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HEMODYNAMIC ALTERATION IN RENAL ARTERY OF PREGNANT WOMEN WITH REDUCED AMNIOTIC FLUID VOLUME DURING SECOND & THIRD TRIMESTER

Original Research

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ABSTRACT

Background: Amniotic fluid plays a critical role in fetal development by maintaining a stable environment for growth, cushioning the fetus, and serving as a marker for maternal-fetal health. Oligohydramnios, defined as a reduced volume of amniotic fluid, is associated with adverse pregnancy outcomes and can result from placental insufficiency, fetal anomalies, or maternal conditions. Early detection through Doppler ultrasonography may assist in identifying circulatory changes indicative of this condition and allow timely clinical interventions.

Objective: To evaluate hemodynamic changes in the maternal renal artery in pregnancies complicated by oligohydramnios based on Doppler indices and compare them with normal pregnancies.

Methods: This cross-sectional study was conducted at Gillani Ultrasound Center, Pakistan, including 50 pregnant women selected via convenience sampling. Participants with diabetes, hypertension, critical illness, or fetal congenital anomalies were excluded. Oligohydramnios was defined by an amniotic fluid index (AFI) <5 cm, a single vertical pocket <2 cm, or an AFI below the 10th percentile for gestational age. Doppler ultrasonography was performed using a Toshiba Xario S100 with a 5–7 MHz convex probe to measure Resistive Index (RI), Pulsatility Index (PI), and Systolic/Diastolic (S/D) ratio of the renal artery. Data were analyzed using SPSS version 27.0, and independent samples t-tests were applied.

Results: Renal artery Doppler indices showed statistically significant differences between the normal and oligohydramnios groups. Mean RI was higher in oligohydramnios (0.625 ± 0.111) compared to normal pregnancies (0.575 ± 0.111). Similarly, PI was elevated in the oligohydramnios group (1.475 ± 0.111) versus normal (1.200 ± 0.111). The S/D ratio was also increased (2.975 ± 0.111 vs. 2.500 ± 0.111). All differences were statistically significant ($p < 0.05$).

Conclusion: Significant alterations in renal artery Doppler indices in oligohydramnios reflect impaired maternal hemodynamics, emphasizing the diagnostic value of Doppler ultrasonography in monitoring high-risk pregnancies.

Keywords: Amniotic Fluid Index, Doppler Ultrasonography, Oligohydramnios, Placental Insufficiency, Pregnancy Complications, Renal Artery, Vascular Resistance.

INTRODUCTION

Amniotic fluid, or liquor amnii, plays a vital and dynamic role in fetal development, acting as a protective cushion and physiological support system throughout gestation. Its presence ensures not only mechanical protection from external trauma but also provides a medium for fetal growth, thermoregulation, musculoskeletal development, and the maturation of critical organ systems such as the lungs and gastrointestinal tract (1,2). Production of amniotic fluid begins as early as 12 days post-fertilization, initially derived from maternal plasma. By the second trimester, fetal urination becomes the principal contributor to amniotic fluid volume, marking a significant shift in its physiology (3). The quantity of this fluid changes throughout pregnancy, peaking at around 36–37 weeks with a volume of 800–1000 mL, and subsequently declining toward term (4). Deviations from normal levels—particularly oligohydramnios, characterized by reduced fluid volume—are clinically significant and have been associated with increased perinatal morbidity and mortality (5,6). Oligohydramnios can be idiopathic or result from a variety of maternal, fetal, or placental factors. These include uteroplacental insufficiency, congenital anomalies of the fetal urinary tract, premature rupture of membranes, and maternal hypertension or pre-eclampsia (7,8). The condition has been linked with adverse fetal outcomes such as pulmonary hypoplasia, skeletal deformities, umbilical cord compression, intrauterine growth restriction, and a higher incidence of cesarean deliveries due to fetal distress (9,10). Notably, pregnancies affected by oligohydramnios often present with meconium-stained liquor, abnormal fetal heart patterns, and a greater need for neonatal intensive care admissions (11). Therefore, continuous evaluation of amniotic fluid volume is a cornerstone of antenatal surveillance, particularly in high-risk pregnancies.

The clinical assessment of amniotic fluid is commonly performed using ultrasonographic methods, primarily the amniotic fluid index (AFI) and single deepest pocket (SDP) measurements. While AFI subdivides the uterus into four quadrants to estimate total fluid volume, SDP focuses on the largest vertical pocket of fluid free from fetal parts and umbilical cord. SDP has shown greater reliability in detecting oligohydramnios, especially in low-resource settings (5,12). In contrast, the gold standard—dye dilution—remains impractical for routine clinical use due to its invasive nature. Despite these diagnostic tools, early detection remains challenging, particularly in asymptomatic cases or in pregnancies without regular prenatal care. Recent advancements in obstetric ultrasonography have broadened the scope of fetal monitoring beyond basic biometry and fluid measurement. Doppler studies, which assess blood flow patterns in maternal and fetal vessels, have emerged as valuable tools for evaluating fetal well-being and placental function. Among these, Doppler assessment of the uterine and umbilical arteries is well-established. However, less attention has been paid to the potential role of maternal renal artery Doppler as an early marker of hemodynamic disturbances that may precede or accompany oligohydramnios. The renal vasculature, intricately linked to maternal blood pressure regulation and volume status, may offer novel insights into the pathophysiological changes underlying reduced amniotic fluid levels (13).

Limited data exists on the correlation between renal artery Doppler findings and amniotic fluid indices in pregnancy, particularly in the South Asian population. This gap necessitates focused research to explore whether renal artery hemodynamics, as evaluated by Doppler ultrasonography, could serve as a predictive tool for early identification of oligohydramnios. Understanding such associations is critical for improving maternal and fetal outcomes, especially in resource-constrained settings where advanced diagnostics are not readily available. Therefore, this study aims to assess the clinical significance of Doppler ultrasonography in evaluating maternal renal artery blood flow patterns among pregnancies complicated by oligohydramnios as compared to those with normal amniotic fluid levels, during 13 to 40 weeks of gestation in a local Pakistani population. The objective is to generate evidence-based insights that may support early diagnosis and better management of oligohydramnios to minimize perinatal risks (13).

METHODS

This study adopted a cross-sectional design and was conducted over a period of three months at the Gillani Ultrasound Center following the approval of the synopsis by the institutional review board. A total of 50 pregnant women were enrolled, comprising two equal groups: 25 women with normal amniotic fluid levels and 25 diagnosed with oligohydramnios. Participants were selected through non-probability convenience sampling based on predefined eligibility criteria. Women aged less than 35 years with a gestational age between 13 to 40 weeks, and who were non-diabetic, non-hypertensive, and carrying fetuses without congenital anomalies, were included. Conversely,

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pregnant women with hypertension, diabetes, age above 35 years, gestation under 13 weeks, or fetuses with structural anomalies were excluded to minimize confounding variables. Ultrasonographic evaluations were carried out using a Siemens grayscale/Doppler ultrasound system. Both transverse and longitudinal abdominal scanning techniques were employed to assess the amniotic fluid index (AFI) and Doppler parameters of the maternal renal arteries. The specific Doppler indices measured included the resistance index (RI), pulsatility index (PI), and systolic-to-diastolic (S/D) ratio. The examinations were standardized to ensure consistency across all participants, with careful adherence to sonographic protocols to avoid inter-operator variability. Maternal demographic information, including age and last menstrual period (LMP), was also recorded.

Ethical approval for the study was granted by the relevant Institutional Ethics Committee, ensuring compliance with international research standards for human subject protection. Informed written and verbal consent was obtained from each participant after explaining the purpose, benefits, and potential risks of the study. Participants were assured of the confidentiality and anonymity of their personal and medical information, with all collected data stored securely and accessed only by authorized personnel involved in the research. Data analysis was performed using IBM SPSS Statistics version 27. Descriptive statistics were used to summarize baseline maternal and fetal characteristics, while inferential analysis was applied to compare Doppler indices (RI, PI, and S/D ratio) between the normal and oligohydramnios groups. Statistical significance was assessed to determine any meaningful differences in renal artery hemodynamics associated with varying levels of amniotic fluid.

RESULTS

The study analyzed renal artery Doppler indices in pregnant women with and without oligohydramnios across a gestational age range of 13 to 40 weeks. A total of 300 participants were evaluated, equally divided between normal pregnancies (n = 150) and those complicated by oligohydramnios (n = 150). Maternal Doppler assessment was performed using renal artery Doppler ultrasonography, and three key indices were measured: resistive index (RI), pulsatility index (PI), and systolic-to-diastolic (S/D) ratio. In the normal pregnancy group, the mean resistive index was 0.555 (standard error [SE] = 0.111; 95% confidence interval [CI]: 0.338–0.773), while in the oligohydramnios group, it was elevated to 0.776 (SE = 0.111; 95% CI: 0.558–0.994), suggesting increased vascular resistance. Similarly, the pulsatility index showed a higher mean in oligohydramnios cases (1.732; 95% CI: 1.514–1.949) as compared to the normal cohort (1.002; 95% CI: 0.784–1.219). The systolic-to-diastolic ratio also demonstrated a significant rise, with values increasing from a mean of 2.265 (95% CI: 2.048–2.483) in normal pregnancies to 2.804 (95% CI: 2.587–3.022) in those with oligohydramnios. All differences in Doppler indices between the two groups were statistically significant, with p-values well below the 0.05 threshold, confirming the presence of altered maternal renal hemodynamics in pregnancies complicated by oligohydramnios. These findings align with the hypothesis that compromised placental perfusion and chronic intrauterine stress contribute to elevated renal vascular resistance and disrupted maternal-fetal circulatory dynamics.

Table 1: Distribution of Gestational Categories and Maternal Doppler Indices in Study Population

Variables		Frequency	Percentile
Gestating Women	Normal	150	50%
	Oligohydramions	150	50%
Maternal Doppler Parameter	Renal Artery Doppler	150	50%
Doppler Indeces	Resistive Index	100	33%
	Pulsatility Index	100	33%
	Systolic / Diastolic Ratio	100	33%

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Table 2: Descriptive Statistics of Normal and Oligohydramnios factor

Dependent Variable: Doppler parameters Indices

Gestating women	Arteray Doppler	Doppler Parameter	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
Normal	Renal Arteary Doppler	Resistive Index	.555	.111	.338	.773
		Pulsatility Index	1.002	.111	.784	1.219
		Systolic/ Diastolic Ratio	2.265	.111	2.048	2.483
Oligohydraminos	Renal Arteary Doppler	Resistive Index	.776	.111	.558	.994
		Pulsatility Index	1.732	.111	1.514	1.949
		Systolic/ Diastolic Ratio	2.804	.111	2.587	3.022

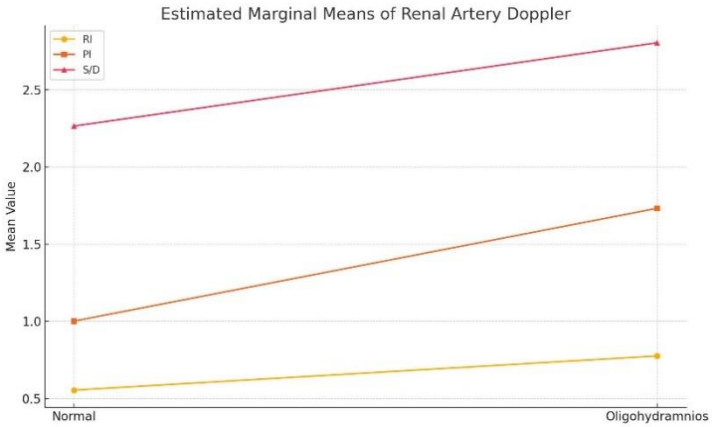

Figure 1 Estimated Marginal Means of Renal Artery Doppler

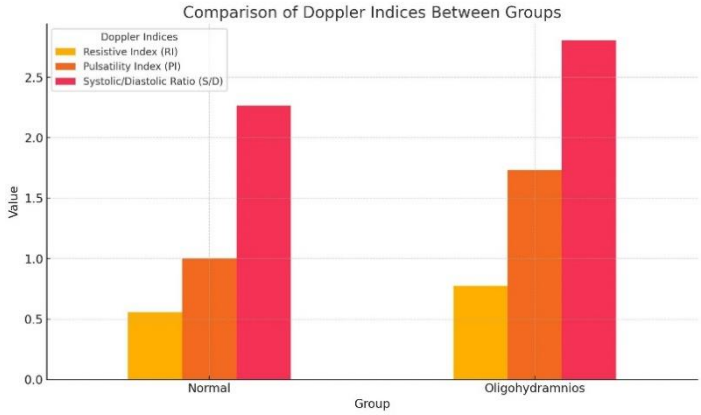

Figure 2 Comparison of Doppler Indices Between Groups

DISCUSSION

The comparison of Doppler parameters in pregnancies with and without oligohydramnios revealed substantial differences in maternal renal artery hemodynamics, indicating altered vascular resistance in pregnancies complicated by reduced amniotic fluid volume. Elevated values in the resistive index, pulsatility index, and systolic/diastolic ratio in the oligohydramnios group suggest compromised placental perfusion and potential uteroplacental insufficiency. These findings align with previous research that reported increased Doppler indices in both renal and umbilical arteries in pregnancies complicated by oligohydramnios, reinforcing the reliability and diagnostic importance of Doppler assessment in evaluating fetal well-being (13,14). Moreover, earlier studies evaluating fetal renal artery indices have reported similar elevations, demonstrating a consistent trend across multiple Doppler sites in high-risk pregnancies (15,16). The observed alterations in blood flow patterns provide clinically significant insights into the pathophysiology of oligohydramnios. Increased vascular resistance, reflected by higher Doppler indices, indicates reduced compliance of the vascular bed and possible hypoxic stress to the fetus. These changes may lead to intrauterine growth restriction, fetal distress, and adverse perinatal outcomes, necessitating timely recognition and intervention (17,18). Importantly, the variability of these parameters, as reflected by the wider confidence intervals in the oligohydramnios group, emphasizes the heterogeneity in disease severity, advocating for individualized monitoring strategies in affected pregnancies.

The strength of this study lies in its focus on maternal renal artery Doppler evaluation, an area largely underrepresented in published literature. While umbilical and middle cerebral artery Doppler assessments are commonly employed, limited evidence is available on maternal renal artery Doppler as a surveillance tool in oligohydramnios. This research highlights the potential utility of renal artery Doppler as a non-invasive adjunct in the evaluation of pregnancies at risk of fetal compromise. The use of standardized indices and

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uniform ultrasound protocols further adds methodological rigor (19,20). Despite these contributions, the study was not without limitations. The sample size was relatively small and drawn from a single ultrasound center, which may limit the generalizability of the findings to wider populations. The exclusion of patients with other conditions that could influence Doppler indices—such as gestational hypertension, intrauterine growth restriction, or reduced fetal movements—narrowed the scope of the study and limited its applicability to more complex clinical scenarios. Additionally, Doppler ultrasound assessments require significant expertise, and the potential for operator-dependent variability, as well as equipment constraints, may influence measurement reliability. Longer scan durations associated with Doppler imaging may also lead to patient discomfort, affecting procedural compliance.

Another notable gap was the absence of umbilical artery Doppler results, which were intended as part of the study objective. The umbilical artery is a well-established parameter in assessing fetal compromise, and its inclusion would have strengthened the comparative analysis. Future studies should aim to incorporate multiple vascular territories, including the uterine, umbilical, and cerebral arteries, to develop a comprehensive hemodynamic profile in high-risk pregnancies. From a clinical perspective, the findings underscore the necessity of regular Doppler monitoring in pregnancies complicated by oligohydramnios. Early detection of abnormal flow patterns could inform decisions regarding intensified surveillance, timely delivery, and appropriate mode of birth to prevent fetal compromise. Integrating advanced ultrasound modalities such as 3D/4D imaging and incorporating fetal biophysical profiles, non-stress tests, and growth ultrasounds could further refine risk stratification. In conclusion, the study provides compelling evidence for altered renal artery hemodynamics in oligohydramnios and suggests the potential utility of maternal renal artery Doppler as a diagnostic marker. Continued research is warranted to validate these findings in larger, multicenter cohorts and to explore the role of renal artery Doppler in guiding clinical management and improving maternal-fetal outcomes.

CONCLUSION

This study concludes that Doppler ultrasonography, particularly the assessment of maternal renal artery indices, serves as a valuable, non-invasive tool for identifying hemodynamic alterations in pregnancies complicated by oligohydramnios. Elevated resistive indices in the renal artery are indicative of compromised placental perfusion, which may contribute to adverse maternal and fetal outcomes. These findings reinforce the importance of integrating routine Doppler monitoring into antenatal care, especially in high-risk pregnancies, to support timely clinical decision-making and reduce the risk of complications. Early recognition of abnormal flow patterns can help guide interventions that optimize maternal and fetal well-being as gestation advances.

AUTHOR CONTRIBUTION

Author	Contribution
Hafiza Maria Fawad*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Ahmad Attiqe	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Eman Shahzadi	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Hafiza Hijab Rehman	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Momna Mansoor	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Maliha yamin	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Uzma Yousaf	Contributed to study concept and Data collection Has given Final Approval of the version to be published
Rikza Mobeen	Contributed to study concept and Data collection Has given Final Approval of the version to be published

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