HOW PREGNANCY AFFECTS BLOOD FLOW IN THE KIDNEYS: A DOPPLER ULTRASOUND STUDY

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ABSTRACT

Background: During pregnancy, the kidneys undergo significant physiologic and hemodynamic adaptations, such as increased renal blood flow and GFR. Renal Doppler ultrasonography is a non-invasive and reliable tool for monitoring these changes through measurements of some parameters like Resistive Index (RI) and Pulsatility Index (PI). But there are not enough regional data on trimester-specific changes of these indices especially in low and middle income countries, like Pakistan. **Objective**: This study was designed to investigate and compare parameters of Doppler ultrasound of renal arteries (RI and PI) in pregnant women in all trimesters, non-pregnant women, find local reference values and examine the changes in these parameters during pregnancy. **Method**: A cross sectional analytical study was done among 200 women (148 pregnant and 52 non-pregnant) at THQ Hospital Sabzazar, Lahore. Convenience sampling was used for the recruitment of participants. The Doppler measurement of the renal blood flow was performed using a Canon Xario 100 G ultrasound machine equipped with convex probe 3.5 MHz. Independent sample t-tests were used to compare pregnant and non-pregnant groups and one-way ANOVA was used to show differences between pregnancy trimesters. P value of < 0.05 was taken as significant. **Results**: The values of RI and PI were significantly lower in pregnant women than in non-pregnant women for both kidneys ($p < .05$). Right RI was higher in non-pregnant women ($M = 0.63$, $SD = 0.05$) compared to pregnant women ($M = 0.59$, $SD = 0.05$), $t(198) = 3.10$, $p = .002$, Cohen's $d = 0.60$. Similar significant increases were observed for Right PI ($p = .026$), Left RI ($p = .006$), and Left PI ($p < .001$). In the trimesters, there were fluctuations but these were not statistically significant, so it did not show a consistent and progressive increase in vascular resistance with increasing gestation in this sample. **Conclusion**: The findings confirm that renal artery Doppler indices RI and PI significantly declined during pregnancy, with notable differences across trimesters. The changes are indicative of physiological adaptations and emphasize the need to have local reference values for correct interpretation.

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INTRODUCTION

Renal Doppler ultrasonography has been conceptualized as one of the most powerful non-invasive imaging techniques that determine hemodynamics especially in physiological conditions such as pregnancy. It provides real-time assessment of renal blood flow and vascular resistance, which is significant with essential parameters i.e. Resistive Index (RI) and Pulsatility Index (PI). The indices are highly specific to the renal vascular resistance and perfusion and greatly helpful in drawing the line between normal and diseased states[1]. During pregnancy, maternal renal physiology starts to change substantially with an increase in the renal blood flow, contributing to the renal perfusion, and the elevated flow of glomeruli (GFR), to a corresponding change in vascular tone brought about by hormonal changes. These are the necessary adaptations that guarantee both the body fluid balance and fetal growth[2]. The detailed reproduction of renal changes during pregnancy is well-known, a problem of differentiation between the normal physiological and pathological alterations still exists (obstructive uropathy, hypertensive disorders, etc.). For example, physiological hydronephrosis, especially common in the second and third trimesters, is difficult to differentiate from pathological dilation on grayscale ultrasound alone. In this context, Doppler ultrasound becomes particularly relevant, allowing clinicians to evaluate functional parameters rather than relying solely on structural imaging[3].

While international studies have investigated renal Doppler indices across different gestational stages, their findings remain inconsistent. Some research has demonstrated increased RI and PI during pregnancy, particularly in the later trimesters, due to rising intra-abdominal pressure and systemic vascular changes[4]. Others, however, found minimal or non-significant differences between pregnant and non-pregnant women, often attributing this to hormonal or individual variability in vascular response[5]. Furthermore, differences have also been observed between the left and right kidneys, with right-sided changes being more pronounced likely due to anatomical and mechanical factors such as uterine pressure on the ureter and renal vasculature[6].

The absence of localized reference data and unavailability of advanced diagnostic protocol in low- and middle-income countries such as in Pakistan further stratifies the prenatal care. It is common practice to base these clinical practices on international standards and guidelines, so they may not incorporate optimal regional physiology, or local population-adaptation[3,4]. This deficit gives rise to the importance of local research, on the renal Doppler parameters of the local population, where ethnic, anatomical, and systemic aspects that may affect the accuracy of the diagnosis might be considered[4,7].

Also, bearing in mind that Doppler ultrasound is increasingly being used in obstetric care, there is a strong need to come up with trimester-based reference values of renal doppler indices. It does not only improve clinical accuracy but it allows early detection of renal complications with an unfavorable effect on maternal and fetal morbidity and mortality. With the distinction between the physiological adaptations and pathology, healthcare providers will make more informed decisions when conducting prenatal assessments. In light of these considerations, the current study aims to evaluate renal artery Doppler parameters specifically RI and PI in normal healthy pregnant women across all three trimesters and compare them with values in non-pregnant women. The goal is to generate baseline data relevant to the local population that could contribute to improved diagnostic interpretation, prenatal care, and overall maternal health services in Pakistan.

Materials and Methods

Study Design

A hospital-based analytical cross-sectional study was conducted to compare renal Doppler ultrasound indices between pregnant and non-pregnant women.

Study Setting and Duration

The study was conducted at the Outpatient and Antenatal Departments of THQ Hospital Sabzazar, Lahore.

Study Population

The study population comprised healthy women aged 20–40 years attending the outpatient and antenatal clinics of THQ Hospital Sabzazar, Lahore.

Eligibility Criteria

Inclusion Criteria

Healthy women aged 20–40 years, including both pregnant women (at any gestational trimester) and non-pregnant women, were eligible to participate.

Exclusion Criteria

Women with twin pregnancies, fetal anomalies, or a history of renal disease were excluded from the study.

Sample Size

A total of 200 women were recruited using a non-probability convenience sampling technique, including 148 pregnant and 52 non-pregnant women. This sample provided approximately 80% statistical power at a 5% level of significance to detect a moderate standardized difference of approximately 0.45 between the two groups using an independent-samples *t*-test. The unequal group allocation reflected the higher availability of pregnant women in the antenatal department during the study period. The pregnant participants were further classified according to the first, second, and third trimesters for subgroup comparisons.

Sampling Technique

Non-probability convenience sampling technique,

Data Collection Procedure

Data were collected using a structured proforma that recorded participants' demographic and clinical characteristics, including age, pregnancy status, gestational trimester, and other relevant clinical information. Renal Doppler ultrasonography was then performed using a Canon Xario 100 G ultrasound system equipped with a 3.5 MHz convex transducer. All examinations were conducted by trained sonographers following a standardized scanning protocol. The Resistive Index (RI) and Pulsatility Index (PI) of both kidneys were measured and recorded as the primary outcome measures. Before data collection, the study objectives and procedures were explained to all participants, and written informed consent was obtained. Participants were assured that their participation was voluntary and that all information would be kept confidential and used solely for research purposes. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and institutional ethical guidelines.

Data Analysis

Data were analyzed using IBM SPSS Statistics version 26. Descriptive statistics were used to summarize participant characteristics. The independent samples t-test was applied to compare Doppler indices between pregnant and non-pregnant women, while one-way analysis of variance (ANOVA) was used to compare measurements across different pregnancy trimesters. A two-tailed p-value < 0.05 was considered statistically significant.

RESULTS

A total of 200 participants were included in the final analysis. Demographic characteristics of the sample are summarized in Table 1. The mean age of participants was 27.24 years (SD = 3.70). Among the total, 74% (n = 148) were pregnant women, while 26% (n = 52) were non-pregnant. The pregnant participants were equally distributed across the three trimesters, with 25% in the first trimester, 25% in the second trimester, and 24% in the third trimester. To assess the impact of pregnancy on renal artery Doppler parameters, independent sample t-tests were conducted to compare Resistive Index (RI) and Pulsatility Index (PI) values between pregnant and non-pregnant groups. The results revealed significantly lower RI and PI values in pregnant women across both kidneys. Specifically, the Right RI was significantly lower in pregnant women (M = 0.59, SD = 0.05) compared to non-pregnant women (M = 0.63, SD = 0.05), $t(198) = 3.10$, $p = .002$, Cohen's d = 0.60. Similarly, Right PI was lower in the pregnant group ($p = .026$), as were Left RI ($p = .006$), similar results were observed for Left PI showing the largest effect size (Cohen's d = 0.70, $p < .001$) (Table 2).

Further analysis using one-way ANOVA was conducted to evaluate differences in Doppler indices across the three pregnancy trimesters. The analysis revealed no statistically significant difference in Right RI across trimesters, although values showed slight variation from the first trimester (M = 0.62, SD = 0.06), second trimester (M = 0.61, SD = 0.06), to the third trimester (M = 0.62, SD = 0.06), $F(2, 145) = 1.23$, $p > .05$, $\eta^2 = .02$. Similarly, Right PI increased slightly from the first (M = 3.95, SD = 0.91) to the third trimester (M = 4.03, SD = 0.06), but the difference was not statistically significant, $F(2, 145) = 0.66$, $p > .05$, $\eta^2 = .01$. For the left kidney, Left RI values remained relatively stable across trimesters—first (M = 0.61, SD = 0.06), second (M = 0.60, SD = 0.07), and third (M = 0.62, SD = 0.06)—with no significant difference, $F(2, 145) = 1.08$, $p > .05$. Left PI showed a small fluctuation (first trimester: M = 1.40, SD = 0.64; second: M = 1.23, SD = 0.43; third: M = 1.31, SD = 0.37), but this too was not statistically significant, $F(2, 145) = 2.05$, $p > .05$, $\eta^2 = .03$ (Table 3).

Table 1: Demographic Characteristics of the Study Sample (N = 200).

Sample	*Categories*	*f (%)*	*Mean ± SD*
Age in years			27.24 ± 3.70
Pregnancy Status	Pregnant	148(74%)	
	Non-Pregnant	52(26%)	
Trimester	First Trimester	50(25%)	
	Second Trimester	50(25%)	
	Third Trimester	48(24%)	

Table 2: Comparison of Renal Artery Doppler Parameters Between Pregnant and Non-Pregnant Women (N=200).

Measures	Pregnant (148)		Non-Pregnant (52)		*t(198)*	*p*	*Cohen's d*
	M	*SD*	*M*	*SD*			
Right RI	0.59	0.05	0.63	0.05	3.10	.002	0.60
Right PI	1.20	0.28	1.45	0.30	2.25	.026	0.45
Left RI	0.60	0.05	0.64	0.06	2.80	.006	0.55
Left PI	1.25	0.30	1.50	0.35	3.55	.000	0.70

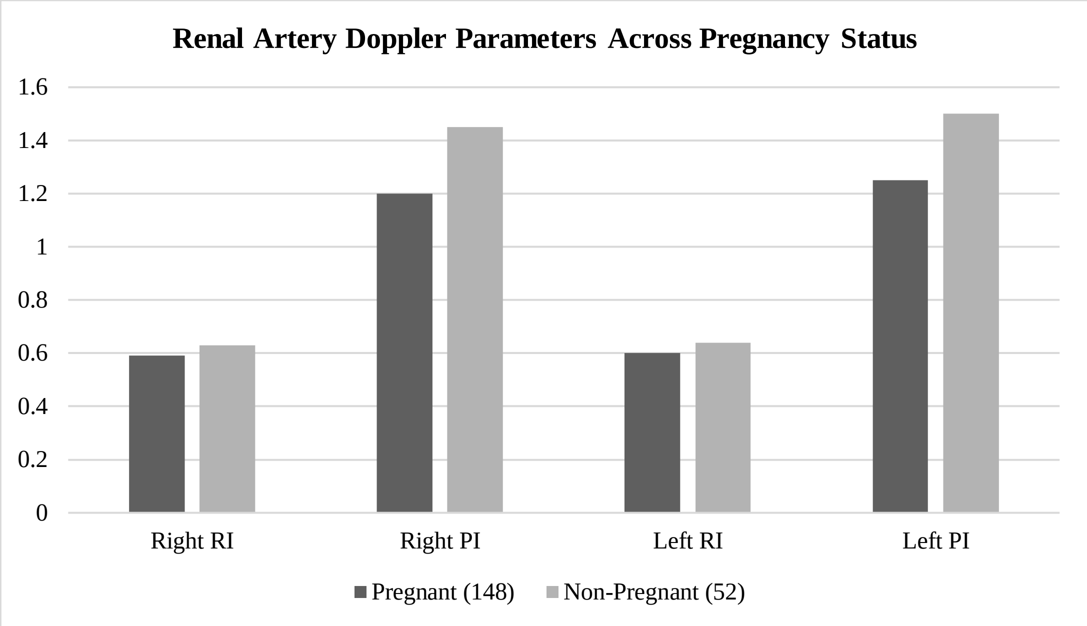

Figure1. *Comparison of Renal Artery Doppler Parameters Between Pregnant and Non-Pregnant Women.*

Table 3: Mean, Standard Deviation, and One-Way Analysis of Variance in Renal Artery Doppler Parameters (RI and PI) Across Pregnancy Trimesters (N=148).

Measures	1st Trimester (n = 50)		2nd Trimester (n = 50)		3rd Trimester (n = 48)		*F (2, 145)*	η^2
	M	*SD*	*M*	*SD*	*M*	*SD*		
Right RI	0.62	0.06	0.61	0.06	0.62	0.06	1.23	.02
Right PI	3.95	0.91	4.03	0.06	1.26	0.35	.66	.01
Left RI	0.61	0.06	0.60	0.07	0.62	0.06	1.08	.05
Left PI	1.40	0.64	1.23	0.43	1.31	0.37	2.05	.03

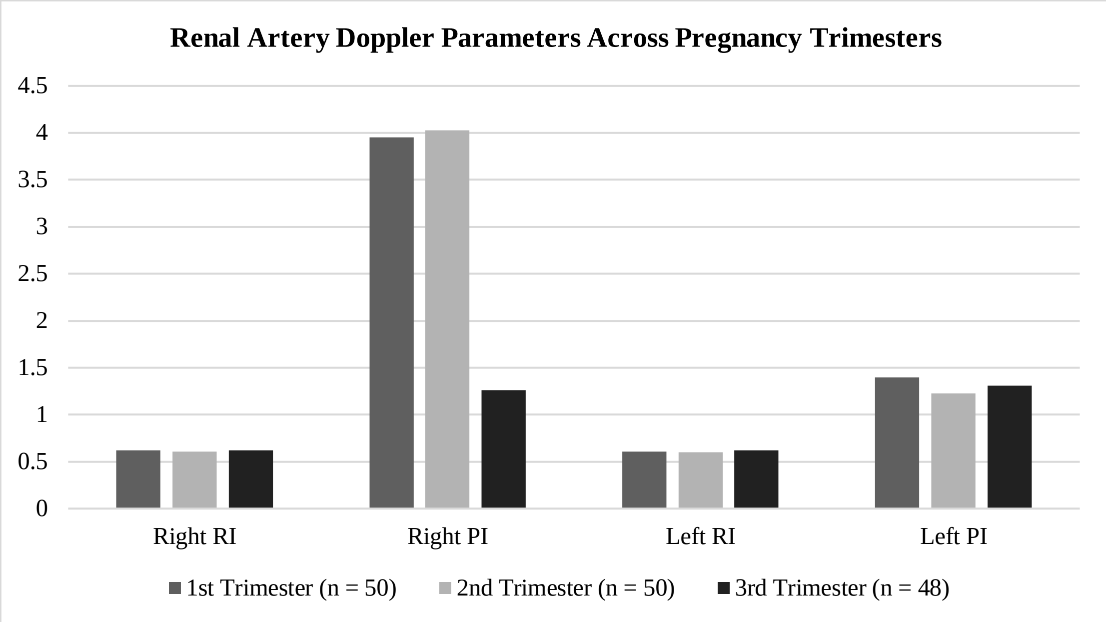

Figure2. Comparison of Renal Artery Doppler Parameters Across Pregnancy Trimesters

DISCUSSION

Pregnancy brings notable changes to renal morphology and function, primarily driven by increased blood volume, hormonal fluctuations, and mechanical effects from the enlarging uterus[8]. The findings of this study showed significantly lower value of Resistive Index (RI) and Pulsatility Index (PI) in pregnant women than in non-pregnant women. The results are in line with literature, which indicates that progesterone and relaxin hormones mediate systemic vasodilation and enhanced renal blood flow as a result of pregnancy, causing an increase in impedance in renal vessels.[9,10] A drop in resistance and pulsatility indices is due to adaptive changes to cope with a higher plasma volume and to provide adequate perfusion for the mother and the fetus. Interestingly, these findings differ from some previous studies which reported increased RI with increasing gestation, suggesting population, or methodological differences. [11]. The consistently lower values in the pregnant group highlight the need for physiological interpretation of renal Doppler in prenatal assessment and the need to be aware that these changes are not necessarily pathological.

One of the most important findings in our study was the stability of the overall RI and PI values throughout the three trimesters of pregnancy, with no statistically significant difference found between any of the trimesters for either of the kidneys. In healthy pregnancies, small differences between the values of Left PI and Right PI were seen in the third trimester, but these were not statistically significant indicating there is a relatively stable renal vascular resistance throughout gestation. This is in contrast to previous reports of a gradual rise in RI during gestation, and differs from studies that noted little change.[12,13] The differences could be attributed to methodological variations, sample size, differences in gestational age distribution, and/or to physiological variations depending on the geographical location. However, no significant side-wise differences were found in Doppler indices as physiological hydronephrosis is more commonly seen on the right side due to anatomical factors like the dextrorotation of the uterus and compression of the right ureter.[14,15] This indicates that renal vascular resistance is symmetrically regulated during uncomplicated pregnancies and that the functional Doppler parameters are not significantly affected by anatomical asymmetry. Findings of our study are also consistent with the literature that underlines the necessity of establishing population-specific reference norms for renal Doppler measurements. Very few studies emphasized the importance of regional differences in both vascular physiology and hormone response and the diagnostic criteria that may affect the interpretation of renal indices.[16,12] Relying on international reference ranges may misinterpret normal pregnancy related hemodynamic changes in resource limited settings like Pakistan. In addition, the variation in estrogen and progesterone levels during gestation has been established to alter vascular compliance and renal blood flow but also promote interindividual variability in Doppler parameters.[15] Although Doppler ultrasonography is a useful supplementary imaging modality in obstetrics, its interpretation must be placed into the context of physiological changes associated with pregnancy instead of pathologies when no other clinical finding supports it.[17,18]

Moreover, our results highlight for the need of trimester and population–specific Reference ranges for renal Doppler parameters. In locations like Pakistan, where such normative data are scarce, reference values used based on other populations may create misleading results. As discussed previously, measuring GFR and SCr throughout pregnancy with Doppler parameters can improve the accuracy of obstetric diagnosis.[2] Localized reference standards could therefore be pivotal in facilitating the improvement of prenatal renal evaluation, early identification of complications and ultimately improved maternal-fetal outcomes.

CONCLUSION

The clinical relevance of these findings is that they are quite profound. Study results describe the decreased RI and PI of pregnant women as physiological vasodilation and improved perfusion of the kidney, which are essential for establishing fluid homeostasis and fetal growth and development. Nevertheless, such normal variations might be misleadingly interpreted as pathological conditions, should deviations be considered beyond the reference values that are specific to the population. Derivation of trimester-specific Doppler reference ranges that are population specific would assist the clinician in distinguishing between normal adaptation and possible renal sequela, including preeclampsia or obstructive uropathy. This would increase the efficiency of prenatal kidney screening results and direct early action.

Limitations

Whereas the study has its contributions, it also has limitations. It can also be said the cross-sectional design used and the convenience sample of a single hospital may restrict the generalization of the findings. Such absence of biochemical markers, as serum creatinine or GFR limited the development of renal functioning during the study. Also, inter-observer variability in the measurement of the Doppler was not studied and it may be an issue to determine the consistency of the measurements.

Recommendations

To confirm these results, future studies should take into consideration multi-center, longitudinal studies and more and diverse sample sizes. Biochemical parameters could also provide an even greater picture of maternal renal health in addition to Doppler indices. Moreover, the specific reference standards during the trimesters and improvement of sonographer education may enhance the interpretation in clinical practice and lead to improved maternal-fetal outcomes in such countries as Pakistan.

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