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Umbilicocerebral Ratio Versus Cerebroplacental Ratio in Predicting Perinatal Outcomes in Pregnancies with Early and Late Onset Fetal Growth Restriction: A Retrospective Comparative Study

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ABSTRACT

Objectives: To compare the predictive accuracy of umbilico-cerebral ratio (UCR) and cerebro-placental ratio (CPR) for adverse perinatal outcomes in pregnancies complicated by early and late onset fetal growth restriction (FGR).

Material and Methods: A retrospective single-centre study was conducted analysing 105 singleton FGR pregnancies (56 early onset, 49 late onset) between April 2023 and April 2024. Adverse outcomes included caesarean section, premature birth, low birth weight, NICU admission, and need for resuscitation. Receiver operating characteristic (ROC) curves, correlation analyses, and logistic regression were performed.

Results: UCR demonstrated superior predictive performance compared to CPR for multiple adverse outcomes in the total FGR cohort. For cesarean section prediction, UCR showed an area under the curve (AUC) of 0.755 versus CPR's 0.573 (p=0.0001). UCR was significantly associated with reduced risk of caesarean section (OR 0.351, 95% CI 0.174-0.709, p=0.003) and NICU admission (OR 0.275, 95% CI 0.123-0.618, p=0.002), while being associated with increased risk of low birth weight (OR 1.93, 95% CI 1.136-3.279, p=0.015). Early onset FGR pregnancies had significantly higher rates of cesarean section (94.64% vs 75.51%, p=0.01) and NICU admission (41.07% vs 12.24%, p=0.001) compared to late onset FGR.

Conclusions: UCR demonstrates superior predictive accuracy compared to CPR for adverse perinatal outcomes in FGR pregnancies, particularly for cesarean section and NICU admission. The inverted ratio may provide clinicians with a more sensitive tool for risk stratification and management decisions in FGR pregnancies.

KEYWORDS: fetal growth restriction, cerebroplacental ratio, umbilico-cerebral ratio, Doppler ultrasound, perinatal outcomes, brain sparing effect

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INTRODUCTION

Fetal growth restriction (FGR) affects 3-10% of all pregnancies and represents a leading cause of perinatal morbidity and mortality worldwide [1]. Based on gestational age at diagnosis, FGR is classified into early onset (<32 weeks) and late onset (≥32 weeks) forms, each with distinct pathophysiological mechanisms and clinical implications [2].

Early fetal growth restriction (FGR) is primarily linked to inadequate maternal blood supply to the placenta, which occurs when the spiral arteries fail to undergo proper remodeling, the placental villi develop pathologic characteristics, and multiple infarcts occur throughout the placenta. These pathological changes collectively create placental insufficiency, representing the predominant mechanism underlying placenta-related fetal growth restriction [3]. Currently, no effective treatment exists for early fetal growth restriction (FGR), although proper identification and management of severe preeclampsia can extend certain pregnancies affected by early FGR. The essential principles of early FGR management include timey steroid administration, using magnesium sulfate, transfer to a specialized tertiary care facility, and deciding the optimal method for delivery. In the end, delivery remains the sole definitive treatment option for early FGR. Conversely, Late FGR is marked by less severe and more nonspecific placental abnormalities and/or changes in oxygen and nutrient transfer.[3] As a result, abnormalities in umbilical artery Doppler and venous flow patterns are rare and we are unable to detect most cases of late FGR or predict poor outcomes in these fetuses.

Reduced fetal tolerance to hypoxemia near term, often correlates with poor perinatal outcomes despite less severe Doppler abnormalities [4].

The cerebroplacental ratio (CPR), calculated as the ratio of middle cerebral artery pulsatility index (MCA PI) to umbilical artery pulsatility index (UA PI), has emerged as a valuable parameter for assessing fetal well-being in growth-restricted pregnancies. CPR reflects the balance between cerebral vasodilation and placental vascular resistance, with values below the 5th centile indicating brain-sparing physiology [5].

The umbilicocerebral ratio (UCR), calculated as the inverse of CPR (UA PI/MCA PI), has been proposed as a potentially more sensitive predictor of adverse perinatal outcomes. Despite being mathematically equivalent to the inverse of CPR, the TRUFFLE study reported better correlations of UCR with neonatal neurodevelopmental impairment [6].

A 2021 German retrospective cohort (Coenen et al.) compared UCR to CPR in FGR pregnancies and found that UCR had stronger independent associations with adverse outcomes including preterm delivery, Apgar <7, and low birthweight below 10th percentile than CPR, though both ratios showed only moderate predictive accuracies on ROC analyses [6]. A more recent Chinese study by Zheng et al. (2024) evaluating multiple Doppler and ratio parameters for severity assessment of FGR found that CPR-PI was particularly useful in diagnosing late-onset FGR, with an AUC of about 0.72, outperforming several UCR variants and simple UA or MCA Doppler indices [7]. Another prospective study by Stumpfe et al. (2022) introduced the Amniotic-Umbilical-to-Cerebral Ratio (AUCR) . AUCR was defined as follows: Single deepest pocket(SDP) / (UA PI/MCA PI). Operative intervention was statistically significantly associated with UCR, SDP, and AUCR, whereas no association was observed for UA PI, MCA PI, and CPR. [8] A Turkish group (Yılmaz et al., 2023) examined various Doppler parameters in late-onset FGR and confirmed that CPR, UCR, UA PI, MCA PI, and newer ratios like CPUR were all associated with adverse neonatal outcomes, even though some parameters had better predictive value than others [9,10]. Finally, a very recent nomogram study by Zhao et al. (2025) showed that while CPR and UCR alone had limited prognostic accuracy for adverse perinatal outcomes (AUCs often <0.70), combining them with gestational age at diagnosis, estimated fetal weight, growth trajectory, and other parameters yielded much better prediction (AUC ~0.85–0.90) [10].

Overall, current evidence suggests that UCR may have an edge over CPR in certain adverse outcome predictions, particularly in early preterm or severe FGR, but CPR-PI (and perhaps combined models) still perform robustly especially in late-onset disease. What remains less clear is how these ratios compare specifically in early vs late onset FGR in the same cohort, how their cut-offs vary by gestational age, and how adding other ultrasound parameters influences their predictive performance.

The aim of our study was to compare UCR with CPR and assess their relative predictive accuracy for adverse perinatal outcomes in pregnancies complicated by early and late onset FGR.

MATERIALS AND METHODS

Study Design and Population

This retrospective single-center study was conducted at the Department of Fetal Medicine, Amrita Institute of Medical Sciences, Faridabad, India. The study was approved by the Institutional Review Board and included consecutive singleton FGR pregnancies presenting for routine ultrasound examinations between April 2023 and April 2024.

FGR was diagnosed according to established criteria including estimated fetal weight <10th centile for gestational age with additional criteria such as abnormal uterine artery Doppler, oligohydramnios, or maternal risk factors. Early onset FGR was defined as diagnosis before 32 weeks of gestation, while late onset FGR was defined as diagnosis at or after 32 weeks.

All ultrasound examinations were performed using Voluson E10 (GE Medical Systems) and EPIQ Elite (Philips Medical Systems) ultrasound machines by experienced operators. Gestational age was calculated using crown-rump length during the first trimester.

Inclusion criteria:

Singleton FGR pregnancies between 24 and 40 weeks of gestation

Complete follow-up data available

Delivery at our institution

Only singleton pregnancies fulfilling the inclusion criteria were analysed. Exclusion criteria included multiple gestation, major fetal structural anomalies or chromosomal aneuploidy, and intrauterine fetal infection.

Data regarding Doppler parameters, estimated fetal weight, and subsequent perinatal outcomes were extracted from the institutional database (ViewPoint, GE Healthcare, USA).

The primary outcome measures included gestational age at delivery, birth weight, Apgar score at five minutes, and mode of delivery. An adverse perinatal outcome was defined as any one or more of the following: Apgar score <7 at 5 minutes, premature birth before 37 weeks, extremely premature birth before 30 weeks, cesarean section due to fetal distress, or birth weight below the 10th or 3rd percentile for gestational age.

Statistical analysis

Statistical analysis was performed using SPSS software version 25. Categorical variables were expressed as frequencies and percentages, and continuous variables were presented as mean ± standard deviation. Normality of data was tested using the Shapiro-Wilk test. Continuous variables were compared using the independent t-test, while categorical data were analyzed using the Chi-square test or Fisher's exact test when applicable. Univariate and multivariate logistic regression analyses were used to assess the association of CPR and UCR with adverse outcomes. Pearson correlation coefficients were calculated to assess the relationship between Doppler indices and perinatal parameters such as gestational age at delivery, birth weight, and Apgar scores. Receiver operating characteristic (ROC) curves were constructed to evaluate the predictive performance of UCR and CPR, and area under the curve (AUC), optimal cutoff values, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were reported. A p-value of <0.05 was considered statistically significant .

RESULTS

A total of 105 singleton FGR pregnancies were included: 56 early onset FGR (53.3%) and 49 late onset FGR (46.7%).

Table 1 demonstrates comparison of parameters between early onset FGR and late onset FGR group , including the maternal characteristics , ultrasound findings and fetal doppler indices , and neonatal outcomes . As expected, early onset FGR pregnancies showed significantly lower abdominal circumference (219.37 ± 36.97 vs 273.84 ± 22.95 mm, p < 0.0001) and estimated fetal weight (1082.54 ± 401.69 vs 2009.82 ± 428.2 g, p < 0.0001) compared to late onset FGR.

Normal vaginal delivery was less frequent in early onset FGR (5.36% vs 22.45%, p=0.01), while cesarean section was more common (94.64% vs 75.51%, p=0.01). No cases of APGAR score <7 at 5 minutes or meconium presence were reported in either group.

On assessment of doppler parameters , umbilical artery PI (1.16 ± 0.3 vs. 1.05 ± 0.26, p value = 0.044), and MCA PI (2.19 ± 0.6 vs. 1.8 ± 0.52, p value = 0.0006) were significantly higher in Early onset FGRs group compared to Late onset FGRs groups . Although cerebroplacental ratio (CPR) did not differ significantly (p = 0.165), the umbilico-cerebral ratio (UCR) showed a strong statistical difference (p < 0.0001), with higher values in the late-onset group,

Early onset FGR was associated with significantly higher rates of NICU admission (41.07% vs 12.24%, p=0.001), while late onset FGR showed higher rates of low birth weight (25% vs 59.18%, p=0.0004). Premature birth rates were similar between groups (28.57% vs 30.61%, p=0.819) . Low birth weight was significantly lower in Early onset FGRs group (25% vs. 59.18%, p value = 0.0004). No cases of APGAR score <7 or presence of meconium were reported in either group. NICU admission was significantly higher in Early onset FGRs group (41.07% vs. 12.24%, p value = 0.001). Need for resuscitation was comparable between groups (7.14% vs. 4.08%, p value = 0.683).

Table 2 analyses univariate logistic regression analysis assessing effect of CPR and UCR on adverse outcomes .In total study population , CPR showed significant association with premature birth before 30 weeks (OR: 59.27, 95% CI: 8.585 to 409.2, p < 0.0001). In contrast, UCR was significantly associated with lower risk of caesarean section (OR: 0.351, 95% CI: 0.174 to 0.709, p = 0.003) and NICU admission (OR: 0.275, 95% CI: 0.123 to 0.618, p = 0.002), while it was associated with higher risk of low birth weight (OR: 1.93, 95% CI: 1.136 to 3.279, p = 0.015). No significant association was found between UCR and premature birth or need for NICU admission. In early onset FGR and late onset late onset FGR groups , CPR and UCR showed no significant association with any adverse perinatal outcome parameter .

Table 3 demonstrates that in FGR cases ,significant weak negative correlation was seen between UCR with birth weight with correlation coefficient of -0.232. In late onset FGR , significant weak positive correlation was seen between CPR with birth weight (kg) with correlation coefficient of 0.315

Table 4 shows receiver operating characteristic curve of CPR and UCR for predicting outcome in growth restricted foetuses . Overall, UCR showed better predictive performance than CPR for most adverse outcomes, particularly caesarean section (AUC = 0.755, p = 0.0001), low birth weight (AUC = 0.641, p = 0.0126), and NICU admission (AUC = 0.72, p = 0.0001). CPR did not demonstrate significant predictive ability for any outcome, while UCR had significant predictive accuracy for

low birth weight and NICU admission.

In early onset FGR group (Table 5), both CPR and UCR demonstrated weak predictive ability for most adverse outcomes. CPR and UCR showed moderate predictive power for low birth weight (CPR: AUC = 0.577, p = 0.409, UCR: AUC = 0.578, p = 0.4051), while CPR and UCR showed slightly better ability for NICU admission (AUC = 0.601).

Whereas in late onset FGR group (Table 6) UCR performed better than CPR for predicting caesarean section (AUC = 0.649, p = 0.0981). CPR showed slightly better performance for predicting premature birth before 37 weeks (AUC = 0.561) and low birth weight (AUC = 0.637, p = 0.0885), but neither was highly predictive.

Univariate and multivariate regression analysis was done using doppler parameters to assess significant risk factors of adverse perinatal outcome in total study subjects, early onset FGR and late onset FGR groups

On performing univariate regression in total study subjects, *UCR was significant risk factor of Caesarean section.* UCR was *significant independent risk factor of NICU admission* after adjusting for confounding factors

On performing univariate regression in early onset FGR group, GA by LMP (weeks) and MCA PI were significant risk factors of Premature birth (<30 weeks). On performing multivariate regression, none of the variable was independent significant risk factor of Premature birth. In late onset FGR group, none of the variables was significant risk factor of adverse perinatal outcome in late onset FGR. (Table 6 to 8) (Figure 1 to 3)

DISCUSSION

The present study evaluated and compared the predictive efficacy of umbilico-cerebral ratio (UCR) and cerebroplacental ratio (CPR) in assessing adverse perinatal outcomes in pregnancies complicated by early and late-onset fetal growth restriction (FGR). Notably, while both indices demonstrated clinical utility, UCR was found to be more significantly associated with key adverse outcomes, including caesarean delivery, low birth weight, and NICU admission. These findings highlight the evolving role of UCR as a potentially superior Doppler parameter in predicting perinatal compromise.

Recent literature supports this paradigm shift. In a prospective analysis by Bahlmann et al., UCR demonstrated greater diagnostic accuracy than CPR in predicting emergency caesarean sections and neonatal acidosis, especially in early-onset FGR cases [11]. Their work emphasized the hemodynamic shift from fetal compensation to decompensation as captured more sensitively by UCR, which increases as cerebral blood flow decreases relative to placental resistance. Similarly, a large multicentric study conducted by Ghi et al. found that UCR abnormalities correlated better with short-term neonatal morbidity and low APGAR scores when compared with CPR, particularly in cases with normal amniotic fluid levels [12].

In line with our findings, Morales-Roselló et al. have suggested that UCR might be more robust in heterogeneous populations, including late-onset FGR, owing to its capacity to detect subtle cerebral vasoconstriction before overt changes in CPR are observed [13]. These researchers argue that CPR may sometimes normalize due to adaptive cerebrovascular responses, thus masking true placental insufficiency — a limitation that UCR overcomes by amplifying subtle vascular changes through its inverse ratio construct.

Moreover, a recent longitudinal cohort study by Rizzo et al. demonstrated that UCR maintains stronger correlations with abnormal perinatal composite outcomes, especially in normotensive pregnancies without other comorbidities, supporting the notion that UCR could become a standard tool in universal FGR surveillance protocols [14]. Additionally, the meta-analysis by Khalil et al. revealed that integrating UCR with other biophysical markers improved risk stratification more than CPR-based models alone, suggesting a future role for UCR in algorithmic antenatal care [15].

UCR may provide more accurate identification of FGR pregnancies at highest risk for adverse outcomes, enabling targeted monitoring and intervention strategies. The superior prediction of cesarean section by UCR could inform discussions about delivery timing and mode, particularly in late onset FGR where management decisions are often challenging.[16]

LIMITATIONS

Several limitations should be acknowledged. The retrospective design introduces potential bias, and the single-center nature may limit generalizability. The sample size, while adequate for primary analyses, limited power for subgroup comparisons. Inter- and intra-observer variability in Doppler measurements could not be assessed due to retrospective nature .

Additionally, while UCR demonstrated statistical superiority, the clinical significance of the improvements in some outcomes remains to be established through prospective studies with larger sample sizes and validation in different populations.

CONCLUSION

UCR demonstrates superior predictive accuracy compared to CPR for adverse perinatal outcomes in FGR pregnancies, particularly for cesarean section and NICU admission.

While neither ratio performed optimally as a sole screening marker, UCR's better correlation with adverse outcomes suggests it may be more suitable for inclusion in multivariable prediction models. The differential performance between early and late onset FGR underscores the importance of gestational age-specific management strategies.

These findings support the incorporation of UCR into clinical practice protocols for FGR management, with the caveat that further prospective validation multi-center studies with large sample size are needed to establish optimal cutoff values and confirm clinical utility across different populations and healthcare settings.

Table 1: Comparison of parameters between early onset FGR and late onset FGR group

Parameters	Early onset FGRs(n=56)	Late onset FGRs(n=49)	Total	P value
Age (years)	29.07 ± 4.35	29.41 ± 4.68	29.23 ± 4.49	0.703‡
Body mass index (kg/m²)	26.51 ± 5.07	25.77 ± 4.07	26.17 ± 4.62	0.415‡
AC (mm)	219.37 ± 36.97	273.84 ± 22.95	244.79 ± 41.37	<.0001‡
EFW (g)	1082.54 ± 401.69	2009.82 ± 428.2	1515.27 ± 621.31	<.0001‡
Fetal doppler parameters				
UA PI	1.16 ± 0.3	1.05 ± 0.26	1.11 ± 0.29	0.044‡
CPR PI	2.02 ± 0.76	1.82 ± 0.66	1.93 ± 0.72	0.165‡
MCA PI	2.19 ± 0.6	1.8 ± 0.52	2 ± 0.59	0.0006‡
UCR	0.56 ± 0.23	1.85 ± 0.59	1.16 ± 0.78	<.0001‡
Gender of neonates				
Female	26 (46.43%)	28 (57.14%)	54 (51.43%)	0.273†
Male	30 (53.57%)	21 (42.86%)	51 (48.57%)	
Mode of delivery				
NVD	3 (5.36%)	11 (22.45%)	14 (13.33%)	0.01*
Vacuum assisted vaginal delivery	0 (0%)	1 (2.04%)	1 (0.95%)	
LSCS	53 (94.64%)	37 (75.51%)	90 (85.71%)	
Neonatal outcomes				
GA at delivery (weeks)	36.85 ± 1.88	37.3 ± 1.42	37.06 ± 1.69	0.175‡
Birth weight (kg)	2.64 ± 0.52	2.34 ± 0.42	2.5 ± 0.5	0.002‡
APGAR score at 1 minute	8 ± 0	8 ± 0	8 ± 0	1‡
APGAR score at 5	9 ± 0	9.02 ± 0.14	9.01 ± 0.1	0.322‡

minutes				
Adverse perinatal outcomes				
Premature birth (<37 weeks)	16 (28.57%)	15 (30.61%)	31 (29.52%)	0.819†
Low birth weight	14 (25%)	29 (59.18%)	43 (40.95%)	0.0004†
APGAR score <7	0 (0%)	0 (0%)	0 (0%)	NA
Presence of meconium	0 (0%)	0 (0%)	0 (0%)	NA
NICU admission	23 (41.07%)	6 (12.24%)	29 (27.62%)	0.001†
Need for resuscitation	4 (7.14%)	2 (4.08%)	6 (5.71%)	0.683*
‡ Independent t test, * Fisher's exact test, † Chi square test				

Table 2: Univariate logistic regression to assess effect of CPR and UCR on adverse outcomes

Variables	Odds ratio (95% CI)		p value	
	CPR	UCR	CPR	UCR
Total study subjects (n =105)				
	1.562(0.672 to 3.63)	0.351(0.174 to 0.709)	0.3	0.003
Premature birth (<37 weeks)	0.899(0.497 to 1.626)	1.085(0.634 to 1.857)	0.724	0.767
Premature birth (<30 weeks)	59.27(8.585 to 409.2)	0.314(0.017 to 5.768)	<0.0001	0.435
Low birth weight	0.824(0.475 to 1.431)	1.93(1.136 to 3.279)	0.492	0.015
NICU admission	1.651(0.915 to 2.979)	0.275(0.123 to 0.618)	0.096	0.002
Need for resuscitation	0.729(0.211 to 2.523)	0.509(0.131 to 1.978)	0.618	0.329
Early onset FGR (n = 56)				
Caesarean section	1.155(0.542 to 2.46)	0.38(0.023 to 6.18)	0.71	0.496
Premature birth (<37 weeks)	1.164(0.549 to 2.468)	0.427(0.028 to 6.551)	0.691	0.541
Premature birth (<30 weeks)	0.656(0.25 to 1.723)	1.283(0.461 to 3.572)	0.392	0.633
Low birth weight	1.747(0.799 to 3.822)	0.114(0.004 to 3.148)	0.162	0.199
NICU admission	1.664(0.804 to 3.444)	0.134(0.009 to 2.047)	0.17	0.149
Need for resuscitation	0.916(0.23 to 3.641)	0.242(0.001 to 51.764)	0.9	0.604
Late onset FGR (n = 46)				
Cesarean section	0.621(0.233 to 1.658)	1.286(0.46 to 3.6)	0.342	0.632

Premature birth (<37 weeks)	6.176(0.78 to 48.907)	0(0 to 63.749)	0.085	0.14
Low birth weight	0.416(0.161 to 1.079)	0.82(0.309 to 2.175)	0.071	0.69
NICU admission	1.089(0.3 to 3.956)	0.56(0.109 to 2.88)	0.897	0.488
Need for resuscitation	0.302(0.023 to 4.024)	0.33(0.016 to 6.816)	0.365	0.473

Table 3: Correlation of CPR and UCR with GA at delivery & birth weight

Variables	**Total subjects N= 105**		**Early onset FGR N= 56**		**Late onset FGR N = 49**	
	GA at delivery (weeks)	Birth weight (kg)	GA at delivery (weeks)	Birth weight (kg)	GA at delivery (weeks)	Birth weight (kg)
CPR						
Correlation coefficient	-0.053	0.040	-0.153	-0.195	0.169	0.315
P value	0.591	0.685	0.261	0.150	0.247	0.027
UCR						
Correlation coefficient	0.120	-0.232	0.082	0.172	-0.017	-0.051
P value	0.223	0.017	0.547	0.205	0.910	0.730

Table 4: Receiver operating characteristic curve of CPR and UCR for predicting outcome in growth restricted foetuses (n- 105)

Variables	Cesarean section		Premature birth (<37 weeks)		Low birth weight		NICU admission		Need for resuscitation	
	CPR	UCR	CPR	UCR	CPR	UCR	CPR	UCR	CPR	UCR
Area under ROC curve (AUC)	0.573	0.755	0.522	0.505	0.553	0.641	0.599	0.72	0.515	0.598
Standard Error	0.0754	0.0664	0.063	0.0635	0.0584	0.0564	0.0642	0.0557	0.108	0.103
95% Confidence interval	0.426 to 0.721	0.625 to 0.885	0.398 to 0.645	0.380 to 0.629	0.438 to 0.667	0.530 to 0.751	0.473 to 0.725	0.611 to 0.829	0.304 to 0.726	0.396 to 0.799
P value	0.3307	0.0001	0.7295	0.9398	0.3683	0.0126	0.1245	0.0001	0.8882	0.343

Cut off	>1.76	≤1.73	≤1.4	>2.08	≤1.76	>1.11	>1.71	≤0.8	≤2.28	≤0.58
Diagnostic accuracy	58.10 %	80.00 %	39.29 %	39.29 %	58.10 %	65.71 %	52.38 %	67.62 %	29.52 %	63.81 %

Table 5: Receiver operating characteristic curve of CPR and UCR for predicting outcome in Early - onset FGR group (n- 56)

Variables	Cesarean section		Premature birth (<37 weeks)		Low birth weight		NICU admission		Need for resuscitation	
	CPR	UCR	CPR	UCR	CPR	UCR	CPR	UCR	CPR	UCR
Area under ROC Curve (AUC)	0.626	0.623	0.509	0.512	0.577	0.578	0.601	0.601	0.514	0.512
Standard Error	0.17	0.172	0.0864	0.0866	0.0937	0.094	0.078	0.0779	0.0974	0.103
95% Confidence interval	0.293 to 0.958	0.285 to 0.960	0.340 to 0.679	0.342 to 0.681	0.394 to 0.761	0.394 to 0.762	0.449 to 0.754	0.448 to 0.754	0.324 to 0.705	0.310 to 0.714
P value	0.4584	0.4764	0.9136	0.8923	0.409	0.4051	0.1934	0.1959	0.8823	0.9071
Cut off	>2.15	≤0.44	>1.1	≤0.77	>1.31	≤0.27	>2.15	≤0.43	>1.71	≤0.58
Diagnostic accuracy	37.50%	35.71 %	39.29 %	39.29 %	39.29 %	78.57 %	62.50 %	62.50 %	39.29 %	35.71 %

Table 6: Receiver operating characteristic curve of CPR and UCR for predicting outcome in Late - onset FGR group (n- 49)

Variables	Cesarean section		Premature birth (<37 weeks)		Low birth weight		NICU admission		Need for resuscitation	
	CPR	UCR	CPR	UCR	CPR	UCR	CPR	UCR	CPR	UCR
Area under ROC curve (AUC)	0.521	0.649	0.561	0.503	0.637	0.558	0.517	0.537	0.638	0.644
Standard Error	0.094	0.0899	0.0956	0.103	0.0805	0.0844	0.164	0.127	0.322	0.071
95% Confidence interval	0.337 to 0.706	0.473 to 0.825	0.373 to 0.748	0.302 to 0.704	0.479 to 0.795	0.392 to 0.723	0.196 to 0.839	0.287 to 0.786	0.00802 to 1.000	0.504 to 0.783
P value	0.82	0.0981	0.5248	0.9771	0.0885	0.4939	0.9153	0.7725	0.6671	0.043

Cut off	>1.75	≤1.73	≤1.24	≤1.3	≤1.22	≤1.48	>0.95	≤2.28	≤0.86	≤1.58
Diagnostic accuracy	57.14 %	63.27 %	73.47 %	71.43 %	59.18 %	53.06 %	14.29 %	30.61 %	93.88%	63.27%

Table 7: Univariate logistic regression to assess significant risk factors of adverse perinatal outcome in total study subjects (N- 105)

Variable	Beta coefficient	Standard error	P value	Odds	Odds ratio Lower bound (95%)	Odds ratio Upper bound (95%)
Caesarean section						
GA by LMP (weeks)	-0.127	0.075	0.088	0.881	0.761	1.019
Umbilical artery PI	-0.893	0.858	0.298	0.410	0.076	2.201
CPR PI	0.396	0.417	0.342	1.486	0.657	3.365
MCA PI	0.265	0.492	0.590	1.303	0.497	3.420
UCR	-1.007	0.352	0.004	0.365	0.183	0.728
Premature birth <37 week						
GA by LMP (weeks)	-0.008	0.050	0.872	0.992	0.900	1.093
Umbilical artery PI	0.491	0.720	0.495	1.635	0.399	6.701
CPR PI	-0.093	0.301	0.757	0.911	0.506	1.642
MCA PI	0.029	0.361	0.935	1.030	0.508	2.090
UCR	0.077	0.273	0.777	1.080	0.632	1.847
Premature birth <30 week						
GA by LMP (weeks)	-0.203	0.138	0.141	0.817	0.623	1.070
Umbilical artery PI	-4.772	3.810	0.210	0.008	0.000	14.794
CPR PI	4.082	0.986	<0.0001	59.270	8.585	409.200
MCA PI	3.826	1.064	0.0003	45.892	5.704	369.266
UCR	-1.159	1.485	0.435	0.314	0.017	5.768
Low birth weight						

GA by LMP (weeks)	0.132	0.053	0.012	1.141	1.029	1.265
Umbilical artery PI	-0.183	0.693	0.792	0.833	0.214	3.241
CPR PI	-0.191	0.281	0.496	0.826	0.476	1.433
MCA PI	-0.376	0.352	0.286	0.686	0.344	1.369
UCR	0.639	0.269	0.018	1.894	1.117	3.212
NICU Admission						
GA by LMP (weeks)	-0.100	0.052	0.052	0.905	0.818	1.001
Umbilical artery PI	-0.013	0.755	0.986	0.987	0.225	4.338
CPR PI	0.490	0.300	0.103	1.632	0.906	2.939
MCA PI	0.788	0.377	0.037	2.200	1.051	4.605
UCR	-1.220	0.400	0.002	0.295	0.135	0.646
Need of resuscitation						
GA by LMP (weeks)	-0.081	0.086	0.347	0.922	0.778	1.092
Umbilical artery PI	0.506	1.234	0.682	1.659	0.148	18.639
CPR PI	-0.212	0.579	0.714	0.809	0.260	2.513
MCA PI	-0.009	0.708	0.990	0.991	0.248	3.967
UCR	-0.511	0.610	0.402	0.600	0.181	1.984

Multivariate logistic regression to assess significant risk factors of adverse perinatal outcomes in total study subjects (N- 105)

Variable	Beta coefficient	Standard error	P value	Odds ratio	Odds ratio Lower bound (95%)	Odds ratio Upper bound (95%)
Premature birth (<30 weeks)						
CPR PI	4.503	1.167	0.0001	90.247	9.164	888.740
MCA PI	0.014	1.137	0.990	1.014	0.109	9.417
Low birth weight in total study subjects						
GA by LMP (weeks)	0.090	0.064	0.162	1.094	0.965	1.240

UCR	0.340	0.334	0.309	1.405	0.730	2.705
NICU admission in total study subjects						
MCA PI	0.575	0.419	0.170	1.777 0.781		4.044
UCR	-0.988	0.378	0.009	0.372	0.177	0.781

Table 8: Univariate logistic regression to assess significant risk factors of adverse perinatal outcome in Early onset FGR Group (N-56)

Variable	Beta coefficient	Standard error	P value	Odds ratio	Odds ratio Lower bound (95%)	Odds ratio Upper bound (95%)
Caesarean section						
GA by LMP (weeks)	0.450	0.150	0.003	1.569	1.168	2.107
Umbilical artery PI	-2.085	1.421	0.142	0.124	0.008	2.013
CPR PI	0.521	0.817	0.523	1.684	0.340	8.347
MCA PI	0.000	1.005	1.000	1.000	0.140	7.164
UCR	-1.807	1.994	0.365	0.164	0.003	8.172
Premature birth <37 week						
GA by LMP (weeks)	0.000	0.098	1.000	1.000	0.824	1.213
Umbilical artery PI	-0.285	0.994	0.774	0.752	0.107	5.276
CPR PI	0.152	0.383	0.691	1.164	0.549	2.468
MCA PI	0.378	0.484	0.435	1.459	0.566	3.765
UCR	-0.851	1.393	0.541	0.427	0.028	6.551
Premature birth **<30 week**						
GA by LMP (weeks)	-0.406	0.148	0.006	0.667	0.499	0.891
Umbilical artery PI	-4.131	3.377	0.221	0.016	0.000	12.041
CPR PI	1.821	1.056	0.085	6.176	0.780	48.907
MCA PI	3.542	1.279	0.006	34.544	2.814	424.007

UCR	-12.683	8.591	0.140	0.000	0.000	63.749
Low birth weight						
GA by LMP (weeks)	-0.001	0.103	0.995	0.999	0.817	1.222
Umbilical artery PI	-0.580	1.061	0.584	0.560	0.070	4.480
CPR PI	0.534	0.397	0.179	1.706	0.783	3.718
MCA PI	0.656	0.504	0.193	1.927	0.718	5.175
UCR	-1.840	1.614	0.254	0.159	0.007	3.754
NICU Admissions						
GA by LMP (weeks)	0.066	0.095	0.486	1.068	0.887	1.286
Umbilical artery PI	-0.585	0.929	0.529	0.557	0.090	3.438
CPR PI	0.477	0.369	0.197	1.611	0.781	3.321
MCA PI	0.690	0.490	0.160	1.993	0.762	5.209
UCR	-1.910	1.371	0.163	0.148	0.010	2.174
Need of resuscitation						
GA by LMP (weeks)	-0.113	0.134	0.397	0.893	0.687	1.160
Umbilical artery PI	-0.048	1.703	0.977	0.953	0.034	26.822
CPR PI	0.000	0.687	1.000	1.000	0.260	3.846
MCA PI	0.000	0.878	1.000	1.000	0.179	5.593
UCR	-0.609	2.249	0.787	0.544	0.007	44.688
Multivariate logistic regression to assess significant risk factors of Premature birth (<30 weeks) in Early onset FGRs group.						
GA by LMP (weeks)	-0.101	0.249	0.685	0.904	0.555	1.472
MCA PI	0.622	1.019	0.541	1.863	0.253	13.722

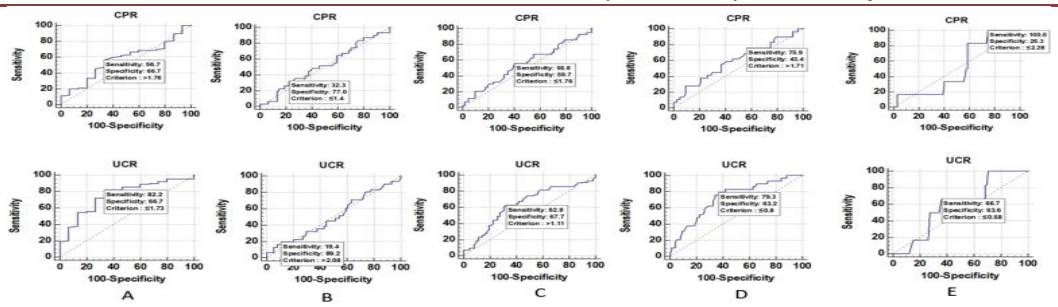

Figure 1: Receiver operating characteristic curve of CPR for predicting adverse perinatal outcomes in total study subjects

A – Cesarean section , B- Premature Birth (<37 weeks), C – Low birth weight , D- NICU Admission , E – Need for resuscitation

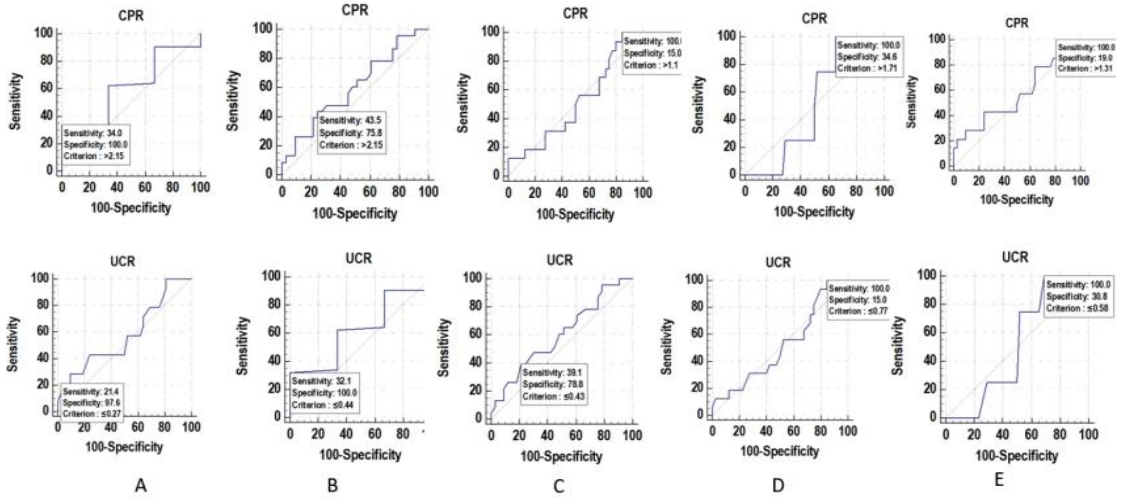

Figure 2: Receiver operating characteristic curve of CPR for predicting adverse perinatal outcomes in early onset FGR group

A – Cesarean section, B- Premature Birth (<37 weeks), C – Low birth weight, D- NICU Admission, E – Need for resuscitation

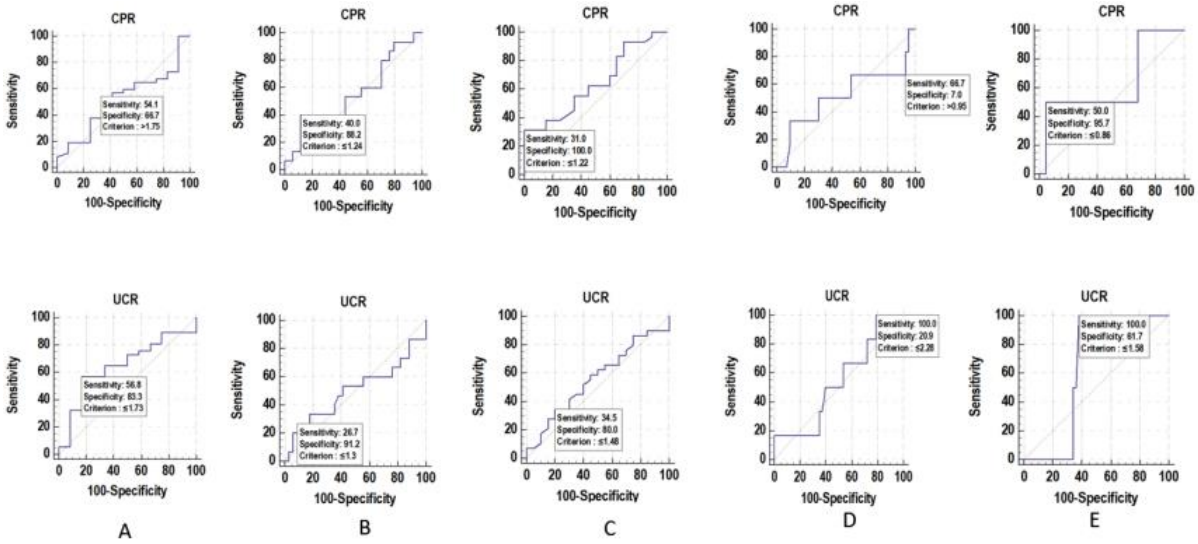

Figure 3: Receiver operating characteristic curve of CPR for predicting adverse perinatal outcomes in late onset FGR group

A – Cesarean section, B- Premature Birth (<37 weeks), C – Low birth weight, D- NICU Admission, E – Need for

resuscitation.

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