| Original Article | # The Value or Cerebro-Placental Ratio, Umbilical and Middle Cerebral Arteries' Pulsatility Indices in Predicting Perinatal Adverse Outcomes Related to Preeclampsia at 34-40 Weeks of Gestation |

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ABSTRACT

Introduction: Proper evaluation of preeclampsia is one of the mainstays of the obstetric practice worldwide. It is important given it has possible devastating consequences, it is one of the leading causes of maternal and perinatal morbidity and mortality.

Methods: This was a prospective case-control study conducted in the emergency department of the maternity department of Kasr-Al Ainy University teaching hospital involving 62 pregnant women diagnosed with preeclampsia and 62 healthy pregnant women all between 34-40 weeks of gestation; they were all submitted to Doppler ultrasound examination of the fetal umbilical and middle cerebral arteries (RI, PI and S/D). Cerebro-placental ratio was also calculated. The link to adverse maternal and perinatal outcomes was examined. The level of statistical significance was set at $p \leq 0.05$.

Results: Among the women diagnosed with preeclampsia, 93.5% delivered via C-section compared to 53.2% in the control group. UA and MCA (PI and S/D) and cerebro-placental ratio were higher in the patients' group compared to the control group. All Doppler parameters were associated with higher incidence of adverse perinatal outcomes including IUGR, low birth weight, metabolic acidosis, and low APGAR score and NICU admission. Abnormal MCA (RI, PI and S/D), UA (PI and S/D) and CPR Doppler indices had 100% specificity in predicting IUGR, low birth weight and NICU admission with 100% PPV.

Conclusion: Assessing Doppler parameters including MCA, UA and CPR is an integral tool to guide the evaluation and management of preeclampsia to avoid complications and improve maternal and perinatal outcomes.

INTRODUCTION

Worldwide, pre-eclampsia (PE) is a leading cause of maternal morbidity, mortality and adverse neonatal outcome. This disease represents 2 to 8% of pregnancy-related complications, more than 50,000 maternal deaths, and over 500,000 fetal deaths worldwide[1].

Preeclampsia is best described as a pregnancy-specific syndrome that can affect virtually every organ system. It is still unknown what exactly causes Preeclampsia, though there is substantial evidence showing excessive maternal systemic inflammatory response and an imbalance between circulating angiogenic and anti-angiogenic factors. The pathophysiology of preeclampsia has been described as incapability of the trophoblast to invade properly the myometrium causing a limited remodelling of spiral arteries. Clinical manifestations of preeclampsia are preceded by the impaired placental perfusion caused by vascular abnormalities. Doppler ultrasound (US) is being tested as an indicator of the hemodynamic repercussion caused by established preeclampsia[2].

Many studies have been dedicated to evaluate the role of fetal Doppler indices (middle cerebral, umbilical artery & MCA/UA Pulsatility index ratio) as a non-invasive tool in the prediction of adverse perinatal outcomes in the infants of women with preeclampsia[3,4].

The aim of this study is to evaluate the effect of preeclampsia on fetal Doppler parameters of MCA and UA in addition to CPR. We investigated the correlation of these Doppler parameters with perinatal outcomes at 34-40 weeks of gestation.

METHODS

This is a prospective case-control study conducted in the emergency department of the maternity department of Kasr-Al Ainy University teaching hospital. A total of 124 patients were recruited and subdivided into 2 groups' Group (A) included 62 pregnant women diagnosed with preeclampsia defined according to the ACOG practice bulletin[2]. Group (B) was the control group and included 62 healthy pregnant women.

The study inclusion criteria included singleton pregnancy, gestational age of 34-40 weeks based on the 1st day of last menstrual period or CRL documented in 1st trimester scan.

The diagnosis of preeclampsia was based on those criteria; hypertension diagnosed after 20 weeks of gestation (systolic blood pressure greater than or equal 140 mm Hg and diastolic blood pressure of 90 mm Hg or higher on 2 occasions at least 4 hours apart) and proteinuria, or in the absence of proteinuria Hypertension plus new onset thrombocytopenia, renal insufficiency, impaired liver function, pulmonary edema and hypertension unresponsive to medication and not accounted for by alternative diagnosis or visual symptoms[2].

The study exclusion criteria were evidence of fetal structural anomalies or aneuploidies, smoking and alcohol intake, associated co-morbidities' diabetes mellitus, hepatic and renal disease.

After informed written consent was obtained, patients rested in a supine position with their backs supported in a 45 degrees position to avoid compression of the IVC in a room with controlled temperature and moderate lighting. All measurements were done by the same sonographer with an experience of 3 years using the same ultrasound machine (Samsung sonoAce R3). Growth scans were done for all participants using the hadlock measurements.

All Doppler measurements were performed with correction for the angle of insonation. This was achieved by aligning the electronic cursor on the display parallel to the direction of blood flow in the insonated artery. The angle correction (angle between the Doppler beam and the long axis of the vessel) for the UA and MCA was less than 150 for maximum Doppler shift.

UA Doppler wave forms were obtained in a free umbilical cord loop, while MCA was visualized using colour flow mapping in an axial view of the fetal head at the level of the cerebral peduncles. In order to register the values in UA and MCA, three spectral continuous and identical waves were considered, after verification of regular maternal and fetal cardiac frequency, without breath and/or fetal movement interference over at least three uniform waveforms of heart cycles.

The CPR was calculated by dividing the obtained MCA-PI by the UA-PI.

Adverse outcomes were defined as the occurrence of one or more of the following; low 5 minutes APGAR score <7, metabolic acidosis at birth <7.2, low birth weight (defined as birth weight of less than 2500g), intrauterine growth restriction (IUGR) below the 10th centile, admission to NICU and perinatal death.

Statistical analysis

The authors initially summarized data as a mean ± standard deviation (SD) in a form of comparison tables and graphs. Range, mean, and SD across participants were calculated for UA-PI, MCA-PI, and CPR. Also, they calculated the 5th, 50th, and 95th percentiles by the mean of the measurements for each parameter. Authors used Student's t-test (unpaired t-test) when comparing variables. They used Pearson's correlation coefficient ® to evaluate the relationships between indices and CPR of controls and gestational hypertension groups, where r > 0 indicates positive relationship, r < 0 indicates negative relationship and r = 0 indicates no relationship; *P-value* was used for the significance of the results. They are significant when *P* is <0.05. Statistical analysis was performed using the standard Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL, USA) version 20 for windows.

RESULTS

A total of 124 women were recruited and subdivided into two groups; 62 in the patients' group and 62 in the control group. General characteristics of the study population are shown in (Table 1). There was a statistically significant increase in the number of C-sections between the 2 groups; in the patients' group 58 (93.5%) had C-sections whereas 4 (6.5%) had normal vaginal deliveries (NVD), in the control group 33 (53.2%) had C-sections whereas 29 (46.8%) had normal vaginal deliveries with a *P value* of <0.001. There is no statistically significant difference between groups as regard Age, Parity & GA (weeks).

Table 1: Comparison of general characteristics between study groups

Baseline characteristics	Pt. group (n=62)	Control Group (n=62)	Test value	*p-value*
Age (years)				
Mean±SD	29.53±6.69	28.42±6.66	t:0.928	0.355
Range	18-40	16-42		
Parity				
Multigravida	44 (71.0%)	48 (77.4%)	x^2:0.674	0.412
Primigravida	18 (29.0%)	14 (22.6%)		
GA (weeks)				
Mean±SD	37.39±1.64	37.90±1.63	t:1.737	0.085
Range	35-40	35-40		
Mode of delivery				
CS	58 (93.5%)	33 (53.2%)	x^2:25.80	<0.001**
NVD	4 (6.5%)	29 (46.8%)		

(Table 2) shows that blood pressure (systolic and diastolic) and pulse rate is higher in the patients' group compared to the control group which is statistically significant.

Table 2: Comparison of systolic and diastolic blood pressure and pulse rate between study groups

Hemodynamic parameters	Patients' group (n=62)	Control Group (n=62)	t-test	*p-value*
SBP (mmHg)				
Mean±SD	155.65±15.11	115.81±10.01	17.309	<0.001**
Range	140-200	80-130		
DBP (mmHg)				
Multigravida	99.76±8.02	75.35±6.46	18.661	<0.001**
Primigravida	90-120	60-90		
Pulse				
CS	91.79±7.51	88.42±8.61	2.323	0.022*
NVD	77-110	70-105		

(Table 3) compares adverse perinatal outcomes in the patients' group compared to the control group and shows that their occurrence is higher in pregnancies complicated with preeclampsia. However, only IUGR, low birthweight, low Apgar score at 5 minutes, and NICU admissions are statistically significant.

**Table 3:** Comparison of perinatal outcome between study groups

Perinatal outcome	Pt. group (n=62)	Control Group (n=62)	Test value	*p-value*
IUGR				
No	45 (72.6%)	62 (100.0%)	x^2:19.70	<0.001**
Yes	17 (27.4%)	0 (0.0%)		
Birth weight (grams)				
Multigravida	2904.03±545.07	3133.06±331.04	t:2.828	0.005*
Primigravida	1600-3800	2300-4000		
Apgar Score a (5min)				
Median (IQR)	6 (5-7)	8 (8-9)	U:6.911	<0.001**
Range	4-9	7-10		
Cord pH				
Mean±SD	7.26±0.04	7.3±1.25	t:1.842	0.068
Range	7.17-7.35	7.25-7.35		
NICU admission				
No	42 (67.7%)	62 (100.0%)	FE	<0.001**
Yes	20 (32.3%)	0 (0.0%)		
Convulsed				
No	59 (95.2%)	62 (100.0%)	FE	0.080
Yes	3 (4.8%)	0 (0.0%)		
Death				
No	60 (96.8%)	62 (100.0%)	FE	0.154
Yes	2 (3.2%)	0 (0.0%)		

(Table 4) summarizes the Doppler ultrasound findings and its comparison between patients and controls. MCA RI, PI, and S/D are higher in the patients' group compared to the control group. Umbilical artery RI is similar in both groups whereas PI is statistically significantly higher in the patients' group compared to the control group. With regards to the S/D it is also significantly higher in the patients' group compared to the control group (Figures 1a,b, 2a,b). Finally, the study compared the CPR among the study groups which is statistically significantly higher in the patients' group compared to the control group.

Table 4: Comparison of Doppler indices between study groups

Doppler	Pt. group (n=62)	Control Group (n=62)	t-test	*p-value*
MCA:				
RI				
Mean±SD	0.70±0.07	0.68±0.07	1.815	0.092
Range	0.6-0.82	0.5-0.8		
PI				
Mean±SD	1.48±0.21	1.37±0.19	3.249	0.002*
Range	1.23-1.97	1.2-1.75		
S/D				
Mean±SD	4.22±0.89	3.74±0.73	3.283	<0.001**
Range	3.16-6.6	3.16-5.33		
UA:				
RI				
Mean±SD	0.53±0.03	0.53±0.03	0.351	0.727
Range	0.5-0.6	0.5-0.6		
PI				
Mean±SD	0.79±0.05	0.76±0.05	3.151	0.002*
Range	0.7-0.9	0.67-0.85		
S/D				
Mean±SD	2.40±0.26	2.28±0.15	3.244	0.002*
Range	2.1-3.47	2.1-2.51		
CPR				
Mean±SD	1.86±0.18	1.77±0.15	2.714	0.008*
Range	1.5-2.2	1.6-2.2		
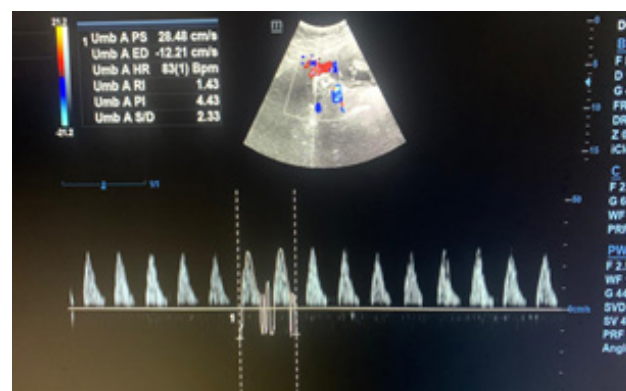
Fig. 1a: Fetal umblical artery UA Doppler indices in patient with preeclampsia P34 w+4days .Notice the absent end-diastolic flow of UA.
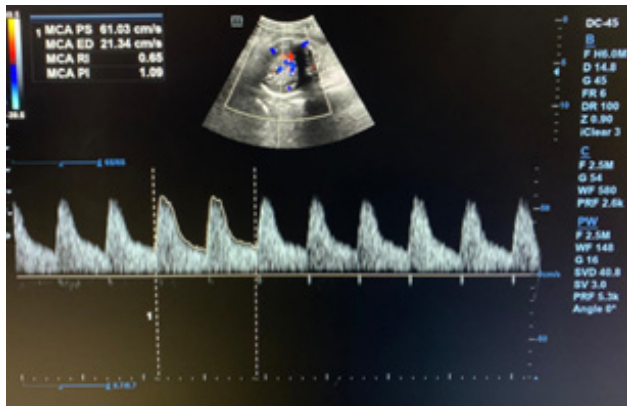
Fig. 1b: Fetal Middle cerebral artery MCA Doppler indices in patient with preeclampsia P34 w+4days. The CPR is > 1.
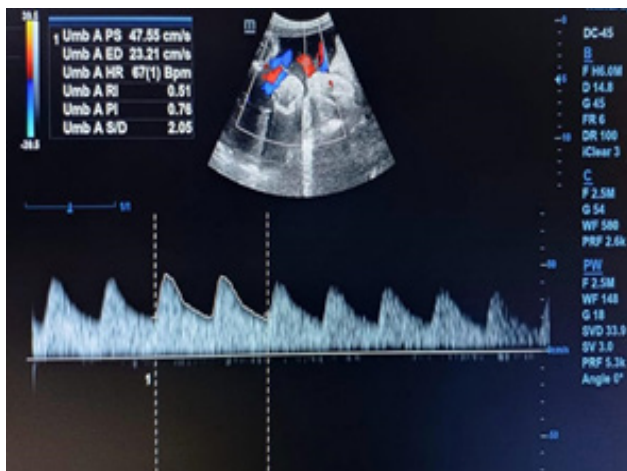

Fig. 2a: Fetal umbilical artery UA Doppler indices in healthy pregnant women without preeclampsia P36 w+5days.
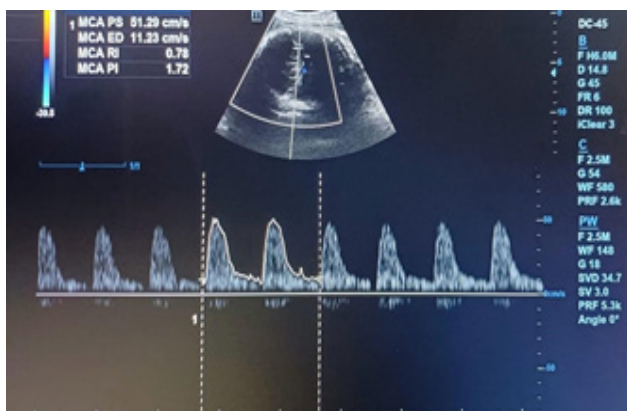

Fig. 2b: Fetal Middle cerebral artery MCA Doppler indices in healthy pregnant women without preeclampsia P36 w+5days. The CPR is >1.

(Table 5) presented that, there were a statistically significant negative correlation between MCA, UA and CPR with Birth weight (grams), Apgar Score a (5min) and Cord pH, with *p-value* (*p*<0.001); while UA-RI insignificant correlation with different parameters with *p-value* (*p*>0.05).

(Table 6) shows that all the parameters are higher in pregnancies associated with IUGR, however, only Umbilical artery RI is statistically insignificant.

(Table 7) shows that all the parameters are higher in new-borns admitted to the NICU. However, only Umbilical artery RI and S/D are statistically insignificant.

Receiver operating characteristics (ROC) curve was used to define the best cut off value of MCA: RI which was ≥0.68 and area under the curve was 0.603(0.501-0.704), with *p-value* 0.051; While cut off value of MCA: PI was ≥1.25 and area under the curve was 0.676 (0.580-0.771) with *p-value* *p*<0.001; Additionally, MCA: S/B cut off value of ≥3.3 and area under the curve was 0.631 (0.531-0.732) with *p-value* *p*=0.013; Also cut off value of UA: RI was ≥0.55 and area under the curve was 0.511 (0.408-0.615) with *p-value* *p*>0.05; while cut off value of UA: PI was ≥0.76 and area under the curve was 0.647 (0.548-0.745) with *p-value* *p*-0.005; as well as UA: S/D cut off value of ≥2.21 and area under the curve was 0.667 (0.571-0.764) with *p-value* *p*<0.001; as for the CPR was cut off value of ≥1.75 and area under the curve was 0.647 (0.548-0.745) with *p-value* *p*=0.005

Based on the data presented in (Figure 3, Table 8), In the current study, the highest overall sensitivity and accuracy were MCA: S/D was Sensitivity (59.0%) and Accuracy (65.0%), followed by MCA: RI was Sensitivity (55.3%) and Accuracy (61.0%) and UA: PI was Sensitivity (54.9%) and Accuracy (60.5%), then MCA: PI was Sensitivity (53.1%) and Accuracy (58.2%), followed by UA: S/D was Sensitivity (53.5%) and Accuracy (58.8%) and CPR was Sensitivity (53.5%) and Accuracy (58.2%), while the lowest value in UA: RI was Sensitivity (50.0%) and Accuracy (53.1%).

If we look at highest (< 90%) sensitivity, specificity, positive and negative predictive values allocated to each adverse outcome, we noticed that:

- MCA RI, PI and S/D have 100% specificity in predicting IUGR, low birth weight and NICU admission with 100% positive predictive value .the overall PPV of MCA RI, PI and S/D are 92.7 %, 96.4 %, 90 % PPV respectively. MCA PI has 95.5 % PPV of low APGAR score.

- UA PI and S/D have 100% specificity in predicting IUGR, low birth weight and NICU admission with 100% positive predictive value. Their overall PPV were 92.3% and 95.7 % respectively.

- CPR has 100% specificity in predicting IUGR, low birth weight and NICU admission with 100% positive predictive value.

Table 5: Correlation between MCA, UA and CPR with low birth weight (less than 2500 gm), Low 5 minutes APGAR score of <7 and low cord blood pH <7.2 mmHg, using Pearson Correlation Coefficient among the study groups:

Perinatal out come RI		MCA			UA			CPR
		PI	S/D	RI	PI	S/D		
Birth weight (grams)	r-value	-0.647	-0.859	-0.866	-0.211	-0.678	-0.524	-0.750
	p-value	<0.001**	<0.001**	<0.001**	0.109	<0.001**	<0.001**	<0.001**
Apgar Score at 5min	r-value	-0.601	-0.764	-0.752	-0.208	-0.620	-0.422	-0.662
	p-value	<0.001**	<0.001**	<0.001**	0.113	<0.001**	<0.001**	<0.001**
Cord pH	r-value	-0.611	-0.824	-0.823	-0.193	-0.656	-0.555	-0.771
	p-value	<0.001**	<0.001**	<0.001**	0.143	<0.001**	<0.001**	<0.001**

Table 6: Association between IUGR and MCA: RI, MCA: PI, MCA:S/D, UA: RI, UA: PI, UA: S/D and CPR in patients' group:

Doppler	IUGR				t-test	*p-value*
	No		Yes			
	Mean	±SD	Mean	±SD		
MCA: RI	0.68	0.06	0.75	0.05	-3.340	<0.001**
MCA: PI	1.41	0.18	1.72	0.11	-6.178	<0.001**
MCA: S/D	3.91	0.73	5.23	0.56	-6.201	<0.001**
UA: RI	0.53	0.03	0.54	0.04	-0.508	0.613
UA: PI	0.78	0.05	0.82	0.04	-3.024	0.004*
UA: S/D	2.36	0.28	2.52	0.05	-2.135	0.037*
CPR	1.80	0.16	2.05	0.13	-5.442	<0.001**

Table 7: Association between NICU admission and MCA: RI, MCA:PI, MCA: S/D, UA: RI, UA: PI, UA: S/D and CPR, in patients' group:

Doppler	NICU admission				t-test	*p-value*
	No		Yes			
	Mean	±SD	Mean	±SD		
MCA: RI	0.68	0.06	0.75	0.05	-3.980	<0.001**
MCA: PI	1.39	0.17	1.71	0.11	-7.248	<0.001**
MCA: S/D	3.84	0.69	5.17	0.55	-7.072	<0.001**
UA: RI	0.53	0.03	0.54	0.04	-0.787	0.435
UA: PI	0.77	0.05	0.82	0.03	-3.908	<0.001**
UA: S/D	2.35	0.29	2.52	0.05	-2.393	0.020*
CPR	1.78	0.14	2.04	0.13	-6.649	<0.001**

Items	Cut-off	Sen.	Spe.	PPV	NPV	AUC [C.I.95%]	*p-value*
MCA: RI	≥0.68	63.9%	59.0%	60.9%	64.3%	0.603[0.501-0.704]	0.051
MCA: PI	≥1.25	66.1%	61.3%	61.9%	65.5%	0.676[0.580-0.771]	<0.001**
MCA: S/D	≥3.3	65.2%	61.4%	61.8%	65.2%	0.631[0.531-0.732]	0.013*
UA: RI	≥0.55	47.5%	51.6%	48.3%	50.8%	0.511[0.408-0.615]	0.834
UA: PI	≥0.76	67.8%	62.9%	63.5%	67.2%	0.647[0.548-0.745]	0.005*
UA: S/D	≥2.21	66.1%	61.3%	61.9%	65.5%	0.667[0.571-0.764]	<0.001**
CPR	≥1.75	62.7%	64.5%	62.7%	64.5%	0.647[0.548-0.745]	0.005*

Sens.: Sensitivity; Spec.: Specificity; PPV: Positive predictive value; NPV: Negative predictive value; AUD: Area Under the Curve; 95%C.I. Confidence interval

Table 8: Diagnostic accuracy of abnormal fetal Doppler indices [umbilical artery, middle cerebral artery and cerebro-placental ratio] in predicting adverse neonatal outcomes:

|	Sens.%	Spec.%	PPV%	NPV%	Accurac%
MCA: RI (≥0.68)					
IUGR	31.8%	100.0%	100.%	66.7%	49.2%
Birth weight	27.3%	100.0%	100.%	68.1%	45.8%
Apgar Score at (5min)	86.4%	60.0%	86.4%	40.0%	79.7%
NICU admission	38.6%	100.0%	100.%	64.3%	54.2%
Overall	55.3%	77.8%	92.7%	56.8%	61.0%
MCA: PI (≥1.25)					
IUGR	28.6%	100.0%	100.%	77.8%	40.7%
Birth weight	24.5%	100.0%	100.%	78.7%	37.3%
Apgar Score at (5min)	85.7%	80.0%	95.5%	46.7%	84.7%
NICU admission	34.7%	100.0%	100.%	76.2%	45.8%
Overall	53.1%	83.3%	96.4%	65.5%	58.2%
MCA: S/D (≥3.3)					
IUGR	35.9%	100.0%	100.0%	55.6%	57.6%
Birth weight	30.8%	100.0%	100.0%	57.4%	54.2%
Apgar Score at (5min)	89.7%	55.0%	79.5%	26.7%	78.0%
NICU admission	43.6%	100.0%	100.%	52.4%	62.7%
Overall	59.0%	76.7%	90.0%	46.5%	65.0%
UA: RI (≥0.55)					
IUGR	26.1%	77.8%	42.9%	37.8%	57.6%
Birth weight	21.7%	80.6%	41.7%	38.3%	57.6%
Apgar Score at (5min)	78.3%	27.8%	40.9%	33.3%	47.5%
NICU admission	34.8%	75.0%	47.1%	35.7%	59.3%
Overall	50.0%	55.1%	42.2%	33.9%	53.1%
UA: PI (≥0.76)					
IUGR	31.8%	100.0%	100.%	66.7%	49.2%
Birth weight	27.3%	100.0%	100.0%	68.1%	45.8%
Apgar Score at (5min)	84.1%	53.3%	84.1%	46.7%	76.3%
NICU admission	38.6%	100.0%	100.%	64.3%	54.2%
Overall	54.9%	76.7%	92.3%	57.9%	60.5%
UA: S/D (≥2.21)					
IUGR	29.2%	100.0%	100.%	75.6%	42.4%
Birth weight	25.0%	100.0%	100.%	76.6%	39.0%
Apgar Score at (5min)	85.4%	72.7%	93.2%	46.7%	83.1%
NICU admission	35.4%	100.0%	100.%	73.8%	47.5%
Overall	53.5%	81.8%	95.7%	63.9%	58.8%
CPR (≥1.75)					
IUGR	32.6%	100.0%	100.%	64.4%	50.8%
Birth weight	27.9%	100.0%	100.%	66.0%	47.5%
Apgar Score at (5min)	79.1%	37.5%	77.3%	60.0%	67.8%
NICU admission	39.5%	100.0%	100.%	61.9%	55.9%
Overall	53.5%	70.9%	89.6%	65.7%	58.2%
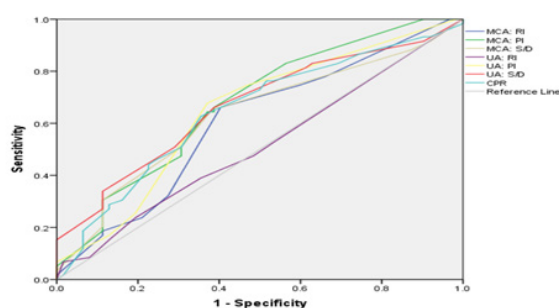
Fig. 3: Receiver-operating characteristic (ROC) curve for Discrimination between preeclampsia group and control group

DISCUSSION

Doppler indices have long been implicated to anticipate poor perinatal outcome of infant of preeclampstic mothers, weather in term of umbilical artery indices or cerebral artery indices or CPR used alone or in combination. CPR has been suggested to be incorporated in ultrasound software for the assessment of the high risk pregnancy[5-7].

The main finding of the study is that the incidence of adverse perinatal outcomes including IUGR, low birth weight, low Apgar score at 5 minutes, low cord PH and NICU admission were statistically significantly higher among preeclampsia group compared to the control group. Prediction of these adverse perinatal outcomes using Doppler indices warranted the delivery by C- section which was also statistically significantly higher in preeclampsia group. In the patient group (93.5%) had C-sections whereas in the control group (53.2%) had C-sections with a *P value* of <0.001.As the rate of CS increases the short term and long term complication of CS follows.

As regard Doppler indices, MCA RI, PI and S/D, UA PI and S/D and CPR were statistically significantly higher in the patients' group compared to healthy pregnant women.

There were a statistically significant negative correlation between MCA Doppler values, UA Doppler values and CPR with Birth weight (grams), Apgar Score a (5 min) and Cord pH, with *p-value* ($p<0.001$); apart from UA-RI which has insignificant correlation with different parameters with *p-value* ($p>0.05$).

The authors also correlated Doppler blood flow parameters with the incidence of IUGR which were all statistically significantly higher in cases of IUGR except for UA RI.

Recent studies were reviewed, and they were generally in agreement with the study results.

Moawad *et al.*,(2022) conducted a prospective cohort study on 60 women diagnosed with severe preeclampsia classified into2 groups based on poor perinatal outcome. Statistically Significant differences were demonstrated UA PI (1.28 ± 0.23 vs. 0.96 ± 0.21, *P* <0.001), UA RI (0.78 ± 0.09 vs. 0.62 ± 0.09, *P* <0.001), MCA PI (1.27 ± 0.28 vs. 1.45±0.20, *P* 0.005), MCA RI (0.67 ± 0.10 vs. 0.76 ± 0.08, *P*<0.001), Cerebroplacental ratio (1.01 ± 0.36 vs. 1.57 ± 0.35, *P* <0.001) in women with adverse and normal perinatal outcome respectively[7].

Oyekale *et al.*, (2021) evaluated the resistive indices (RIs) of the fetal umbilical and middle cerebral arteries and the cerebro-placental ratio (CPR) in fetuses of women with hypertension. They found that maternal hypertension during pregnancy appears to be associated with increased fetal umbilical artery RI, reduced fetal middle cerebral artery RI and low CPR. The mean umbilical artery RI was significantly higher in the group of hypertensive women than in the healthy group (0.67 ± 0.14 vs. 0.61 ± 0.08; $p = 0.012$), whereas the mean middle cerebral artery RI was significantly higher in the healthy group (0.80 ± 0.05 vs. 0.76 ± 0.08; $p = 0.001$). Among the women with hypertension, the mean CPR was significantly lower for those with proteinuria than for those without (1.07 ± 0.26 vs. 1.27 ± 0.22)[8].

In a meta-analysis done by Heidweiller-Schreurs CA *et al.*, (2021), the prognostic value of combining CPR with UA PI, versus UA PI only and CPR only were compared, with a one-stage IPD approach. Subgroup analyses were done according to gestational age, birthweight centile and estimated fetal weight centile. The main outcome measures were poor perinatal outcome, defined as perinatal death, CS for fetal compromise or NICU admission. Adverse outcomes occurred in 3423 (18%) participants. The model with UA PI alone resulted in an area under the curve (AUC) of 0.775 (95% CI 0.709–0.828) and with CPR alone in an AUC of 0.778 (95% CI 0.715–0.831). Addition of CPR to the UA PI model resulted in an increase in the AUC of 0.003 points (0.778, 95% CI 0.714–0.831). These results were consistent across all subgroups. Thus it concluded that CPR has a limited value in anticipating adverse perinatal outcome beyond UA PI, when assessing singleton pregnancies, irrespective of gestational age or fetal size[9].

In an earlier systematic review and meta-analysis done by Heidweiller-Schreurs CA *et al.*, (2018) examining the prognostic accuracy of cerebroplacental ratio and middle cerebral artery Doppler for adverse perinatal outcome, it concluded that Calculating the CPR with MCA Doppler can add value to UA Doppler assessment in the prediction of adverse perinatal outcome in women with a singleton pregnancy[10].

On reviewing the International Society of Ultrasound in Obstetrics and Genecology practice guidelines; they concluded that absent or reversed end-diastolic velocity in the UA is strongly linked with perinatal morbidity

and mortality. Reduced MCA-PI $< 10^{th}$ percentile is an indicator of brain vasodilatation and has been linked with emergency Caesarean sections due to non-reassuring fetal heart rate in CTG traces of growth-restricted fetuses. CPR $< 10^{th}$ percentile is considered to be an indicator of hemodynamic redistribution and can be observed even earlier than the affection of the UA. And thus amongst their recommendations were Examination of fetal biometry, amniotic fluid volume, uterine artery, umbilical artery (UA) and fetal middle cerebral artery (MCA) PI and cerebroplacental ratio (CPR), as well as placental visualization to exclude abruption, should be considered for women admitted for PE or with suspected PE, as well as for those with severe PE or HELLP syndrome (GOOD PRACTICE POINT)[11].

In the current study, the highest overall sensitivity and accuracy were MCA: S/D was Sensitivity (59.0%) and Accuracy (65.0%), followed by MCA: RI was Sensitivity (55.3%) and Accuracy (61.0%) and UA: PI was Sensitivity (54.9%) and Accuracy (60.5%), then MCA: PI was Sensitivity (53.1%) and Accuracy (58.2%), followed by UA: S/D was Sensitivity (53.5%) and Accuracy (58.8%) and CPR was Sensitivity (53.5%) and Accuracy (58.2%).

Many researches has been conducted to investigate the accuracy and sensitivity of Doppler indices in pregnant women with preeclampsia .Lin *et al*.,(2023) investigated the fetal MCA, UA blood flow values and CPR to predict fetal distress and small for gestational age (SGA) in patient with gestational hypertension. The MCA-RI (sensitivity: 70.1%, specificity: 64.3%) and MCA-RI (sensitivity: 52.4%, specificity: 84.6%) were the best indices to predict fetal distress and SGA, respectively during GA of 35-40 weeks[12].

Zarean *et al*.,(2022) evaluated the CRP in patient suffering from hypertensive disorders during pregnancy and its correlation to adverse perinatal outcomes (namely SGA, poor APGAR, requirement of assisted respiration, academia and NICU admission). In general CPR had sensitivity, specificity, PP, NPV, and accuracy of 51.8%, 71.2%, 40%, 80%, and 66%, respectively in the prediction of such poor outcomes[13].

In the same context Moawad *et al*.,(2022) concluded that abnormal UA PI and RI represented the most specific tool for predicting IUGR, low Apgar score with positive predictive values were 52, 87 and 57%, respectively[7].

CONCLUSION

Our study concluded when comparing the study groups that CPR was a good parameter in predicting adverse perinatal outcome (IUGR, low APGAR score, low birth weight and NICU admission). It is beneficial to add CPR to other ultrasound blood flow values in the assessment of high risk pregnancy.

CONFLICT OF INTERESTS

There are no conflicts of interest.

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