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Original Research Article

COMPARATIVE STUDY OF CEREBRAL AND UMBILICAL ARTERIAL BLOOD FLOW VELOCITIES IN NORMAL VERSUS GROWTH-RESTRICTED PREGNANCIES

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ABSTRACT

Background: Fetal growth restriction (FGR) is a significant cause of perinatal morbidity and mortality, often resulting from placental insufficiency. Doppler velocimetry of the umbilical artery (UA), middle cerebral artery (MCA), and cerebroplacental ratio (CPR) provides a noninvasive assessment of fetal hemodynamics and helps predict adverse outcomes.

Materials and Methods: This comparative study included 100 pregnant women, with 50 cases each of normal and FGR pregnancies. Doppler ultrasound was used to evaluate UA and MCA indices (PI, RI, S/D ratio), and CPR was calculated. Perinatal outcomes were analyzed in relation to these parameters.

Results: FGR pregnancies showed significantly higher UA PI, RI, and S/D ratio ($p<0.001$) and significantly lower MCA indices ($p<0.001$), indicating increased placental resistance and cerebral vasodilation. CPR was significantly lower in FGR cases, and values ≤ 1.08 were strongly associated with higher NICU admissions and cesarean deliveries for fetal distress ($p<0.05$).

Conclusion: Doppler evaluation of UA, MCA, and CPR is a valuable tool for identifying FGR and predicting adverse perinatal outcomes. CPR is especially useful as a combined index of fetal compromise.

Keywords: Fetal Growth Restriction (FGR), Umbilical Artery Doppler, Middle Cerebral Artery Cerebroplacental Ratio (CPR).

INTRODUCTION

Fetal growth restriction (FGR), also referred to as intrauterine growth restriction (IUGR) is a major cause of perinatal morbidity and mortality all over the world. It can be defined as a condition whereby a fetus cannot attain its genetically predicted growth potential and it is often diagnosed when the estimated fetal weight is below the 10th percentile of the gestational age, usually caused by placenta insufficiency or chronic hypoxia.[1] Accurate diagnosis is important in clinical practice to cause timely intervention and results since the only difference between constitutionally small fetuses and fetuses that are pathologically constricted in growth has to be distinguished.[2] Doppler ultrasonography has become an important, non-invasive method of determining fetal hemodynamics, especially during FGR-complicated pregnancies. It allows us to estimate blood flow in the main fetal vessels, with the umbilical artery (UA) and middle cerebral artery (MCA) being predominant. The umbilical artery is the indicator of placental resistance, and the abnormal result (high resistance index (RI), high pulsatility index (PI), absence, or reversal of the end-diastolic flow) demonstrates the high level of the resistance of the placenta.[3] On the contrary, in the case of chronic cerebral hypoxia cerebral circulation undergoes vasodilatory changes, a process referred to as the brain-sparing effect and this leads to low PI in the MCA.[4] The cerebroplacental ratio (CPR) defined

as the ratio between the PI of the MCA and the UA has been used as a sensitive measure of fetal compromise. A low CPR implies the priority of redistribution of blood to the brain at the other organs which is typical of FGR fetuses.[5] Though such a state of compensatory adaptation is initially protective, it is linked to poor perinatal outcomes if the duration of this adaptive response is protracted.[6]

The study of the blood flow velocities in UA and MCA at the time of normal and growth-restricted pregnancy may help to fill the knowledge gaps about the evaluation of pathophysiological changes and assist in risk stratification. Characteristic of normal pregnancies, the UA flow will be of low resistance whereas MCA exhibits high-resistance characteristics as cerebral circulation was not essential at this stage in a low-resistance pattern. By contrast, FGR fetuses have a stronger UA resistance and a weaker MCA resistance which is the adaptive procedure to the intrauterine hypoxia.[7] This has been linked with the early detection of abnormal Doppler parameters and the provision of timely delivery and appropriate perinatal care resulting in improved neonatal outcomes. Some studies have indicated that the co-existence of UA and MCA Doppler velocimetry is associated with a better predictive value than a single parameter alone.[8] Thus, the comparison of these indices with normal and growth-restricted fetuses is also clinically meaningful to further tailor the diagnostic cut points and optimal treatment interventions. The current study aimed to assess and compare the Doppler-derived flow velocity indices in the cerebral (MCA) and umbilical arteries of fetuses with FGR and compare them to those with normal pregnancies.

MATERIALS AND METHODS

This was a prospective, comparative, observational study conducted in the Department of Obstetrics and Gynecology in collaboration with the Department of Radiodiagnosis at Govt Medical College and Hospital, Khammam, Telangana. It is a tertiary care teaching hospital. The study was carried out over a period of 12 months after obtaining institutional ethical clearance. Written consent was obtained from all the patients of the study after explaining the nature of the study in the vernacular language.

A total of 100 pregnant women between 28 to 40 weeks of gestation were enrolled and divided into two groups:

Group A (Control group): 50 healthy pregnancies with appropriate-for-gestational-age fetuses.

Group B (Study group): 50 pregnancies diagnosed with fetal growth restriction (FGR) based on clinical and ultrasound criteria.

Inclusion Criteria

1. Singleton pregnancies
2. Gestational age between 28–40 weeks confirmed by first-trimester ultrasound.
3. For Group B: Estimated fetal weight <10th percentile for gestational age with or without abnormal Doppler findings
4. Willing to participate in the study voluntarily.

Exclusion Criteria

1. Multiple pregnancies
2. Major fetal anomalies or congenital malformations
3. Pregnancies complicated by gestational diabetes mellitus, pre-existing hypertension, or chronic renal disease
4. Patients with unreliable gestational dating

All the included patients were subjected to a detailed obstetric and medical history. Clinical examination and routine antenatal investigations were performed on all participants.

Ultrasound and Doppler Assessment: All patients underwent ultrasonographic evaluation using a high-resolution ultrasound machine equipped with a 3.5–5 MHz convex transducer. Doppler studies were performed in a semi-recumbent position with minimal fetal movement and no maternal breath-holding.

The following parameters were recorded:

- **Umbilical Artery (UA):** Pulsatility Index (PI), Resistance Index (RI), and Systolic/Diastolic (S/D) ratio were measured from a free-floating loop of the umbilical cord.
- **Middle Cerebral Artery (MCA)**: PI, RI, and S/D ratio were measured from an axial section of the fetal head at the level of the thalami and sphenoid wings.
- **Cerebroplacental Ratio (CPR):** Calculated as the ratio of MCA PI to UA PI.

Each Doppler was measured when the fetus was in quiescence, and this was done twice. The mean of two values was noted.

Outcome measures: Comparison of UA and MCA Doppler indices and CPR of normal and growth-restricted fetuses was regarded as a primary outcome. The secondary outcome involved a comparison of abnormal Doppler indices with gestational age and degrees of growth limitation.

Statistical Analysis: The data entries were done in Microsoft Excel and statistical analysis was made on SPSS software version 25. Results of continuous data were reported as the means of SD and analyzed with the help of the student's t-test. The chi-square test was used in the analysis of categorical variables. The p-value of less than 0.05 was used as major significance.

RESULTS

A total of 100 cases were included in the study. Table 1 shows the comparison of the Doppler index of the umbilical artery in normal and FGR pregnancies. The values of mean PI, RI, and S/D ratio were markedly different in the FGR group (1.52, 0.79, and 5.12 respectively) than in the

control group (0.98, 0.62, and 2.65). All of the three p-values were less than 0.001, thus there was statistically significant higher placental resistance in these growth-restricted fetuses. The results show the usefulness of umbilical artery Doppler as a sensitive diagnosis method of placental insufficiency in cases of FGR.

Table 1: Umbilical Artery Doppler Indices

Parameter	*Control Group (n=50)*	*FGR Group (n=50)*	*p-value*
PI (mean ± SD)	0.98 ± 0.15	1.52 ± 0.32	<0.001*
RI (mean ± SD)	0.62 ± 0.08	0.79 ± 0.09	<0.001*
S/D ratio	2.65 ± 0.45	5.12 ± 1.58	<0.001*

***Significant**

A critical analysis of Table 2, shows that there is a great decrease in MCA Doppler indices of FGR pregnancies. The PI and RI of the FGR group (1.32 and 0.66) were significantly less in comparison to controls (1.85 and 0.78), with p-values less than 0.001. In the same breath, S/D ratio was lower in FGR fetuses (4.23 vs 5.12; p=0.001). The results show that vasodilation is a brain-sparing effect to intrauterine hypoxia and also the importance of MCA Doppler to find compromised fetal circulation.

Table 2: Middle Cerebral Artery Doppler Indices

Parameter	*Control Group (n=50)*	*FGR Group (n=50)*	*p-value*
PI (mean ± SD)	1.85 + 0.28	1.32 ± 0.31	<0.001*
RI (mean ± SD)	0.78 + 0.06	0.66 ± O.08	<0.001*
S/D ratio	5.12 + 1.05	4.23 ± 1.21	0.001*

***Significant**

Table 3 depicts the Cerebroumbilical (C/U) Ratio in the Control Group. The analysis of the table shows that the mean cerebroplacental ratio (CPR) in the control group is 1.92 ± 0.35, with a range from 1.20 to 2.75. These values are typical of normal cerebral and placental hemodynamics of healthy fetuses. The CPR, derived from the ratio of MCA PI to UA PI, serves as an integrated marker of fetal well-being. A CPR value significantly lower than this baseline in FGR fetuses is indicative of fetal compromise due to altered perfusion dynamics.

Table 3: Cerebroumbilical (C/U) Ratio in Control Group

Parameter	*Value*
C/U Ratio (CPR)	1.92 ± 0.35
Range	1.20 - 2.75

Table 4 presents the correlates of perinatal outcomes with MCA PI in FGR pregnancies. Among the MCA PI <1.2 (n=32), the NICU admission rates were increased (78.1% vs 33.3%, p=0.001) as well as cesarean deliveries associated with fetal distress (62.5% vs 27.8%, p=0.015) in comparison with PI = 1.2. Though the low-PI group had more cases of low Apgar scores and perinatal mortality, these were not significant. This points to the fact that abnormal MCA PI correlates with unfavorable neonatal outcomes in FGR.

Table 4: Perinatal Outcomes by MCA PI in FGR Group (MCA PI < 1.2 = Abnormal brain-sparing; n=32)

Outcome	*MCA PI 21.2 (n=18)*	*MCA PI <1.2 (n=32)*	*p-value*
NICU admission	6 (33.3%)	25 (78.1%)	0.001*
Cesarean for distress	5 (27.8%)	20 (62.5%)	0.015*
5-min Apgar <7	1 (5.6%)	8 (25.0%)	0.075
Perinatal mortality	o (0%)	4 (12.596)	0.105

***Significant**

Table 5 gives the features of five FGR cases (10 percent of the FGR group) that had absent end-diastolic velocity (AEDV) or reversed end-diastolic velocity (REDV) in the umbilical artery. The gestation ages were between 28.5 to 32.1 weeks. The cerebroplacental ratios (CPR: 0.4\0.65) were significantly low in all the cases and MCA PI (0.85\1.1) was lower, pointing to a hemodynamic compromise. Three neonates still needed an extended stay in NICU (7 14 days) and two patients with REDV were found dead. It is indicated in this subgroup that the use of AEDV/REDV is correlated with poor fetal outcomes and that Doppler plays an important role in diagnosing severe placental insufficiency in FGR.

Table 5: Characteristics of FGR Cases with AEDV/REDV *0=5; 10% of FGR group)

Case	*GA (weeks)*	*UA Doppler*	*MCA PI*	*CPR*	*Perinatal Outcome*
1	32.1	AEDV	1.05	0.65	NICU 7 days
2	30.5	REDV	0.92	0.52	Perinatal death
3	29.8	AEDV	1.1	0.6	NICU 14 days
4	31.2	AEDV	1	0.58	NICU 10 days
5	28.5	REDV	0.85	0.4	Perinatal death

Table 6 shows the perinatal outcome by CPR ≤1.08 in the FGR Group This table assesses outcomes based on CPR in FGR fetuses, using a cutoff of 1.08 (determined by ROC analysis. Fetuses with CPR ≤1.08 had significantly higher NICU admissions (77.1% vs 26.7%, p=0.001) and cesarean deliveries for distress (62.9% vs 20.0%, p=0.006). UA pH <7.10 and perinatal mortality were also more common but not statistically significant. The relative risk of NICU admission was 4.52 for low CPR, indicating that CPR is a strong predictor of neonatal morbidity in growth-restricted pregnancies.

Table 6: Perinatal Outcomes by C/U Ratio 61.08 in FGR Group (Cutoff determined by ROC analysis)

Outcome	CPR >1.08 (n=15)	CPR 31.08 (n=35)	p-value	RR (95% CD
NICU admission	4 (26.7%)	27 (77.1%)	0.001	4.52 (1.82-1 1.24)
Cesarean for distress	3 (20.0%)	22 (62.9%)	0.006	3.89 (1.32-1 1.46)
UA pH <7.10	1 (6.7%)	11 (31.4%)	0.057	3.12 (0.98-9.91)
Perinatal mortality	0 (0%)	4 (11.4%)	0.180	Undefined

Significant

DISCUSSION

Fetal Growth Restriction (FGR) is one of the significant problems of obstetrics because of its association with adverse perinatal outcomes. Doppler velocimetry of the umbilical artery (UA) and middle cerebral artery (MCA) and the cerebroplacental ratio (CPR) provide a useful non-invasive approach to the investigation of fetal wellness and subsequent hypoxic compromise. The results of this study showed that elevated UV Doppler indices such as pulsatility index (PI), resistance index (RI) and systolic/ diastolic (S/D) ratio in FGR pregnancies were higher compared to normal controls. This indicates a higher placental resistance in FGR fetuses. These results are in agreement with similar studies in the literature which relate high UA resistance with placental insufficiency of poor trophoblastic invasion and vascular remodelling.[9,10] The presence of abnormal waveforms (such as absent end-diastolic velocity [AEDV] or reversed end-diastolic velocity [REDV]) only emphasizes the heaviness of the placental dysfunction.[11] We also found that MCA indices were significantly reduced in FGR cases showing the brain-sparing effect. The reduced PI and RI in MCA is an indication of compensatory cerebral vasodilation in response to hypoxia. The purpose of this is to protect the fetal brain however, it also signifies worsening placental insufficiency when persistent.[12,13] Our results reflect the results shown by other similar studies in this field showing this cerebral adaptation is a crucial marker of fetal compromise.[14] The cerebroplacental ratio (CPR) which is estimated as the ratio of the MCA PI to the UA PI provides a detailed picture of fetal oxygenation and vascular redistribution. The CPR was found to be a lot lower in FGR cases in our cohort. The presence of a CPR value of 1.08 or less, as calculated on ROC analysis, was significantly associated with poor outcomes in the form of NICU admission (77.1%), and fetal-distress cesarean section (62.9). These results are compatible with other past findings that highlighted CPR as a better predictor of perinatal outcomes than UA or MCA alone.[15,16]

Further insight into the subgroup of FGR fetuses with AEDV or REDV-10% of the FGR population is given in Table 5. The CPR values of these fetuses were extremely low (0.40- 0.65), and MCA PI values were <1.1. Two of them had REDV and experienced perinatal mortality; the other three had to stay long in the NICU (714 days). These findings highlight how AEDV/REDV, when coupled with low CPR and MCA PI indicates extreme fetal distress and requires emergency treatment. The occurrence of REDV specifically is even said to be a sign of an end game of placental inadequacy.[17] and as such, the prognosis is usually grim unless relieved by immediate labor. The subset analysis therefore supports the usefulness of incorporating the Doppler information into clinical decision making especially when determining the time of deliveries in severe FGR. All in all, our study confirms the applicability of UA and MCA Doppler indices and CPR as essential surveillance indicators in high-risk pregnancies and indicates CPR as a sensitive indicator of an eventual impending fetal decompensation.

Limitations of the current study: The following limitations must be kept in mind before generalizing the results. The sample size was modest, particularly in the subgroup with abnormal Doppler findings such as AEDV/REDV. Third, Doppler parameters were measured at a single time point and may not reflect the dynamic progression of fetal compromise. Longitudinal assessment could provide better insight into fetal adaptation over time.

CONCLUSION

The present study showed that umbilical artery and middle cerebral artery Doppler indices and the cerebroplacental ratio (CPR) are effective indicators of the fetal condition in pregnancies complicated by fetal growth restriction. UA resistance was significantly higher in FGR cases, and cerebral perfusion was lower, showing a higher CPR, which is a brain-sparing effect. A CPR of 1.08 and below was closely associated with poor perinatal events. Moreover, AEDV/REDV-positive UA Doppler was associated with severe fetal distress, larger NICU travel, and perinatal mortality. These results confirm that Doppler velocimetry in the clinical setting is useful for the early detection and management of at-risk fetuses.

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