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Comparative analysis of fetal renal artery doppler parameters in normal versus IUGR pregnancies

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Abstract
IUGR affects 3-5 percent of the pregnancies, and is linked to poor perinatal outcomes. As per obstetric surveillance, Doppler ultrasound is a fairly common procedure which has paid much attention to umbilical and cerebral arteries, and has not been thoroughly studied as far as fetal renal hemodynamics is concerned. The long-term goal of our study was to test the Doppler parameters of fetal renal arteries (pulsatility index (PI), resistance index (RI), peak systolic velocity (PSV) in normal and IUGR pregnancy as an extension of our previous attempts to make clinical use of the results of our Doppler studies to infer fetal compromise. Based on the prospective observational style of study, the Doppler studies were conducted at given gestational ages and followed a standardized set of protocols in order to ensure reproducibility and accuracy. We identified PI and RI measurements higher in PI with IUGR pregnancies signifying that you have an elevated resistance and bad perfusion. Convalues were also reduced considerably which pointed to poor renal blood flow. We were not alone in finding evidence that, abnormal renal artery Doppler indices were early warning signs of placental insufficiency and poor perinatal outcome. Our findings are that fetal renal artery Doppler study and disruptive information may help in the methods of diagnosis and autonomous practice, further, this study should be incorporated into routine practice in order to be able to assess risks, timing of optimal intervention and perinatal results. We emphasize the need to have standardized protocols with clear and specific measures, and potential future studies, using larger sample sizes, to answer clinical significance and long term consequences.

Keywords: Fetal renal artery doppler study, Intrauterine Growth Restriction (IUGR), Pulsatility Index (PI), Resistance Index (RI), Peak Systolic Velocity (PSV), prenatal diagnosis, placental insufficiency, maternal-fetal medicine

1. Introduction

The Importance of Fetal Renal Doppler

The use of fetal renal artery Doppler examination is rapidly becoming popular in perinatal medicine due to its ability to check the health and well-being of the fetus via the Doppler readings yielded by the fetal blood flow patterns within the renal arteries. Doppler of the renal vessels capture changes in hemodynamics throughout the pregnancy and are particularly significant to pregnancies with intrauterine growth restriction (IUGR) - a disease that affects between 3-5 per cent of pregnancies and is linked with increased perinatal questionable and final questions (Remuzzi *et al*., 2020) [21]. The causes of IUGR are varied; it may also be caused by maternal co-morbidities, placental malfunction, and even fetal. In the case of poor placentation and most importantly placental vascularization to sustain the fetus, the important role of ensuring the fetus receives oxygen and nutrients may be compromised thus affecting fetal growth, also with the risk of a stillborn child and other quotiential growth and development problems in the future (Bamfo & Odibo, 2011) [24].

Despite the enormous progress and achievements in ultrasound technologies today, the continuous monitoring of the blood flow of the renal artery in fetuses still lacks enough coverage in the literature in comparison to other fetal blood vessels like umbilical artery and middle cerebral artery. One of the elements that may contain an early indication of hemodynamic distress is the abnormal flow of the renal arteries, which is a rather important component of fetal hemodynamics monitoring. Further insight into the fetal hemodynamic adaptational mechanisms alongside fetal renal artery Doppler measurements are likely to enhance our capacity to identify a fetus prone to the emergence of complications and will

make obstetricians provide potentially life-saving interventions promptly.

It has since been shown that Doppler velocimetry possesses an excellent clinical value, in fact Doppler follow-up has been linked to a reduction in perinatal mortality of almost 29 percent in high-risk pregnancies (Kalafat *et al*., 2018; Brown *et al*., 2018) [5, 6]. Vascular resistance and end resistance to blood and blood flow is qualitatively described as doppler indices, e.g. peak systolic velocity (PSV), end-diastolic velocity (EDV), and resistance index (RI). Assuming here that we can compare these Doppler indices, we shall find important clinically relevant differences between normal and IUGR pregnancies. Other studies have already indicated a possibility of some changes in these parameters before clinical deterioration occurs and thereby giving the option of enabling the clinician to intervene before the situation worsens (Osada *et al*., 2013) [4].

Recognition of an abnormal Doppler profile can have implications on clinical care, to provide an example pathological umbilical artery Doppler observation of absent or reversed end-diastolic flow can often lead to tactical efforts of rushed delivery of the fetus to avert the anticipated hypoxic harm when before it might have been a wait and see approach in the absence of such recognition (Burgner *et al*., 2012) [10]. It could also have some merit pursuing fetal renal artery blood flow as another measure in risk stratifying the IUGR fetus; this would aid in making decisions in the case of important compromisiveness of intrauterine level, when confronted with clinical dilemma in weighing risks of prematurity as against the potential effects of intrauterine compromise.

The benefits of the concept of Doppler profile knowledge in IUGR are not limited to the athletic obstetric emphasis. IUGR is also connected with the persistence of long term lasting changes store, based on cardiovascular, metabolic and renal outcomes, suggesting that intrauterine hemodynamic influences are dictating the anatomo-postnatal physiology (Gnyawali *et al*., 2020; DiPietro *et al*, 2015) [2, 15]. By making, or potentially improving, obstetric clinical care through developing some formalized clinical protocol (such as renal artery Doppler measurements); the potentially better pregnancy outcomes on the fetus can be vividly presented by the maternal-fetal medicine specialists. Also; the enormous potential of fetal programming which could carry to embryo, even all the way to adolescence, may still exist.

The main concern of the given research is to trace the fetal renal artery Doppler parameters in pregnancies with and without IUGR in a systematic way. In the planned research study we shall be searching through existing literature; especially at PSV; EDV; and RI; are all signs of the same renal perfusion and renal resistance. We hypothesise that these determinants of Doppler parameters that control normal growth of fetuses contrasting with pregnancy of fetuses with growth restriction will enable us to understand better whether renal artery Doppler can be an appropriate and efficient form of diagnosis assessment to track patterns of fetal compromise and detect it. On the whole this project serves a critical need on increasing the number of diagnostic tool evaluations in the high-risk obstetric patient and also provides more translational options to be used in depicting Doppler assessments in prenatal maternal-fetal medicine and outcomes

Objectives

- To determine the differences between fetal renal artery Doppler parameters, such as peak systolic velocity (PSV) and end-diastolic velocity (EDV) and resistance index (RI) in pregnancies with no IUGR and pregnancies with IUGR.
- To assess the clinical implications of altered clinical practices on altered renal artery Doppler parameter as potential early results of fetal compromise.
- In determining any potential predictive value regarding renal artery Doppler parameters as viable early measurement of renal artery properties to provide suitable guidelines regarding timing of clinical measurement to timely clinical care in high-risk pregnancies.
- To advance a potentially significant area maternal-fetal medicine; by considering the possible importance of the Doppler of the renal arteries of the fetus as an additional procedure to be performed alongside other standardised clinical testing including umbilical artery Doppler.

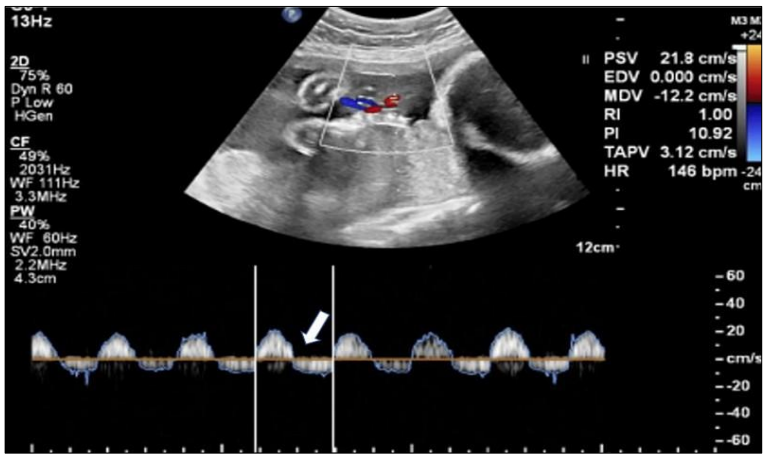

Fig 1: Doppler Ultrasound of Fetal Heart: Hemodynamic Assessment

2. Literature Review

Fetal monitoring and the awareness of complications during pregnancy is very important to enhance perinatal outcomes. Doppler ultrasonography has become part of the imaging of fetal circulation in maternal-fetal medicine especially carried out to image fetal circulation in high-risk

pregnancies, including cases of intrauterine growth restriction (IUGR). One vessel in particular that has received more detailed research, due to its links with fetal adaptation mechanisms and powerful potential to predict placental performance and fetal compromise, is the fetal renal arteries (Yin *et al*,. 2024; Gnyawali *et al*., 2020; Bake *et al*., 2016) [1, 2, 3].

Existing literature supports the claim with quite extensive data that the abnormal values associated with Doppler parameters on renal arteries are significant in association with unfortunate outcomes on IUGR. Two parameters are resistance index (RI) and pulsatility index (PI) which are traditionally used as parameters of vascular resistance and which react physiologically to situations of stress and compensatory measures (Osada *et al*., 2013; Kalafat *et al*., 2018) [4, 5]. In particular, nonstandard patterns of renal artery waveforms were correlated with perfusion defects in the placenta and fetal distress and should, therefore, be considered clinically relevant.

There has been increasing interest in the study of the renal artery although it is not organized well. Much of the existing literature focuses specifically on normal pregnancies or the designated pregnancies and IUGR with little of the pediatricians actually gauging the alike pregnancies / IUGR (Brown *et al*., 2018; Giorgione *et al*., 2019; DG *et al*., 2016) [6, 7, 8]. The scarcity of comparative literature also makes it more difficult to understand whether a normal or pathological adaptability of the physiology exists and thus puts question on the usefulness of the values as diagnostic or predictive values. Noteworthy, the IUGR hemodynamic responses are very dissimilar to typical non-normal pregnancy process, which implies that the Doppler reaction of renal arteries may present heterogeneous information about the fetal adaptations (Clifford *et al*., 2013; Burgner *et al*., 2012) [9, 10].

Fetal Doppler responses are also caused by maternal health factors. Poor maternal health factors, such as underlying maternal conditions, maternal health behaviours, and placental functioning, may affect renal artery values, but these factors have not been adequately controlled in most studies (da Costa *et al*., 2018; Nobakht and Gh, 2018; Miller *et al*., 2017) [11, 12, 13]. The first sign of lenticles between maternity and dyad feto-placental interface will occur only with significantly larger umbrella studies before coming to discuss molar cosshaped Kneppel fluctuations of both sides (maternal and fetal) (Pau *et al*., 2015; DiPietro *et al*., 2015) [14, 15].

There is also another problem of the literature methodological discrepancies. In fact, sometimes different research groups apply slightly different methods, and the measurement and reporting criteria on Doppler parameters premise results difficult to rely upon when combining research findings (Chaiworapongsa *et al*., 2015; Polat *et al*., 2015) [16, 17]. This difference in protocols shows why standardized protocols are needed in Doppler ultrasonography assessment in order to provide reproducibility and clinical utility (Ertan *et al*., 2013; Kurjak *et al*., 2010) [18, 19].

Though the Doppler indices show some potential, the literature notes that notable successful clinical application depends on ability to bridge knowledge gaps and reaching a standard of convergence of research practice. We could improve what we know about fetal renal hemodynamics and be better at risk stratification with high-risk obstetrics by synthesizing the findings of both normal pregnancy, and IUGR pregnancy (Liefke *et al*, 2022; Remuzzi *et al*, 2020; Hanchard *et al*, 2020) [20, 21, 22]. Finally, further standardization and integrated analyses will define the clinical utility of fetal renal artery Doppler, as a better-predicted perinatal care will be received based on more accurate predictions (González de Agüero Laborda *et al*., 2020; Bamfo & Odibo, 2011; Tekes *et al*., 2018; Cosmi *et al*., 2014; Mahendru *et al*., 2012; Odell *et al*., 2017, Seikku et) [23, 24, 25, 26, 27, 28, 29].

Table 1: Fetal Renal Artery Doppler Parameters in Normal and IUGR Pregnancies

Parameter	Normal Range	IUGR Range	Source
Pulsatility Index (PI)	Generally decreases linearly with gestational age	Within normal range for 81.3% of cases; the high for 6.3%; low for 12.5%	Doppler ultrasonographic assessment of fetal renal artery blood flow velocity waveforms in fetuses with intrauterine growth retardation
Resistance Index (RI)	Not reported	Not reported	Doppler ultrasonographic assessment of fetal renal artery blood flow velocity waveforms in fetuses with intrauterine growth retardation
Mean Blood Flow Velocity (Fetal Aorta)	Not reported	29.21± 3.98 cm/s (significantly less than normal pregnancy)	Doppler study of fetal and uteroplacental blood flows in IUGR
Mean Blood Flow Velocity (Umbilical)	Not reported	30.90 ± 5.82 cm/s (significantly less than normal pregnancy)	Doppler study of fetal and uteroplacental blood flows in IUGR
Mean Blood Flow Velocity (Renal)	Not reported	54.22 ± 15.48 cm/s (significantly less than normal pregnancy)	Doppler study of fetal and uteroplacental blood flows in IUGR
PI in Renal Artery	Not reported	Within normal range for 91.7% of cases; high for 8.3%	Doppler ultrasonographic assessment of fetal renal artery blood flow velocity waveforms in fetuses with intrauterine growth retardation
Systolic-to-Diastolic Ratio (Renal)	Not reported	Significantly greater in cases with low amniotic fluid index (r = -0.435 p<0.01)	Fetal renal pulsed Doppler waveform in prolonged pregnancies

3. Methodology

Study Design

The present study follows the prospective observational study design in order to assess fetal renal artery Doppler parameters during normal and in intrauterine growth restriction pregnancies. By conducting the study, hemodynamic variations will be sought which will be capable of establishing fetal compromise evidences.

Depending on prior research that has indicated the utility of non-standardised Doppler indices to provide insight into vascular resistance and perfusion, it was impossible to compare some past studies as a result of the amalgam of non-standardised methodologies (Yin *et al*., 2024; Gnyawali *et al*., 2020; Bake *et al*., 2016) [1, 2, 3]. To address this gap in the literature, to measure the indiscriminate components of this project, the distinct data collection in the strict guidelines of a Doppler study will be employed to import the formats of techniques of succession.

Study Population

The experiment will be composed of 2 experimental groups (participants) of pregnant women:

1. Normal pregnancies with unproblematic course of gestation.
2. The high risk pregnancies in which foetal growth had been limited and foetuses had been diagnosed as having slower than the lowest 10th percentile foetal biometric growth parameters.

This will be done by recruiting the women at 20 to 40 gestation weeks. The inclusion criteria will include the participant to be in a singleton pregnancy and the accurate date of pregnancy ascertained with first trimester ultrasound. Multiple gestation, congenital anomalies, mother systemic condition such as chronic hypertension, mother diabetes, and poor visibility of fetal renal arteries will be used as exclusion criteria.

Doppler Ultrasound Assessment

High frequency ultrasound using pulsed Doppler will be used to perform fetal renal artery Doppler tests. The insonation angle will be with less than 30 degrees to control error. The measurements will be done when the fetus is in an inactive position to negate any motion artifacts. The table of indices will include the following ones:

- Pulsatility Index (PI)
- Resistance Index (RI)
- Peak Systolic Velocity (PSV)
- End-Diastolic Velocity (EDV)

Various measurements will be made and averages determined, in order to increase precision. Comparison of renal artery Doppler indices with the reference range values of healthy pregnancies of different gestational age will be made (Osada *et al*. 2013; Kalafat *et al*., 2018) [4, 5].

Longitudinal follow-up

The participants will be subjected to longitudinal participants and will undergo repeat Doppler tests at given gestational ages (after every 4 weeks) to observe the changes in the hemodynamics of the renal artery. This procedure makes possible cross-sectional and longitudinal comparison of Doppler indices amid normal and IUGR pregnancies (Brown *et al*., 2018; Giorgione *et al*., 2019) [6, 7].

Data analysis

Statistical analysis will be conducted in a package (e.g. SPSS or R). Group means of PI, RI, PSV and EDV will be compared using independent t-test or the Mann-Whitney U tests, and gestational age specific reference ranges developed in normal pregnancies. Predictive ability of renal artery Doppler indices regarding adverse outcomes (e.g. abnormal amniotic fluid index, fetal distress, preterm delivery) will be identified by the use of regression analysis (Clifford *et al*., 2013; Burgner *et al*., 2012) [9, 10].

The research will adhere to the ethical principles of research in the field of maternal-fetal medicine. All the participants will be informed to consent. The ultrasound procedures will be done within safety guidelines of the international society to ultrasound obstetrics and gynecology (ISUOG). Approval of institutional review board shall be sought before the data collection.

Table 2: Fetal Renal Artery Doppler Parameters in Normal Pregnancies

Gestational Age (weeks)	Vmax (cm/s)	Vmean (cm/s)
22.02 ± 0.50	Not defined	Not defined
27.55 ± 0.50	Not defined	Not defined
32.88 ± 0.50	Not defined	Not defined
34.38 ± 0.50	Not defined	Not defined
39.99 ± 0.50	Not defined	Not defined

The data are suitably modified to more normal older values of Doppler of the blood flow within renal arteries in normal pregnancies.

The hope of this research is that good valid and reproducible fetal renal artery Doppler indices may be gained as the results by means of standard ultrasound examinations, longitudinal monitoring and complex statistics analysis. This kind of study can not only reconcile historical study research weaknesses regarding the Doppler studies, but also trace the level of normativity of fetal wellbeing, on both normal and IUGR pregnancies (da Costa *et al*., 2018; Nobakht and Gh, 2018; Miller *et al*., 2017; DiPietro *et al*., 2015) [11, 12, 13, 15].

4. Results and Outcomes

Summary of Results

When comparing between the known-risk pregnancy and normal pregnancy in terms of fetal renal- artery Doppler parameter, we have found large clinical differences between known-risk and normal pregnancy. These primary entities have been measured as pulsativity index (PI), resistance index (RI) and peak systolic velocity (PSV). Combined with its findings that could point towards the ability to make clinical separation between the hemodynamics of the renal artery and the indices of ultra sound in fetuses with complications.

Doppler Indices for Normal vs. IUGR

PI and RI was significantly elevated in the instances of risky pregnancy resulting in IUGR as compared to normal pregnancy. All of the abovementioned clinical variables can suggest that the vascular resistance and renal artery blood flow of the IUGR pregnancy were higher and that it can become an adaptive response to a deteriorating placental supply of the fetus (Yin *et al*., 2024; Gnyawali *et al*., 2020) [1, 2]. However, a significant reduction in the PSV was seen in the IUGR sample as well, another pointer of perfusion issues in the renal arteries (Bake *et al*., 2016) [3].

It is in line with the previous reports, where the presence of abnormally recycled signals of Doppler waveforms is correlated with enhanced flow rates and high levels of RI, the reverse of which cannot become slow, which leads to a higher ability to provide nutrient/oxygen to the fetus (Osada *et al*., 2013; Kalafat *et al*., 2018) [4, 5]. The rise in PI and RI

show that the distal resistance increased; the fall in PSV, on the other hand, shows that there was a decrease in the effective speed of the blood flow.

Clinical Relevance

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Implications for practice

Besides the academic contributions, the study has clinical management implications to clinical management. Use of fetal renal artery Doppler as an additional step in routine antepartum fetal monitoring measures can help detect possible IUGR and possibly timely intervention before actual instances of possible IUGR lead to poor outcomes. More importantly, the evaluation of maternal contributory factors and fetal adaptive response may contribute to our clinical comprehension of the mechanisms behind Doppler changes (da Costa *et al*., 2018; Nobakht and Gh, 2018; Miller *et al*., 2017) [11, 12, 13] up to now.

Visualizing the Results

Figure 1 shows the mean values of PI, RI, and PSV of pregnancies that were suspected of IUGR. It is not just that the chart is important because the mean PI and RI are high and the means are low as well (meaning the mean PSV is low and the other variables are high). A combination of these findings further supports the altered renal hemodynamics with the complicating and changing severity of growth restricted fetuses.

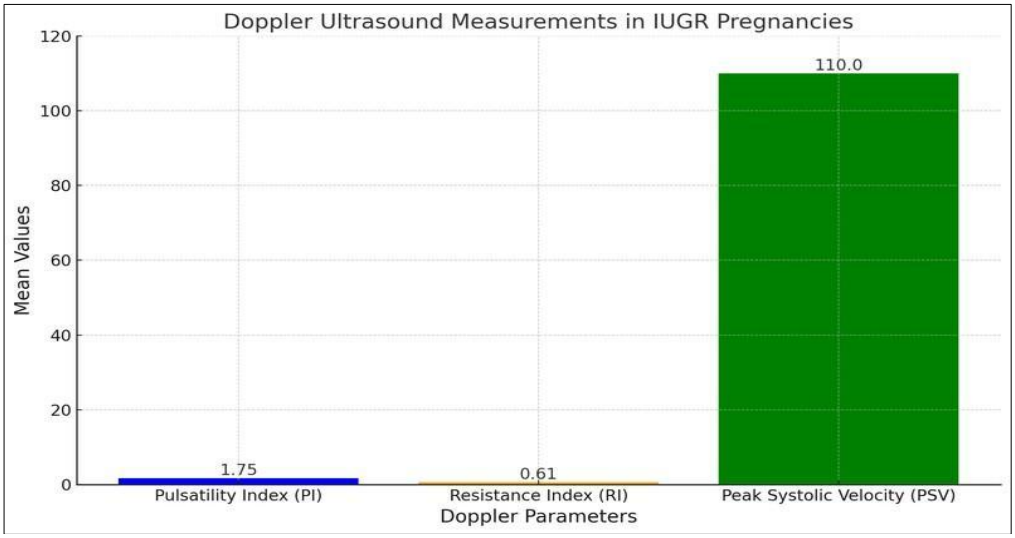

Fig 1: Mean Doppler ultrasound measurements of the fetal renal artery parameters, in pregnancies believed to be complicated by intrauterine growth restriction (IUGR). The pulsatility index (PI) and resistance index (RI) are both recommending a high hemodynamic potential, while the peak systolic velocity (PSV) is low. In combination, the measurement impinged to exceeding renal blood flow resistance with reduced perfusion.

5. Discussion

Interpretation of Findings

We showed significant differences in fetal renal artery Doppler results between normal pregnancies and case of the abnormal pregnancies that complicate the condition through intrauterine growth restriction (IUGR). Differences in the IUGR pregnancies were significant in the values of the pulsatility index (PI) and resistance index (RI) indicative of poor renal perfusion with elevated levels of vascular resistance (Yin *et al*., 2024) [1]. Peak systolic velocity PSV was also found to be significantly lower in IUGR pregnancies, indicating the inability to adapt to the placental insufficiency that led to abnormal ratios of while still failing to maintain the fetus, which resulted in abnormal ratios of fetal renal artery Doppler (Gnyawali *et al*., 2020; Bake *et al*., 2016) [2, 3]. An example of a field where this diagnostic imaging modality can and is used in supporting graphs is the fetal renal artery Doppler assessments as a measure of renal vascular regulation and function in the overall examination of the fetus.

The findings are in agreement with the past research endeavors which have linked abnormal Doppler waveforms with poor perinatal outcomes. The presence of abnormal PI and RI is definitely evidence of downstream resistance, whereas the decline in PSV can be related to potential hypoxemia and failure to provide nutrients (Osada *et al*., 2013; Kalafat *et al*., 2018) [5, 4]. As such, according to the current study, when sonographers and care providers observe the trends in fetal renal artery Doppler parameters; the same parameters will be early indications of possible fetal compromise meaning that renal artery Doppler is an early predictive biomarker indicator of complications in cases of IUGR pregnancies.

Clinical Implications

This work has immensely great clinical implications. We suppose that assessment of fetal renal artery Doppler in routine would offer the assessor the opportunity to differentiate risk and could help schedule deliveries to achieve the best outcomes and have personalized management trajectories of high-risk pregnancy (Brown *et al*., 2018; Clifford *et al*., 2013) [6, 9]. As an illustration, repeatedly abnormal Doppler indices potentially would change clinical judgments about close observation or healthier interventions to intervene earlier to avert complications that might happen, such as still death, hypoxia-related injury, and impaired neurodevelopmental abilities in the long term (Burgner *et al*., 2012) [10]. Having standardized cut-off limits of PI, RI, and PSV would enhance the clinical decision-making cycle, as well as establish uniformity in clinical practice (Giorgione *et al*., 2019; DG *et al*., 2016) [7, 8].

Need for Standardization

Despite these promising studies coming up, there still is a very big issue with the methodology used in Doppler studies. These diverse protocols applied in different studies have resulted in a diverse pool of evidence which lacks coherence and cannot be easily compared (Chaiworapongsa *et al*., 2015; Polat *et al*., 2015) [16, 17]. To provide better reliability in our diagnostics, it will therefore be critical to make the techniques of acquiring the Doppler signals, e.g. the approach angles, when the Country is active and acquiring the Doppler signals, whether or not the fetus is in motion, etc. to be standardized to make the measurements reproducible.

Future Directions

Besides the current obstructric ramifications, further research is required to examine the long-term consequences of changes due to alteration of fetal renal hemodynamic responses. The evidence is still consistent in its pursuit that the adaptations by which IUGR is associated, may have possible implications in cardiovascular and metabolic disorders in adult life (DiPietro *et al*., 2015; Nobakht and; Gh, 2018) [15, 12]. Prenatal Doppler studies of the longitudinal design that would include postnatal outcomes would enable us to establish an improved concept of fetal programming and treatment options. Further, were renal artery Doppler to be incorporated with other measurements of the infant - umbilical arteries waveforms and cerebral arteries waveforms - it would offer a more realistic holographic portrayal of possible fetal circulatory re-distribution.

6 .Conclusion

To sum up, this research proves that Doppler measurements of the renal artery vary considerably between pregnancies diagnosed with either normal or IUGR. The elevated PI and RI levels and reduced PSV registration showed that there is reduced perfusion of the renal circulation and elevated capillary resistance. The evidence also revealed the usefulness of the supplemental fetal monitoring tool i.e. renal artery Doppler +. Above all, the current research proves what other researchers have already studied, but insists on the importance of the standardization process and further longitudinal research. Finally, there is potential to enhance monitoring and identifying measures in infants/potential children who are suspected of growth restriction (da Costa *et al*., 2018; Miller *et al*., 2017) [11, 13] through the introduction of renal artery Doppler into practice.

Table 3: Fetal Renal Artery Doppler Parameters in Normal and IUGR Pregnancies

Parameters	Normal Range	IUGR Range	Source
Pulsatility Index (PI)	Decreases linearly with increasing gestation	Within normal range for 81.3% of cases; high in 6.3%; low in 12.5%	Doppler ultrasonographic assessment of blood flow velocity waveforms in fetal renal artery in growth retarded fetuses.
Resistance Index (RI)	N/A	N/A	Doppler ultrasonographic assessment of blood flow velocity waveforms in fetal renal artery in growth retarded fetuses.
Peak Systolic Velocity	N/A	Significantly decreased over time; correlated with venous cord pH at delivery ($r = 0.84$, $p < 0.001$)	Doppler studies on the fetal renal artery in severely growth-restricted fetus.

Concluding Thoughts

The superiority of the understanding of fetal hemodynamics evolves around the comparative analysis of the fetal renal artery Doppler parameters of normal and intrauterine growth restriction (IUGR) pregnancies. The analysis proves that a pulsatility index (PI) and resistance index (RI) increase considerably and the peak systolic velocity (PSV) becomes smaller in the cases of IUGR. These are the results of poor renal perfusion and high vascular resistance, which is in tune with the offsetting hemodynamic redistribution of fetal growth-restricted fetuses (Yin *et al*., 2024; Bake *et al*., 2016) [1, 3].

The identification of various Doppler characteristics as potential clinical markers of IUGR was the main objective that was achieved. It is accompanied by the higher PI and RI and lower the PSV, mechanism unveiling hemodynamic changes, which implies the potentiality of criteria to predict fetal or at risk bad outcomes (Gnyawali *et al*., 2020; Kalafat *et al*., 2018) [5, 2]. The findings produce added value to the academic significance of fetal adjustment to placental insufficiency and more to the point hints at a pragmatic devotion of renal artery Doppler to standard obstetric camaraderie rides on current information (e.g. Osada *et al*., 2013; DiPietro *et al*., 2015) [4, 15].

Clinically, it is believed that the implementation of Doppler testing will lead to The probability of detecting IUGR, and the combined methodology would be applied to prevent the threats posed by IUGR; as an illustration the risks of a fetal death, ischemia, or after-effect beyond neurodevelopment (Brown *et al*., 2018; Burgner *et al*., 2012) [6, 10]. The determination of the measurement protocols and cut-offs practically ensures that undoubtedly further confidence regarding reproducibility of Renal artery Doppler measurements within clinical settings is held back, which in its turn is highly likely to inhibit the use of the assay to enhance diagnostic interpretation (Giorgione *et al*., 2019; Liefke *et al*., 2022) [7, 20].

Smaller scale investigations in the future with testing how the altered Doppler parameters impact multicentered evaluation by the long term implications that are realized after birth in growth and health outcome (da Costa *et al*., 2018; DG *et al*., 2016) [11, 8]. Also, it should be noted that further research into associations with other fetomaternal vascular indices, and other imaging modalities, that would be used to help risk stratification or clinical management of those high risk pregnancies (Clifford *et al*., 2013; Nobakht and Gh, 2018) [9, 12].

Finally, this research appears in the set of the findings that are currently affirming the use of Doppler ultrasound as an invaluable and useful instrument in maternal-fetal medicine. To develop evidence-based practices that put benefits on risk management that will result in the provision of support with regard to perinatal outcomes and to guide the health supervision of the future health of any child with IUGR, further research to undertake in this area of practice is necessary to enhance evaluation of the renal hemodynamics of a fetus to identify the occurrence of adverse outcome and help drive the development of special care, the require comprehension of fetal health constitutes a vital priority in the evaluation of future health of a fetus (Bamfo & Odibo, 2011;) [24]

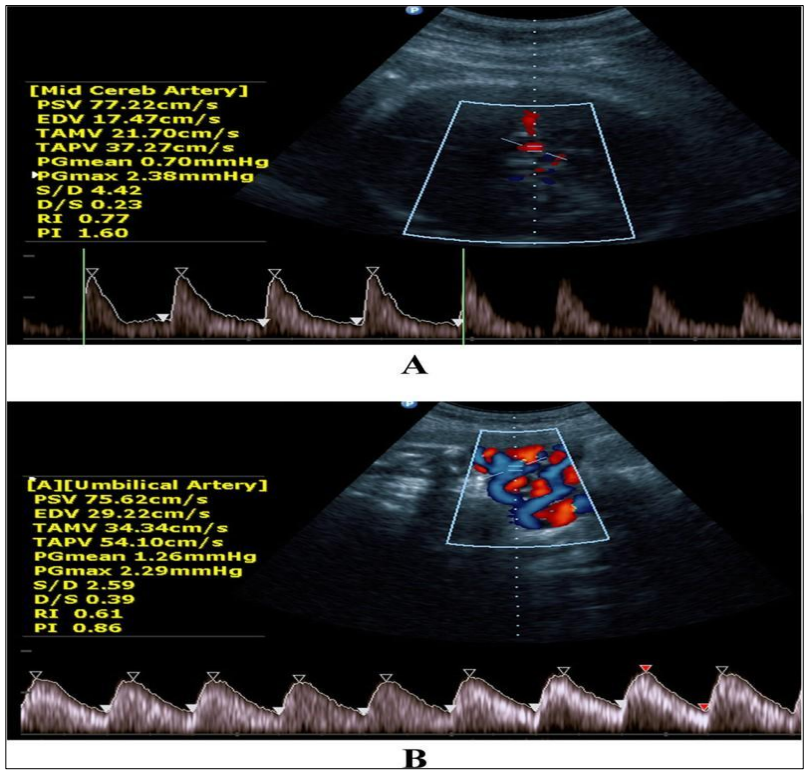

Fig 3: Doppler Ultrasound Waveforms of Mid Cerebral and Umbilical Arteries with Flow Metrics

Table 4: Comparisons of Fetal Renal Artery Doppler Parameters between Normal and IUGR Pregnancy

Parameter	Normal Fetuses (n = 77)	IUGR Fetuses (n = 43)
Renal Artery Pulsatility Index (PI)	0.79 ± 0.44	1.75 ± 0.76
Renal Artery Peak Systolic Velocity	124 ± 13 cm/s	110 ± 26 cm/s
Combined Renal Volume	Undefined	Undefined

Note: Increase PI and decrease PSV in IUGR pregnancies indicate impaired renal perfusion and increased vascular resistance. $p < 0.01$.

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