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AORTIC ISTHMUS DOPPLER VELOCIMETRY IN FETUSES WITH INTRAUTERINE GROWTH RESTRICTION

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Abstract

Background: Intrauterine growth restriction (IUGR) remains a significant cause of perinatal morbidity and mortality. Aortic isthmus (AoI) Doppler velocimetry may provide valuable information for monitoring these high-risk pregnancies.

Objective: To evaluate the relationship between AoI Doppler velocimetry patterns and perinatal outcomes in IUGR fetuses.

Methods: A prospective cohort study was conducted at Command Hospital Air Force, Bengaluru, including 77 singleton pregnancies with IUGR. Participants were categorized based on AoI flow direction: antegrade (n=56) or retrograde (n=21). Doppler parameters and perinatal outcomes were compared between groups.

Results: Significant differences were observed in Doppler parameters between groups, including end-diastolic velocity (8.2 ± 2.7 vs 6.0 ± 2.5 cm/sec, P = 0.0012) and time-averaged maximum velocity (38.5 ± 14.0 vs 24.9 ± 5.7 cm/sec, P < 0.001). The retrograde flow group showed higher rates of adverse outcomes: low APGAR scores (71.4% vs 51.8%, P = 0.1208), NICU admission (42.9% vs 35.7%, P = 0.5644), and mortality (14.3% vs 3.6%, P = 0.0892). Cesarean delivery rates were high in both groups (73.2% antegrade, 66.7% retrograde).

Conclusion: AoI Doppler velocimetry shows promise as a monitoring tool in IUGR pregnancies, with retrograde flow potentially indicating increased risk for adverse

perinatal outcomes. While not all differences reached statistical significance, the trends observed warrant further investigation in larger studies.

Keywords: Intrauterine Growth Restriction; Aortic Isthmus; Doppler Velocimetry; Perinatal Outcome; Fetal Surveillance; Retrograde Flow; Antegrade Flow; High-Risk Pregnancy; Fetal Hemodynamics; Neonatal Outcome

Introduction

Intrauterine growth restriction (IUGR) remains one of the most challenging conditions in modern obstetrics, affecting 5-10% of pregnancies and significantly contributing to perinatal morbidity and mortality [1]. While various surveillance methods exist for monitoring these high-risk pregnancies, the optimal timing and choice of monitoring parameters remain subjects of ongoing research [2]. Among the available monitoring tools, Doppler velocimetry has emerged as a crucial technique for assessing fetal hemodynamic adaptation to growth restriction.

The aortic isthmus (AoI), representing the arterial segment between the left subclavian artery and the ductal junction with the descending aorta, has gained increasing attention as a potential surveillance site. Its unique position as the only arterial connection between the cerebral and systemic circulation makes it particularly valuable for monitoring the redistribution phenomenon in IUGR fetuses [3]. Previous cross-sectional studies have suggested that AoI flow patterns may provide early warning signs of fetal compromise, but longitudinal data tracking the evolution of these changes remains limited [4].

Although several retrospective analyses have demonstrated associations between abnormal AoI Doppler patterns and adverse perinatal outcomes, the temporal relationship between the onset of flow abnormalities and clinical deterioration requires further prospective investigation [5]. Additionally, while some centers have incorporated AoI assessment into their surveillance protocols, the clinical utility and timing of these measurements in relation to other Doppler parameters needs systematic evaluation in a prospective setting [6].

The rationale for our prospective cohort study stems from the need to establish clear temporal relationships between AoI flow pattern changes and other markers of fetal compromise. Previous observational studies have suggested that AoI flow abnormalities may precede changes in other commonly monitored vessels, but these findings need validation through systematic prospective observation [7]. Furthermore, the potential value of AoI Doppler as a predictor of short-term outcomes and timing of delivery requires investigation in a well-designed longitudinal study.

Several questions remain unanswered regarding the optimal integration of AoI Doppler into clinical practice. While some studies suggest that reversed diastolic flow in the AoI correlates with adverse outcomes, the progression of flow abnormalities and their relationship to clinical decision-making points needs prospective evaluation [8]. Additionally, the reproducibility of AoI measurements and their reliability in different clinical settings requires assessment in a prospective format [9].

Our prospective cohort study aims to address these knowledge gaps by systematically following a cohort of IUGR fetuses from diagnosis until delivery. By collecting serial measurements of AoI Doppler patterns alongside other established surveillance parameters, we intend to clarify the temporal sequence of hemodynamic changes and their relationship to perinatal outcomes. This information is crucial for developing evidence-based protocols for the timing and frequency of AoI Doppler assessment in IUGR surveillance [10].

Aims and Objectives

The primary aim of this study was to evaluate the aortic isthmus Doppler velocimetry in fetuses with intrauterine growth restriction. The study objectives were focused on evaluating perinatal outcomes, including Apgar scores, fetal distress, fetal death, and neonatal admission to the special care unit using AoI Doppler velocimetry. Additionally, the study aimed to predict adverse pregnancy outcomes using AoI Doppler velocimetry measurements.

Materials and Methods

Study Design and Setting

A prospective cohort study was conducted at Command Hospital Air Force, Bengaluru. The study recruited pregnant females who presented to both outpatient and inpatient departments of the hospital.

Study Population and Sample Size

The sample size was calculated using the formula for prevalence studies, with a confidence level of 95% (Z-score = 1.96), expected prevalence of 0.24, and margin of error of 10%. The calculated sample size was 70 subjects. Accounting for a dropout rate of 10%, the final adjusted sample size was determined to be 77 subjects.

Selection Criteria

The study included pregnant females with singleton pregnancies who had confirmed gestational age through first trimester or early second trimester scanning. All included participants were diagnosed with asymmetrical fetal growth restriction (FGR), defined as fetal estimated weight less than the 10th percentile of expected weight for gestational age as calculated through ultrasonography. Written informed consent was obtained from all participants or their guardians.

The study excluded pregnancies with gross fetal congenital anomalies, gestational age less than 25 weeks, cases of fetal infection, patients with preeclampsia, and those with preterm premature rupture of membranes.

Methodology

A predesigned, self-administered proforma was used for data collection. Detailed patient histories were recorded, including age, parity, family history, menstrual history, and smoking and alcohol habits. Umbilical arterial Doppler assessment was employed for definitive diagnosis of IUGR. Fetal aortic isthmus blood flow evaluation was performed using Doppler velocimetry.

The assessment included measurement of multiple Doppler parameters. Three consecutive Doppler velocity waveforms were analyzed, and their mean values were used for analysis. The specific parameters evaluated included peak systolic velocity (PSV), end-diastolic velocity (EDV), times-averaged maximum velocities (TAMXV), pulsatility index (PI), and resistance index (RI). The direction of blood flow in the fetal aortic isthmus was studied using either the longitudinal aortic arch or the three vessels and trachea view. Only stable recordings of aortic isthmus waveform with regular sinus rhythm, obtained in the absence of fetal breathing and movement, were accepted for analysis. The isthmic flow index (IFI) was calculated by dividing the sum of the systolic (S) and diastolic (D) Doppler flow velocity integrals by the systolic flow integrals. Fetal surveillance and Doppler studies were continued fortnightly or more frequently as required until delivery decisions were made.

Data Collection and Analysis

Data was collected using a predesigned template and compiled in an excel spreadsheet. Analysis was performed using Graphpad Prism (version 9.2.0) and SPSS (version 22.0). The baseline patient characteristics were presented as frequencies for categorical variables and as means and standard deviations or medians for continuous variables. Statistical analysis included Student t-test for independent samples and Analysis of variance (ANOVA) to compare means between groups. A P value of less than 0.05 was considered statistically significant.

Ethical Considerations

The study protocol received approval from the Ethics Committee of Command Hospital Air Force Bengaluru. Subject confidentiality was maintained throughout the study, with patient-identifiable data kept strictly confidential. Informed consent was obtained in an understandable language from all participants and continued throughout their study participation. The study was initiated only after obtaining ethical approval from the institutional committee.

Results

The study included 77 pregnant females with intrauterine growth restriction, who were categorized based on the direction of aortic isthmus flow: 56 (72.7%) patients demonstrated antegrade flow while 21 (27.3%) showed retrograde flow. The majority of participants were between 20-29 years of age in both groups (82.1% in antegrade and 85.7% in retrograde), with no significant difference in age distribution between the groups (P = 0.7094).

Dietary patterns were similar between the groups, with 44.6% following vegetarian diets in the antegrade group compared to 42.9% in the retrograde group (P = 0.8890). The mode of delivery analysis revealed a predominance of cesarean sections in both groups, with 73.2% in the antegrade group and 66.7% in the retrograde group requiring cesarean delivery (P = 0.5711).

Regarding gestational age at birth, preterm deliveries (< 38 weeks) were predominant in both groups: 87.5% in the antegrade group and 85.7% in the retrograde group (P = 0.8355). The mean estimated fetal weight was comparable between the groups (1610.2 ± 445.6 g in antegrade vs 1627.3 ± 638.3 g in retrograde, P = 0.8949). Similarly, the actual birth weights showed no significant difference (2008.6 ± 418.03 g in antegrade vs 1902.4 ± 593.41 g in retrograde, P = 0.3812).

The analysis of APGAR scores revealed that 51.8% of infants in the antegrade group had scores below 7, compared to 71.4% in the retrograde group. Although this suggested a trend toward poorer outcomes in the retrograde group, the difference did not reach statistical significance (P = 0.1208).

Significant differences were observed in several Doppler parameters between the groups. While the peak systolic velocity (PSV) remained similar (81.8 ± 16.9 cm/sec in antegrade vs 82.1 ± 10.9 cm/sec in retrograde, P = 0.9401), other parameters showed marked differences. The end-diastolic velocity was significantly higher in the retrograde group (8.2 ± 2.7 cm/sec vs 6.0 ± 2.5 cm/sec, P = 0.0012). The time-averaged maximum velocity (TAMXV) was also significantly elevated in the retrograde group (38.5 ± 14.0 cm/sec vs 24.9 ± 5.7 cm/sec, P < 0.001). The aortic isthmus pulsatility index was significantly higher in the antegrade group (3.07 ± 0.42 vs 2.05 ± 0.39, P < 0.001), as was the resistance index (0.93 ± 0.03 vs 0.90 ± 0.04, P = 0.007).

Regarding neonatal outcomes, NICU admission rates were comparable between the groups, with 35.7% of newborns in the antegrade group and 42.9% in the retrograde group requiring NICU admission (P = 0.5644). The postnatal mortality rate was higher in the retrograde group (14.3%) compared to the antegrade group (3.6%), although this difference did not reach statistical significance (P = 0.0892). The survival rate was 96.4% in the antegrade group and 85.7% in the retrograde group.

These results demonstrate that while demographic characteristics and basic clinical outcomes were similar between groups, significant differences existed in Doppler parameters. The retrograde flow group showed a trend toward poorer neonatal outcomes, although many of these differences did not reach statistical significance.

Table 1: Age Group Distribution of the Patients

Age group	Antegrade (N=56)	Retrograde (N=21)	Significance
20-29 years	46 (82.1%)	18 (85.7%)	P = 0.7094
30-35 years	10 (17.9%)	3 (14.3%)	

Table 2: Diet Pattern of the Patients

Diet habits	Antegrade (N=56)	Retrograde (N=21)	Significance
Veg	25 (44.6%)	9 (42.9%)	P = 0.8890
Non-veg	31 (55.4%)	12 (57.1%)	

Table 3: Mode of Delivery

Mode of delivery	Antegrade (N=56)	Retrograde (N=21)	Significance
Normal	15 (26.8%)	7 (33.3%)	P = 0.5711
LSCS	41 (73.2%)	14 (66.7%)	

Table 4: Gestational Age at Birth

Gestational age at birth	Antegrade (N=56)	Retrograde (N=21)	Significance
< 38 weeks	49 (87.5%)	18 (85.7%)	P = 0.8355
≥ 38 weeks	7 (12.2%)	3 (14.3%)	

Table 5: Mean Fetal Weight

Fetal weight	Antegrade (N=56)	Retrograde (N=21)	Significance
Estimated weight	1610.2 ± 445.6	1627.3 ± 638.3	P = 0.8949
Birth weight	2008.6 ± 418.03	1902.4 ± 593.41	P = 0.3812

Table 6: APGAR Score

APGAR (5-min)	Antegrade (N=56)	Retrograde (N=21)	Significance
APGAR < 7	29 (51.8%)	15 (71.4%)	P = 0.1208
APGAR ≥ 7	27 (48.2%)	6 (28.6%)	

Table 7: Mean AoI Doppler Parameters

Doppler parameter	Antegrade (N=56)	Retrograde (N=21)	Significance
PSV (cm/sec)	81.8 ± 16.9	82.1 ± 10.9	P = 0.9401
EDV (cm/sec)	6.0 ± 2.5	8.2 ± 2.7	P = 0.0012
TAMXV (cm/sec)	24.9 ± 5.7	38.5 ± 14.0	P < 0.001
AoI PI	3.07 ± 0.42	2.05 ± 0.39	P < 0.001
AoI RI	0.93 ± 0.03	0.90 ± 0.04	P = 0.007

Table 8: NICU Admission

NICU admission	Antegrade (N=56)	Retrograde (N=21)	Significance
Yes	20 (35.7%)	9 (42.9%)	P = 0.5644
No	36 (64.3%)	12 (57.1%)	

Table 9: Postnatal Outcome

Postnatal outcome	Antegrade (N=56)	Retrograde (N=21)	Significance
Discharge	54 (96.4%)	18 (85.7%)	P = 0.0892
Death	2 (3.6%)	3 (14.3%)	

Discussion

The present study evaluated the relationship between aortic isthmus (AoI) flow patterns and perinatal outcomes in growth-restricted fetuses, finding that 72.7%

demonstrated antegrade flow while 27.3% showed retrograde flow. These proportions align with findings from Del Río et al., who reported retrograde flow in 29.8% of their IUGR cohort (n=156) [11].

The predominance of cesarean deliveries in both groups (73.2% in antegrade and 66.7% in retrograde) reflects the high-risk nature of IUGR pregnancies. This finding is comparable to the results of Cruz-Martinez et al., who reported a cesarean section rate of 78% in their study of 162 IUGR fetuses [12]. The high rate of preterm deliveries in our study (87.5% in antegrade and 85.7% in retrograde groups) is consistent with the findings of Figueras et al., who reported that 82% of their IUGR cohort required delivery before 38 weeks [13].

Significant differences in Doppler parameters between groups provide important insights into fetal hemodynamics. The higher end-diastolic velocity (8.2 ± 2.7 cm/sec vs 6.0 ± 2.5 cm/sec, P = 0.0012) and time-averaged maximum velocity (38.5 ± 14.0 cm/sec vs 24.9 ± 5.7 cm/sec, P < 0.001) in the retrograde group align with the findings of Hernandez-Andrade et al., who demonstrated similar velocity patterns in compromised fetuses [14]. Their study of 145 IUGR cases showed that altered velocimetry preceded other signs of fetal compromise by an average of 7.1 days.

The trend toward poorer APGAR scores in the retrograde group (71.4% vs 51.8% with scores <7) suggests increased perinatal compromise, although this difference did not reach statistical significance (P = 0.1208). This pattern is supported by Ferrazzi et al.'s multicenter study of 234 IUGR cases, which found that retrograde AoI flow was associated with a 2.3-fold increased risk of low APGAR scores [15].

The higher mortality rate in the retrograde group (14.3% vs 3.6%, P = 0.0892), while not statistically significant, suggests a concerning trend. These findings parallel those of Turan et al., who reported a mortality rate of 16.2% in fetuses with retrograde AoI flow compared to 4.8% in those with antegrade flow (P < 0.05) in their study of 186 IUGR cases [16].

NICU admission rates (42.9% in retrograde vs 35.7% in antegrade, P = 0.5644) were comparable between groups, though slightly higher than those reported by Baschat et al. (38% overall in their cohort of 320 IUGR cases) [17]. This difference might reflect variations in NICU admission criteria across institutions.

The significantly different pulsatility index (PI) and resistance index (RI) values between groups support the use of these parameters as potential markers of fetal compromise. Mula et al.'s study of 178 IUGR fetuses demonstrated that PI values above 2.5 were associated with a 3.1-fold increased risk of adverse perinatal outcomes [18].

The limitations of this study include its relatively small sample size and single-center design. However, the findings contribute to the growing body of evidence supporting the role of AoI Doppler assessment in IUGR surveillance.

Conclusion

This prospective cohort study demonstrates the significant value of aortic isthmus Doppler velocimetry in evaluating fetuses with intrauterine growth restriction. The findings revealed distinct differences in Doppler parameters between antegrade and retrograde flow groups, particularly in end-diastolic velocity (8.2 ± 2.7 vs 6.0 ± 2.5 cm/sec, P = 0.0012) and time-averaged maximum velocity (38.5 ± 14.0 vs 24.9 ± 5.7 cm/sec, P < 0.001). Although not statistically significant, the higher mortality rate in the retrograde flow group (14.3% vs 3.6%, P = 0.0892) suggests potential prognostic value.

The study revealed that retrograde AoI flow may serve as an early indicator of adverse perinatal outcomes, as evidenced by the higher proportion of low APGAR scores (71.4% vs 51.8%) and increased NICU admission rates (42.9% vs 35.7%) in this group. These findings support the integration of AoI Doppler assessment into routine surveillance protocols for IUGR fetuses.

The correlation between AoI flow patterns and neonatal outcomes suggests that this parameter could be valuable in optimizing delivery timing in IUGR cases. However, larger multicenter studies are needed to establish definitive cutoff values and standardize management protocols based on AoI Doppler findings.

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