internal organs in normal conditions in pregnant women will make it possible to increase the effectiveness of diagnostic measures and allow purposefully and timely correction of the detection of pathological processes and reduce the likelihood of their over-diagnosis.
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Introduction

The stable level of morbidity in the Russian Federation of pregnant women with gestational arterial hypertension (GAH) and as a consequence of the disability of women of working age and their offspring actualizes the search for early ultrasound markers of this pathology. The development and application in clinical practice of adequate safe and accurate methods for assessing the biometric parameters of internal organs in normal conditions in pregnant women will make it possible to increase the effectiveness of diagnostic measures and allow purposefully and timely correction of the detection of pathological processes and reduce the likelihood of their over-diagnosis. Ultrasound is one of the most rapidly developing imaging methods. Being relatively inexpensive, highly informative, and practically safe for staff and pregnant women, ultrasonography is recognized as a diagnostic search method that is very informative for most conditions of organs and systems of the human body (1,2).

Objectives

Despite the variety of publications on ultrasound semiotics of the kidneys, there are no specific biometric parameters of the kidneys in pregnant women without somatic pathology, which actualizes this study.

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Patients and Methods

Patients

Around 489 outpatient and inpatient patients women with physiologically proceeding pregnancy aged 16 to 45 years (average age 27.9 ± 4.7 years) were included in this study.

Study design

GAH group; 183 (duration of disease 8.8±4.0 weeks, average daily systolic blood pressure (SBP) at admission 150.2 ± 4.8 mm Hg, the average daily diastolic blood pressure (DBP) 93.1 ± 6 mm Hg).

Control group: 306 women with physiologically proceeding pregnancy in the same age range without clinic of somatic pathology and indications for it in the anamnesis.

Ethical issues

All stages of the study comply with the legislation of the Russian Federation, international ethical standards and normative documents of research organizations, as well as approved by the Ethics Committee of the Sechenov First Moscow State Medical University (Sechenov University). Informed consent was obtained from all observed. The study of the kidneys carried out by ultrasonic devices using 3.5 MHz convection sensors in accordance with the recommendations (1, 2). The research followed the tenets of the Declaration of Helsinki. This study is part of the Natalia A. Konyshko dissertation research for the degree of MD, Ivan Michailovich Sechenov First Moscow State Medical University, Russian Federation.

Statistical analysis

Statistical processing of research results was carried out with the help of specially developed electronic databases and methods of descriptive statistics and the use of Microsoft Excel software package, “IBM SPSS Statistics”. For the evaluation of quality indicators was determined in absolute values and percentage values of the Fisher’s exact test. Parametric and nonparametric statistical indicators were calculated for quantitative parameters. The statistical significance of the difference between the group parameters and the correlation was evaluated by parametric and nonparametric criteria at P<0.05.

Results

We analyzed the ultrasound changes of the kidneys in the main and control groups in order to detect kidney remodeling in pregnant women with gestational hypertension against the background of physiologically proceeding gestation. The data presented in Table 1 show that the length of the right kidney, the thickness of the parenchyma of both kidneys, the diameter of the renal calyces of the right kidney in the study groups were not significantly increased (P > 0.05).

The diagrams in Figures 1-3 graphically reflect the biometric data of the kidneys in the study groups.

The length and thickness of the kidneys remained the

Table 1. Ultrasonic biometric parameters of kidneys observed (mean ± standard deviation)

Parameters (cm)	Group 1 (n=183)	Control (n=306)	*P* value[a]
Right renal Length RL	10.53±0.21	10.57±0.22	-
Right renal Height RH	4.63±0.2	4.56±0.31	-
Right renal Thickness RT	4.4±0.27	4.34±0.26	-
Right renal Volume RV	114.32±15.13	111.64±14.9	-
Renal Surface area RS	1.88±0.15*	1.78±0.12	0.0001
Right renal shape factor RJ	1.17±0.07*	1.19±0.07	0.021
Right renal calyces diameter RDC	1.05±0.09	1.06±0.09	-
Right renal pelvis diameter RDP	2.62±0.33*	2.47±0.28	0.0002
Left renal length LL	10.21±0.25	10.26±0.25	-
Left renal height LH	4.51±0.26*	4.44±0.24	0.04
Left renal thickness LT	4.3±0.2	4.28±0.2	-
Left renal volume LV	105.5±10.93*	103.48±10.7	0.047
Left renal shape index LJ	1.16±0.06*	1.18±0.06	0.025
Left renal calyces diameter LDC	0.96±0.11	0.98±0.11	-
Left renal pelvis diameter LDP	2.43±0.33*	2.31±0.29	0.004

* Statistically significant difference with the control group, P < 0.05.

[a] Mann-Whitney U-test group 1 – control.

Right renal length; RL, right renal height; RH, right renal thickness; RT, right renal volume; RV, renal surface area; RS, right renal shape factor; RJ, right renal calyces diameter; RDC, right renal pelvis diameter; RDP, left renal length; LL, left renal height; LH, left renal thickness; LT, left renal volume; LV, left renal shape index; LJ, left renal calyces diameter; LDC, left renal pelvis diameter; LDP.

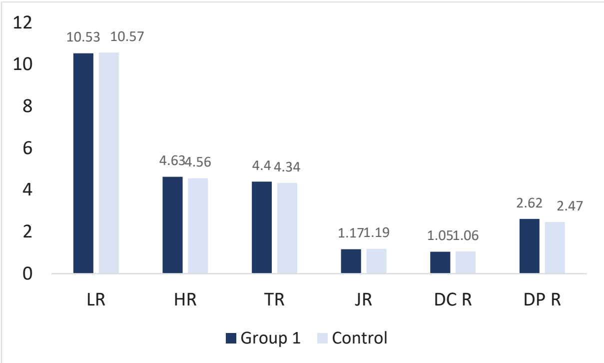

Figure 1. Mean biometric data of the right kidney in the observed, (measurements in centimeters). LR; right renal length, HR; right renal height, TR; right renal thickness, JR; right renal shape factor, DCR; right renal calyces diameter, DPR; right renal pelvis diameter

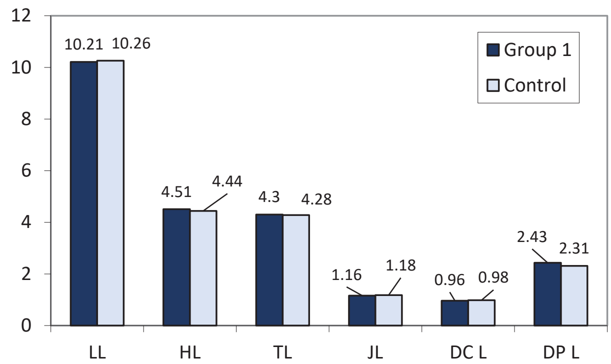

Figure 2. Mean biometric data of the left kidney in the observed, (measurements in centimeters). LL; left renal length, HL; left renal height, TL; left renal thickness, JL; left renal shape index, DCL; left renal calyces diameter, DPL; left renal pelvis diameter.

most unchanged parameters in the main groups during and after gestation ($P > 0.05$). Kidney volume, due to the width of the right in group 2 and due to the width of the left in the group of patients with gestational hypertension, pelvis diameter in the main groups increased by the second trimester of pregnancy in comparison with the control. Dilatation of the pelvis of the right kidney was more pronounced in the group with hypertension. The diameter of the renal calices significantly increased in the group of pregnant women with arterial hypertension in comparison with the control. It should be noted that in healthy pregnant women of the control group, according to our data, the diameter of the renal calices from the second trimester goes beyond the normal values in the general population, exceeding the upper established limit of the norm by no more than 1.6 times. Kidney shape index (J) decreased in the main group, kidney sphering was observed ($P = 0.021$ in comparison with the control).

According to the carried-out factor analysis the statistical connection of average degree between length of kidneys and growth of women is revealed.

The ratio of linear dimensions of the kidneys among themselves and with anthropometric parameters – the asymmetry coefficient (CA = VR/VL), the height of the kidney to its thickness (H/T) in the observed are presented in Table 2. There was a significant increase in the coefficient of asymmetry, the ratio of the volume of the right kidney to the surface area of the body, the volume of the kidneys to growth, in pregnant women with obesity in comparison with other groups and controls. The ratio of width and thickness of the kidneys increased from the right to the left of the main group, in comparison with the control. There is a decrease in the ratio of kidney volume and length to weight and body surface area in the group with GAH.

The ratio of kidney volume to body weight (V/M) and to body mass index increases, compared to the control group. Dilatation of the renal calices and pelvis relative to the volume of the kidneys in comparison with the control shown. Dilatation of the renal calices and pelvis relative to the volume of the kidneys (DC/V, DL/V) most

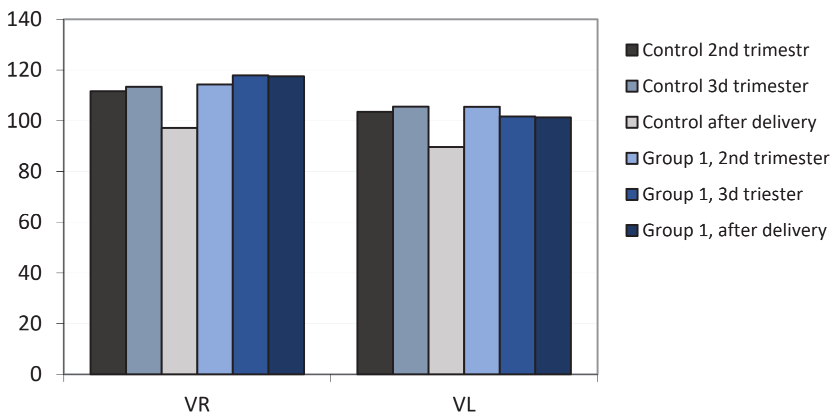

Figure 3. The volume of the right (VR) and left (VL) kidney in the studied groups.

Table 2. Correlation of ultrasonic linear parameters of renal biometrics and anthropometric data observed

Parameter	Group 1 (n=183)	Control (n=306)	*P* value[a]
VR/body weight	1.5 ± 0.24*	1.63 ± 0.23	0.00003
VR/ body mass index	4.07 ± 0.64*	4.46 ± 0.65	0.00004
VL/body surface area	56.43 ± 0.24*	58.39 ± 5.84	0.03
VL/body weight	1.39 ± 0.22*	1.52 ± 0.2	0.00001
VL/body mass index	3.77 ± 0.58*	4.14 ± 0.56	0.00001
DCL/VL	0.09 ± 0.001*	0.01 ± 0.001	0.022
DPR/VR	0.02 ± 0.002*	0.02 ± 0.002	0.013
DPL/VL	0.02±0.002*	0.02±0.002	0.02

The volume of the right (VR) and left (VL) kidney, DPR; right renal pelvis diameter, DCL; left renal calyces diameter, DPL; left renal pelvis diameter (per centimeter), the ratio of parameters to the body weight, to the body mass index and to the body surface area was calculated.
[a] Mann–Whitney.

pronounced in the group of patients with hypertension.

Table 3 presents the data of ultrasound biometry of the kidneys depending on the type and degree of hypertension in pregnant women.

The largest number of pregnant women of the main group had systolic hypertension of 1 degree (48.09%), systolic hypertension of 1 degree was detected in 15.85% of women of this group.

The least common type was mainly systolic hypertension of 2 degrees: in group GAH 6.01%; in group 2 - 6.1%. Noted significant increase in the volume of the right kidney, the shape index of the left kidney, the diameter of the renal calices and pelvis, the asymmetry factor, the ratio of the diameter of the renal calyces to the volume of the right kidney with the increase of gestational

Table 3. Renal biometric data depending on the type and degree of gestational hypertension in patients of the main group

Parameters	SAH1 (n=29)	SDAH1(n=88)	SAH2 (n=11)	SDAH2 (n=55)
LR	10.57 ± 0.13	10.52 ± 0.21	10.52 ± 0.18[b]	10.5 ± 0.27[a]
HR	4.54 ± 0.31	4.65 ± 0.36	4.54 ± 0.25	4.68 ± 0.29
TR	4.33 ± 0.24	4.39 ± 0.25	4.32 ± 0.24	4.48 ± 0.31[a]
VR	110.85 ± 13.54	114.5 ± 15.01	109.87 ± 13.7	117.53 ± 15.41[a]
Renal surface area	1.86 ± 0.11	1.86 ± 0.15	1.89 ± 0.15	1.99 ± 0.15[a]
JR	1.2 ± 0.08	1.17 ± 0.07	1.19 ± 0.05	1.15 ± 0.07
DC R	1.08 ± 0.06	1.07 ± 0.09	1.04 ± 0.06	0.96 ± 0.15[a]
DL R	2.46 ± 0.25	2.62 ± 0.34	2.57 ± 0.28[b]	2.78 ± 0.28[a]
LL	10.33 ± 0.17	10.24 ± 0.22	10.2 ± 0.22[b]	10.02 ± 0.33
HL	4.44 ± 0.25	4.51 ± 0.26	4.44 ± 0.25	4.54 ± 0.26
TL	4.28 ± 0.17	4.33 ± 0.19	4.23 ± 0.13	4.30 ± 0.29
VL	104.31 ± 9.56	106.33 ± 10.27	101.96 ± 9.14	104.79 ± 14.03
JL	1.19 ± 0.06	1.16 ± 0.06	1.18 ± 0.05	1.14 ± 0.06[a]
DC L	0.98 ± 0.08	0.96 ± 0.1	0.91 ± 0.08[b]	0.91 ± 0.13[a]
DL L	2.29 ± 0.26	2.42 ± 0.34	2.42 ± 0.27[b]	2.61 ± 0.33[a]
Skewness coefficient	1.06 ± 0.05	1.07 ± 0.06	1.08 ± 0.08[b]	1.13 ± 0.06[a]
HR/TR	1.05 ± 0.03	1.06 ± 0.03	1.05 ± 0.026	1.05 ± 0.04
HL/TL	1.04 ± 0.04	1.04 ± 0.04	1.05 ± 0.04	1.06 ± 0.04
VR/body mass index	59.87 ± 7.08	61.92 ± 7.74	58.48 ± 8.3	59.55 ± 7.84
VR/body weight	1.49 ± 0.19	1.54 ± 0.24	1.43 ± 0.25[b]	1.38 ± 0.24[a]
VR/height	0.67 ± 0.09	0.7 ± 0.09	0.67 ± 0.08	0.72 ± 0.09
VR/bod mass index	4.1 ± 0.5	4.16 ± 0.65	3.85 ± 0.71[b]	3.67 ± 0.61[a]
VL/body surface area	56.43 ± 5.25	57.62 ± 6.14	54.14 ± 5.55[b]	53.19 ± 8.4[a]
VL/body weight	1.41 ± 0.18	1.44 ± 0.22	1.32 ± 0.17[b]	1.23 ± 0.25[a]
VL/height	0.63 ± 0.06	0.65 ± 0.065	0.62 ± 0.054	0.64 ± 0.08
VL/Mass index body	3.87 ± 0.48	3.87 ± 0.57	3.57 ± 0.71[b]	3.28 ± 0.65[a]
DCR/VR	0.099 ± 0.001	0.0094 ± 0.0012	0.0097 ± 0.001	0.0081 ± 0.0007[a]
DCL/VL	0.0095 ± 0.001	0.0091 ± 0.001	0.0091 ± 0.001[b]	0.0087 ± 0.0008
DLR/VR	0.022 ± 0.002	0.023 ± 0.002	0.024 ± 0.003[b]	0.024 ± 0.002
DLL/VL	0.022 ± 0.001	0.023 ± 0.002	0.024 ± 0.003[b]	0.025 ± 0.003

SAH-systolic arterial hypertension, SDAH-systolic-diastolic arterial hypertension, 1-the first stage of arterial hypertension, 2-the second stage of arterial hypertension; The volume of the right (VR) and left (VL) kidney; LR right renal length; HR right renal height; TR right renal thickness; JR right renal shape factor; DCR right renal calyces diameter; DPR right renal pelvis diameter; LL left renal length; HL left renal height; TL left renal thickness; JL left renal shape index; DCL left renal calyces diameter; DPL left renal pelvis diameter
[a] Statistically significant difference between SDAH1 and SDAH2 groups, $P < 0.05$.
[b] Statistically significant difference between groups SAH1 and SAH2, $P < 0.05$.

hypertension (P = 0.0006; 0.00008; 0.00001; 0.009; 0.0001; 0.0007, respectively). A significant increase in the volume of both kidneys and the asymmetry coefficient with the aggravation of the degree of arterial hypertension (P = 0.007) was shown.

The correlation analysis of biometric data and hemodynamic parameters revealed a positive significant relationship; in the group with a GAH level, the average DBP and length of the left kidney (P = 0.0005), with the thickness of the right kidney (P = 0.01, r=0.26), and due to this with the volume of the right kidney; the diameter of the right renal pelvis (P = 0.02, r=0.24) and left kidney (P = 0.03 and r=0.22); The results of the polynomial regression analysis of the dependence of kidney volume (V) on the average daily levels of SBP (SSBP) and DBP (SDBP) have the nature of mathematical models: in the group with GAH: V=122.847-0.290299×SSBP + 0.376858×SDBP.

Discussion

On the basis of the presented parameters, it is possible to speak about progressive with increase in severity of GAH increase in volume mainly of the right kidney, and, accordingly, and coefficient of asymmetry, diameter of pelvises, decrease in an index of the form of kidneys (increase of spherization) and decrease in values of ratios volume of kidneys/index of weight of a body and diameter of a pelvis/volume of kidneys. Our findings are consistent with the literature: the increase in kidney volume during pregnancy may be for a number of reasons. The combination of mechanical (growing uterus) and hormonal factors (estrogen and progesterone) leads to hypotension and compression of the urinary tract, hydronephrosis, decreased systolic blood flow rate in the renal arteries, peripheral vascular resistance at normal microcirculation in healthy pregnant women (3). In addition, the increase in the kidneys may be due to the influence of growth factors, an increase in the volume of circulating fluid, with anatomical features of the urinary system during pregnancy. Blood supply to the kidneys is normally 20% of the cardiac output and it is carried out by the renal arteries, which depart from the abdominal aorta. Reduction of renal perfusion in pregnant women with hypertension causes stimulation of the renin-angiotensin system. Increased activity leads to disruption of auto-regulation of the tone of the afferent and efferent arterioles of the renal glomerulus, increasing glomerular filtration rate and increase of flow in the renal tubules. The speed of venous blood flow is much greater in the right kidney, which is due to anatomical differences: with a large diameter of the right renal vessel and the frequent presence of additional renal veins on the right. The difference in venous blood flow is 10%-15% in pregnant women, which corresponds to the different diameters of the pelvis of the right and left kidneys. Pathology of renal blood flow is detected even at the early and preclinical stages of cardiovascular diseases in pregnant women (4). In pregnant women with chronic and gestational hypertension, there was a significant decrease in regional renal hemodynamics at different levels of the renal vascular bed, an increase in peripheral vascular resistance, systolic-diastolic ratio, endothelial dysfunction, and the severity of hypertension correlated with the biometric parameters of the kidneys (5). An increase in the concentration of sodium and chlorine ions, increased reabsorption of serum proteins lead to damage to the proximal tubules due to the release of cytokines, edema of the renal parenchyma, tubulointerstitial inflammation and fibrosis with a longer duration of arterial hypertension. Asymmetric renal remodeling in hypertension may be associated not only with anatomical features, but also with the prevalence of one of the interstitial processes in patients with chronic hypertension – in the formation of nephropathy. In addition, the scientific literature shows the strengthening of regional sympathetic influences on the side of the dominance of blood pressure-lateralization due to the inclusion of the renovascular mechanism of hypertension (5,6).

Ultrasonic parameters of kidney can be considered as a biometric markers of remodeling and structural changes of progressive kidney during gestation: increased kidneys, reducing the shape index and the dilation of the calyces-pelvis-plating system; in chronic arterial hypertension in pregnant women: an increase of the index of asymmetry of the kidneys, reducing the shape index (spherization) of the kidneys, increasing the diameter of the renal calices and pelvis, decreasing the ratio of the diameter of the renal calices and pelvis to the renal volume; in gestational hypertension: asymmetric increase in kidney volume, decrease in the ratio of kidney volume to anthropometric parameters, increase in pelvis diameter and decrease in the ratio of calyx and pelvis diameter to kidney volume; in obesity: increase in kidney volume due to proportional increase in all linear sizes of both kidneys, increase in the ratio of kidney volume to growth.

Conclusion

As predictors of structural remodeling of kidneys of pregnant women at GAH it is possible to consider: decrease in the index of the form less than 1.2 ± 0.08 of the right kidney, 1.19±0.06 – left, increase in diameter of pelvises more than 2.46±0.25 of the right kidney, 2.29±0.26–the left kidney. Structural changes of kidneys are interconnected with hemodynamic parameters observed and can be expressed by mathematical model.

Limitations of the study

The findings of this study have to be seen in light of some limitations; the study involved only persons of Caucasian race who permanently reside in the Central Federal District of the Russian Federation

Authors' contribution

MTE, KNA, SEO and KAS were the principal investigators of the study. MTE, KNA, SEO and KAS were included in preparing the concept and design. MTE and KNA revisited the manuscript and critically evaluated the intellectual contents. All authors participated in preparing the final draft of the manuscript, revised the manuscript and critically evaluated the intellectual contents. All authors have read and approved the content of the manuscript and confirmed the accuracy or integrity of any part of the work.

Conflicts of interest

The authors declare that they have no competing interests.

Ethical considerations

Ethical issues (including plagiarism, data fabrication, double publication) have been completely observed by the authors.

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