Doppler parameters of maternal renal blood flow in normal pregnancy

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Summary

The purpose of this investigation was to evaluate changes in maternal renal arterial blood flow during pregnancy. *Materials and Methods:* The study included 40 non-pregnant, 200 pregnant, and 30 women after delivery. The authors measured pulsatility index (*Pi*) and resistance index (*Ri*) in the right and left renal arteries in the hilus. The authors compared the values between non-pregnant and women during first, second, and third trimester and post-partum period and tested correlation with gestational age. *Results:* The authors did not find a statistical difference in *Pi* and *Ri* between the right and left kidneys. There was no difference in *Pi* and *Ri* in pregnancy trimester compared to the non-pregnant state. There was no correlation between the values of *Pi* and *Ri* and gestational weeks. *Conclusion:* During pregnancy there are no changes in the values of maternal renal *Pi* and renal *Ri*. Unchanged total vascular resistance may result from physiological changes of the glomerular filtration rate.

Key words: Kidney; Maternal; Renal artery; Doppler; Pregnancy.

Introduction

During pregnancy, changes in maternal circulation occur that are the result of intense arteriolar vasodilatation and are essential for successful pregnancy outcome [1].

The application of Doppler ultrasound for the evaluation of maternal circulatory changes could be useful in the intensive follow up of high-risk pregnancies with preeclampsia. Along with uterine circulation, other vascular beds that may be of interest during pregnancy are those also affected with preeclampsia. The kidney is usually affected in severe preeclampsia and the most severe condition may result in acute renal failure [2]. Early detection of renal affection during preeclampsia and follow up of renal diseases may include Doppler evaluation of renal circulation. However, the renal circulation must be evaluated in normal pregnancy, so that comparison with normal blood flow can be made in potentially hazardous conditions. Until now there are many studies concerning renal blood flow in normal pregnancy and in pregnancy hypertension [3-7]. These studies were usually performed with a limited number of patients, and a study evaluating substantial number of patients may be of importance.

The purpose of this investigation was to evaluate the presence of changes in Doppler resistance indices in maternal arterial renal blood flow depending on gestational age by comparing the values in pregnancy with the values before pregnancy and after delivery.

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Materials and Methods

This clinical study included 200 healthy pregnant women with a gestational age between six and 40 weeks and 40 healthy non-pregnant women. There was no previous history of any chronic disease in all the cases (essential hypertension, diabetes mellitus, liver, renal, or cardiac disease). All the pregnancies were single, with no presence of gestational hypertension or preeclampsia. Institutional approval for the study was granted by the ethical committee and each patient signed informed consent form for the participation in this study.

The authors registered gestational age, maternal age, parity, and arterial blood pressure. Gestational age was calculated from the last menstrual period and confirmed by first trimester sonographic survey.

The authors also measured renal blood flow by assessing the renal artery (*RA*) at the renal hilus before it branches into the interlobar arteries by pulsed Doppler ultrasound (*Voluson Expert Pro*) with a 3.5 *MHz* convex transducer. All the measurements were recorded after at least six hours of fasting and ten minutes rest. The subjects were in the left and right lateral positions and instructed to suspend respiration during measurements. The kidneys were first visualized in the B-mode image. In all the evaluated subjects, there were no changes in the renal position, size, contour, and parenchymal structure [8]. After obtaining an optimum B-mode view, color flow was activated and blood flow was measured under the beam angle under 30°. The authors measured the pulsatility index (*Pi*) and the resistance (*Ri*) index, calculated by original computer software, first in right and then in left *RA* (Figure 1). At least three similar sequential Doppler waveforms were measured. A mean value was calculated from the resistance indices for each kidney and mean intrarenal *Pi* and *Ri* were also calculated [8, 9].

Pregnant women (200) were divided according to pregnancy trimester: 30 women in the first trimester group; 85 in the second trimester group; and 85 in the third trimester group. From the third trimester group, 30 women after delivery were evaluated.

The authors compared the values between the subjects who were not pregnant and pregnant women during the first, second,

and third trimesters of pregnancy and those evaluated at postpartum as well. Correlation of *Pi* and *Ri* with gestational age were also tested and correlation curves were made for both parameters. A comparison was then made between the values of the right and left kidneys and between intrarenal values in all the groups.

The statistical analysis was performed with the *SPSS* program version 10 (*SPSS INC, Chicago, IL*) using *chi-square* test, one way *ANOVA,* followed by post-hoc, and two-tailed Pearson and Spearman correlation. The difference was considered to be significant if $p < 0.05$.

All the measurements were performed by two of the most experienced investigators (VM and MD) and calculated intraobserver and interobserver reproducibility by using intraclass correlation coefficient – *RI*. The agreement was considered acceptable from a clinical point of view when *RI* value was ≥ *0.60*.

Results

There were no significant differences between the groups in the maternal age ($t = 0.364$; $p > 0.05$) and parity ($\chi^2 = 4.486$; $p > 0.05$). Both systolic ($F = 1.989$, $p < 0.05$) and diastolic ($F = 2.704$, $p < 0.01$) blood pressure were significantly lower in third trimester group (Table 1).

The authors did not find significant difference in the values of *Pi* of the right ($F = 1.4$, $p > 0.05$) and left kidneys ($F = 0.327$, $p > 0.05$), nor the mean intrarenal *Pi* ($F = 0.62$, $p > 0.05$) and *Ri* of the right ($F = 0.603$, $p > 0.05$) and left kidneys ($F = 1.578$, $p > 0.05$), nor the mean intrarenal *Ri* ($F = 1.415$, $p > 0.05$) among the pregnant, non-pregnants and post-partal groups. There were no difference between the values of *Pi* ($t = 0.948$; $p > 0.05$) and *Ri* ($t = 1.389$; $p > 0.05$) in the right and left sides, Table 2.

The authors did not observe the presence of correlation between mean values of evaluated parameters and parity (*Pi*, $r = -0.181$, $p > 0.05$; *Ri*, $r = -0.230$, $p > 0.05$), maternal age (*Pi*, $r = -0.054$, $p > 0.05$; *Ri*, $r = 0.043$, $p > 0.05$), nor the values of systolic (*Pi*, $r = -0.098$, $p > 0.05$; *Ri*, $r = -0.086$, $p > 0.05$) and diastolic blood pressure (*Pi*, $r = -0.059$, $p > 0.05$; *Ri*, $r = -0.184$, $p > 0.05$).

Furthermore the authors did not observe correlation between the values of mean intrarenal *Pi* ($r = -0.096$, $p > 0.05$) and *Ri* ($r = -0.113$, $p > 0.05$) with the gestational age (Figure 2).

Interobserver variability was good for both *Pi* and *Ri* (*Pi* – 0.69; *Ri* – 0.68). Intraobserver variability was also good for both *Pi* and *Ri* (*Pi* – 0.62; *Ri* – 0.63). Thus, both interobserver and intraobserver reproducibility of blood flow measurements were clinically acceptable in this study.

Discussion

Doppler examination of the renal circulation has proved to be useful in assessing kidney failure. Factors that must be taken into account when assessing renal circulation are: age, acute renal failure, obstruction of renal pelvis, extrarenal compression, low diastolic blood pressure, bradycardia, and interstitial scarring. Comparable values are obtained only when arteries of equal order are sampled [6, 10].

The authors considered justified the choice of assessing RA in the hilus, as hilar blood flow reflects downstream flow, and Ri is an index of the kidney's peripheral arterial resistance. Although intrarenal arteries are significant in the evaluation of parenchymal blood flow, the authors chose the RA as there is no significant variation in vascular resistance among different branches of the renal circulation [10]. Furthermore, the authors did not experience any technical problems during ultrasound surveys, although the subjects were pregnant, the majority being in the second and third trimester. The physiological pyelectasies were discarded, as they do not influence renal blood flow [11].

The authors measured renal blood flow by using Ri. In all other studies, Ri were measured [3, 5-7, 11-17], but also peak systolic and end-diastolic velocities, acceleration time, and systolic acceleration [6, 17]. Although the measurement of different parameters is certainly superior to measurement of only one parameter, the authors chose the Ri because it is more reliable as Doppler beam angle may vary in different measurements [9, 10].

Furthermore, the authors did not find any difference in *Pi* and *Ri* between the right and the left kidneys, and therefore decided to introduce mean intrarenal parameters. In

Table 1. — *Maternal age, parity, and systolic and diastolic arterial blood pressure in the groups of non-pregnant, pregnant women during first, second, and third trimesters, and after delivery*.

	Non-pregnant n = 40	First trimester n = 30	Second trimester n = 85	Third trimester n = 85	After delivery n = 30 (%)
Maternal age (years)	29.90 ± 6.172	27.95 ± 9.064	27.51 ± 6.005	27.98 ± 7.505	29.23 ± 6.637
Parity - nulipara		13 (43.3 %)	42 (49.4%)	39 (45.9%)	14 (46.7%)
Systolic blood pressure *(mmHg)*	113.30 ± 13.10	111.55 ± 13.19	108.96 ± 13.49	104.90 ± 14.23*	107.74 ± 12.89
Diastolic blood pressure *(mmHg)*	76.500 ± 6.228	76.250 ± 7.684	73.207 ± 7.649	71.012 ± 8.573§	72.26 ± 9.384

* - $p < 0.05$; § - $p < 0.01$

Table 2. — *The renal artery pulsatility and resistance indices in the right and left kidneys and mean intrarenal values in the groups of non-pregnant and pregnant women during first, second, and third trimesters and after delivery*.

	RA Pi			*RA Ri*		
Group	Right kidney	Left kidney	Mean intrarenal value	Right kidney	Left kidney	Mean intarenal value
Non-pregnant n = 40	1.031 ± 0.140	1.026 ± 0.113	1.028 ± 0.117	0.605 ± 0.081	0.594 ± 0.073	0.601 ± 0.066
First trimester n = 30	1.049 ± 0.156	1.031 ± 0.135	1.037 ± 0.141	0.622 ± 0.083	0.615 ± 0.063	0.619 ± 0.068
Second trimester n = 85	1.048 ± 0.133	1.032 ± 0.14	1.040 ± 0.12	0.623 ± 0.062	0.622 ± 0.063	0.624 ± 0.053
Third trimester n = 85	1.000 ± 0.155	1.011 ± 0.140	1.001 ± 0.137	0.616 ± 0.060	0.607 ± 0.055	0.609 ± 0.050
After delivery n = 30	1.048 ± 0.175	1.031 ± 0.145	1.040 ± 0.151	0.611 ± 0.073	0.608 ± 0.055	0.610 ± 0.058

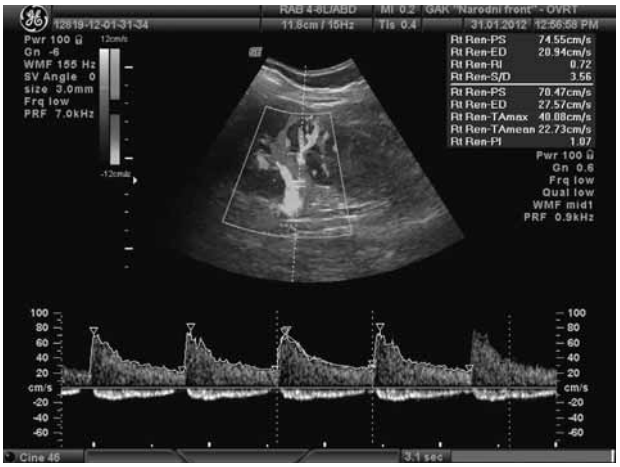

Figure 1. — Doppler waveform of the renal artery.

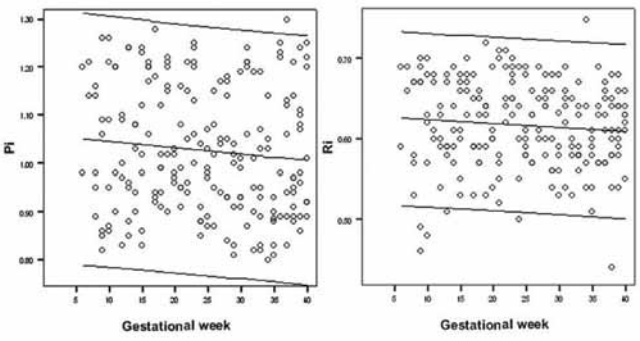

Figure 2. — Correlation between renal artery Pi and Ri values and gestation.

healthy subjects, the *Ri* values will show only minimal difference within one kidney and between kidneys [8-10]. Previous studies confirmed that there was no difference in Ri between the right and left sides [11-14] and mean intrarenal parameters were also used by other authors [11, 13]. The authors considered justified the calculation of mean values, as only healthy subjects with normal renal function were evaluated and the conditions that could change renal blood flow would potentially influence both kidneys. Evaluation of renal circulation may be done by measuring intrarenal values or only by measuring the right side which may be preferred for technical convenience.

The authors did not find correlation between the RA, Ri with the values of systolic and diastolic blood pressure, which is in accordance with the results of previous studies [15]. The absence of correlation between blood pressure and Ri may be explained by the fact that the values of blood pressure do not influence the vessel impendance.

The results in the present study show that there is no significant difference between *Pi* and *Ri* values during pregnancy and the values of non-pregnant women and women after delivery. These results are similar to the results of many previous studies [3, 7, 12-14, 16]. The majority of these studies evaluated a small number of participants, mostly in late second and third trimesters, and they mixed normal and hypertensive pregnancies, while this study evaluated 200 normal pregnancies [3, 7, 13-14, 16]. The only study that assessed a significant number of subjects (n = 338) included only women at 21-24 weeks gestation [12]. The current study is instead the first that includes pregnant women in all gestational weeks including women after delivery.

Inter- and intra-observer reproducibility was good for both *Pi* and *Ri*. This is contributed by the fact that the two most experienced investigators performed all the exams. Other studies emphasize that operator experience is the most important in obtaining reliable results [17, 18].

Concerning the given results, a question could be raised, why the values of Ri are unchanged during pregnancy. In all the other evaluated maternal circulations, beginning from uterine, decreased Ri that are the result of intense arteriolar vasodilatation are observed and they are essential for the successful pregnancy outcome [19]. Along with the uterus, the kidney is the organ with the highest blood flow during pregnancy, as plasma volume is increased by 60%-80% and significant decrease of Ri throughout the gestation could be expected [1]. The absence of these changes may be explained by normal increase of glomerular filtration rate (GFR) which increases up to 50% from the sixth gestational week [1, 2]. GFR depends upon glomerular capillary pressure which is the product of the glomerular blood flow and glomerular resistance. Glomerular blood flow reflects renal blood flow and depends upon the afferent arteriole (pre-glomerular) tone that depends upon arterial blood pressure. Glomerular resistance depends upon efferent arteriolar tone. An increase of glomerular capillary pressure and GFR is achieved by the vasodilatation of afferent and moderate vasoconstriction of efferent arteriole vessels, while severe vasoconstriction of efferent vessels causes reduced glomerular filtration [20]. Therefore, unchanged total vascular resistance in normal pregnancy might be the result of physiological hyperfiltration especially during the first and second trimesters. Decreased tonus of the afferent and increased tonus of the efferent arterioles may be under the influence of hormones during pregnancy, predominantly progesterone, along with the influence of local factors.

The authors may conclude that during pregnancy, maternal renal circulation undergoes no significant changes in relation to the values of renal pulsatility and resistance indices. Unchanged total vascular resistance could be the increased tonus of efferent arterioles. Evaluation of renal circulation may be expressed in intrarenal mean pulsatility and resistance indices, or by Doppler measuring only in the right kidney.

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