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Relationship Between Cerebroplacental Ratio and Fetal Outcome Among Women with Preeclampsia in Irrua, Edo State, Nigeria

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ABSTRACT

Background: Fetal Doppler ultrasound scan has become a quick way of screening for fetal compromise and determining appropriate management in high-risk pregnancies such as preeclampsia. The role of cerebroplacental ratio for this purpose is being explored. Aim: The aim of this study is to evaluate the relationship between cerebroplacental ratio and fetal outcome among women with preeclampsia. Methodology: This prospective cohort study was among 100 consecutive women with singleton pregnancies and preeclampsia between

34weeks and 37 weeks of gestation, recruited for umbilical and middle cerebral artery Doppler with the cerebroplacental ratio (CPR) determined. Statistical analysis was performed using SPSS 23.0, with significance set at $p < 0.05$. Results: Among them, 19% had pathologic CPR of <1 while 81% had normal CPR. The APGAR scores were significantly lower among those with pathologic CPR in the first minute (X^2=40.443, df=2, P<0.001) and fifth minute (X^2=17.311, df=2, P<0.001) respectively. Out of those admitted in the special care baby unit (SCBU), 62.1% had abnormal CPR while 37.9% had normal CPR (X^2=49.23, df=1, P<0.001). One intrauterine fetal death occurred in each group and of the cases of Early Neonatal Death (ENND), 5(83.3%) had abnormal CPR and 1(16.7%) had a normal CPR which was statistically significant (X^2=14.118, df=2. p=0.001). Conclusion: A significant relationship between CPR and adverse perinatal outcome exists, in terms of low APGAR scores, SCBU admission and perinatal mortality in neonates of women with preeclampsia with no significant difference in the mode of delivery.

Keywords: Fetal Doppler, cerebroplacental ratio (CPR), preeclampsia, perinatal outcome.

BACKGROUND

Globally, Preeclampsia and other hypertensive disorder of pregnancy are a leading cause of maternal and infant illness and death. By conservative estimates, these disorders are responsible for 76,000 maternal and 500,000 infant deaths each year (*Wenda et al, 2014*) affecting about 2-10% of pregnant women and is a major cause of fetomaternal morbidity and mortality (*Osungbade et al 2011*). The etiology of preeclampsia is still not completely known, it has been long assumed that insufficient uterine, placental, and fetal circulations result in adverse pregnancy outcomes and that those abnormalities can be defined by the use of Doppler ultrasonography (*Oforma et al, 2025*).

Moreover, a few local studies more representative of our immediate population focused more on uterine and/or umbilical artery Doppler indices as predictors of pregnancy outcome in women with preeclampsia (*Adekanmi et al,2019*). The role of cerebroplacental ratio could however be a more reliable predictor of fetal outcome among women with preeclampsia as it was previously demonstrated in predicting adverse perinatal outcome among women with high risk pregnancies generally *(Anita et al,2017)*. It was also demonstrated that MCA/UA Pulsatility Index (PI) ratio was the best Doppler indices and timely interventions improved perinatal outcome however this was not specific to preeclampsia only and the sample size was rather small.

Furthermore, another study showed that conditional centile of cerebroplacental ratio is an independent predictor of perinatal outcomes however this was also among a general high risk population with significant inter-observer variations as a total of nineteen doctors performed the Doppler measurements (*Karlsen et al, 2016*).The knowledge of the cerebroplacental ratio in women with preeclampsia can therefore serve as a template for modifying obstetric care and interventions in women with preeclampsia and this research utilized more composite Doppler indices which is the MCA/UA PI ratio pattern with less inter-observer variations and the relationship with fetal outcome among women with preeclampsia in Irrua was determined.

REVIEW OF LITERATURE

The international society for the study of hypertension in pregnancy (ISSHP) defines preeclampsia as the occurrence of hypertension in combination with proteinuria, developing after 20 weeks gestation in a previously normotensive non-proteinuric patient (*Davy et al, 1988*). A study to assess the effect of asymptomatic malaria parasitemia on the uterine and umbilical artery blood flow impedance in third-trimester singleton Southwestern Nigerian pregnant women by Adelodun et al showed Doppler ultrasound to be safe and effective (*Adelodun et al, 2018*).

Doppler velocimetry studies of umbilical artery can provide obstetricians important information regarding fetal wellbeing to improve the fetal outcome. The relationship between abnormal umbilical artery Doppler and perinatal outcome in high risk pregnancies have been demonstrated (*Abdulrazak H et al, 2015*). Meanwhile, in a retrospective hospital based cohort study in which CPR was compared with umbilical cord pH, APGAR scores, birth weight and mode of delivery in 2,270 singleton pregnancies, the APGAR score and birth weights of the neonates were found to be significantly lower in the group of patients with pathologic CPR compared to the group of patients with normal CPR (p<0.001). (*Gruttner et al, 2019*).

A prospective study over a year period assessed the association of CPR in women above 37years of gestation with known risk factors for small for gestational age who had Doppler ultrasound done a week to delivery. The patients were followed up till delivery and out of the 117 analyzed, 23(19.6%) had pathologic CPR <1 of which 22(91.30%) had adverse outcomes while among 4 patients (80.34%) who had normal CPR≥1 only 19(20.21%) had adverse perinatal outcomes. This was found to be statistically significant (p<0.0001) (*Anand et al, 2020*). In sub-Saharan Africa where adverse perinatal outcome resulting from preeclampsia is common, this can be obviated by early detection of fetal compromise using not only the umbilical artery Doppler findings but also by considering the entire cerebroplacental circulation, which necessitated this study.

Aim

The aim of this study is to evaluate the relationship between cerebroplacental ratio and fetal outcome among women with preeclampsia.

METHODOLOGY

Study Area and Population

This study was conducted at the Obstetrics and Gynecology Department of Irrua Specialist Teaching Hospital (ISTH), located in Irrua, the local government headquarters of Esan Central Local Government Area in Edo State, Nigeria, with a study population of pregnant women who met the inclusion criteria for participation which includes: women with single gestation and an elevated blood pressure of SBP ≥140mmHg and/or DBP ≥90mmHg and significant proteinuria of ≥300mg in a 24hr urinary protein estimation or ≥ 2+ of protein on dip stick urinalysis after the 20th week of gestation, participants between 34 completed weeks of gestation and 37 completed weeks of gestation with gestational age reliably determined from a last menstrual period or from an early ultrasound scan, those from whom a written informed consent had been obtained and those with no other known coexisting medical condition(s). In the same vein, Preeclamptic women with fetal congenital anomalies, multiple gestation or intrauterine fetal

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death at recruitment and those who refuse to give a written informed consent were summarily excluded from this research.

Study Design

This was a prospective cohort study that was conducted in the antenatal clinic, antenatal ward, Labour ward, special care baby unit and the postnatal ward of Irrua specialist teaching hospital (ISTH), Irrua, Edo State, Nigeria.

Sample Size Determination

The sample size was calculated using an estimated prevalence of preeclampsia of 6% from a previous Nigerian study (*Swati et al 2014*) and with 10% anticipated loss to follow up, the sample size was 97 at a confidence level of 95% using the Kish and Leslie formula (*Suresh et al 2012*), a total of 100 participants however were recruited.

$$N = Z^2pq/d^2$$

- N = The minimum sample size
- Z = The area under the curve corresponding to 95% confidence interval which is set at 1.96
- P = Prevalence of preeclampsia (6%)

$$q = 1- p$$

- d = Degree of accuracy of the study set at 0.05 at 95% confidence interval

$$N = \frac{(1.96^2)(0.06)(0.94)}{(0.05^2)}$$

$$N = \frac{0.0216666}{0.0025}$$

$$N= 86.670$$

To make for attrition (none response rate) at 10%

$$n_s = \frac{N}{1 - n_n}$$

Where:

- n_s = Actual sample size for research
- N = Sample size calculated
- n_n = Non response rate (10%)
- $n_s = \frac{86.67}{1-0.1} = \frac{86.67}{0.9} = 96.3$
- $n_s = 97 \approx 100$ participants were thus recruited

Sampling Technique/Patient Selection

Consecutive pregnant women who met the inclusion criteria were counselled and written informed consents obtained from them prior to recruitment into this study. The questionnaire was used as a tool in collecting data from the participants before and after delivery.

Methods

All participants who met the inclusion criteria were counselled by the researcher (and trained research assistants), informed consents were obtained from them and thereafter they were enrolled into the study. Participants went through a detailed history, physical examination, ultrasound study biometry and Doppler study which involved:

(a) Umbilical artery peak systolic to end diastolic velocity ratio (S/D), end diastolic velocity (EDV), resistance index (UA RI), pulsatility index (UA PI)

(b) Middle cerebral artery peak systolic to end diastolic velocity ratio (S/D), end diastolic velocity (EDV), resistance index (MCA RI), pulsatility index (MCA PI)

(c) Cerebroplacental ratio (CPR) which is the ratio of the middle cerebral artery pulsatility index to the umbilical artery pulsatility index (MCA PI/UA PI). The APGAR scores in the 1st and 5th minutes of the neonate were determined and any value <7 was taken as abnormal (*Karlsen et al, 2016*), birth weight measurement of the fetus and measurement of placental weight and the neonates were followed up through the neonatal period to assess for specific neonatal complication(s), need for SCBU admission or mortality.

Procedure of Ultrasound & Doppler Examinations

Transabdominal ultrasound was performed on all study participants with the patient in the recumbent position and the transducer in the longitudinal plane. Data was collected using a CE0123Mindray^{R} ultrasound machine with a convex probe 3.5MHz (Model: DC-3,8N-MU-24007499; 2012-04; 220-240V;50/60 Hz, 600VA; Shenzen mindray bio-medical electronics.co.Ltd) with colour flow and spectral wave Doppler capabilities as well as onscreen display of flow velocity scales or pulse repetition frequency (PRF) following application of water soluble coupling gel over the abdomen.

Ultrasonography for fetal biometry and morphology was done following which Doppler was switched on, then the transducer was placed over the uterus and carefully manipulated till a free loop of umbilical cord is seen by Grey scale imaging and colour was used to identify the umbilical artery. Thus Doppler waveform was obtained and recordings of umbilical artery was obtained from a free loop of umbilical cord. These was identified with the characteristic "saw-tooth" appearance and typical Doppler shift wave forms appearance on the screen. It was done in fetal apnea as breathing alters the Doppler shifts, with sampling gate placed over both the umbilical artery and vein and the probe was angulated at 45^{0}. Waveforms obtained had a maximum frequency shift along with venous flow signals display in reverse side. Seeing 3 or 4 waves of equal heights, the images were frozen and measurements were obtained directly from the machine. A complete Doppler interrogation of the cord was ensured by obtaining the umbilical venous signals simultaneously with the arterial signals.

To investigate the middle cerebral artery, a transverse view of the fetal brain was obtained at the level of the biparietal diameter, the transducer was then moved towards the base of the skull at the level of the lesser wing of the sphenoid bone. The middle cerebral artery was seen using colour flow imaging as a major lateral branch of the circle of Willis, running antero-

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laterally at the borderline between the anterior and the middle cerebral fossae. The pulsed Doppler sample gate was then placed on the middle portion of this vessel to obtain flow velocity waveforms at an angle of insonation less than 10°, the readings were then obtained from the machine. Care was taken to apply minimal pressure to the maternal abdomen with the transducer.

Parameters studied include the S/D ratio,PI and RI in the umbilical artery and in the middle cerebral artery. In both arteries, abnormalities in these indices were noted. A reduced, absent or reversed end diastolic flow velocity in umbilical artery or an increased end diastolic velocity in the middle cerebral artery were noted. The cerebroplacental ratio (CPR) was determined by taking the ratio of the Middle cerebral artery pulsatility index (MCA PI) and the Umbilical artery pulsatility index (UAD PI). CPR: ≥1.0 was taken as normal and < 1.0 was taken as abnormal (*Flood et al, 2014*).

These patients were followed up till delivery with details of pregnancy events, labour,delivery and fetal outcome noted such as 1st and 5th minute APGAR scores,birth weights and SCBU admissions among others.

Data Analysis

The cerebroplacental ratio obtained and fetal outcomes were entered into Microsoft spread sheet. The data was analysed using IBM SPSS version 23.0 software. Statistical tests were considered significant at P <0.05 at 95% confidence level. Test of associations between determinants of primary outcome was done using the chi-square test. The results were presented using tables and bar charts.

Ethical Consideration

Approval for the study was obtained from the ISTH Health Research Ethics Committee through the Head of Department of Obstetrics and Gynaecology. Informed written consent was obtained from the participants in an environment free of coercion or undue influence before recruitment into the study. Privacy was ensured and all information that was supplied were handled confidentially. Participants were also informed that there were no penalties or loss of benefits for refusal to participate in the study or withdrawal from it. Overall ethical considerations in this study was based on the general ethical principles as applicable to human subjects (*CIOMS 1993*), these are respect for persons, beneficence, non-maleficence and justice.

RESULTS

A total of 100 consenting women with preeclampsia at a gestational age of 34-37 weeks were recruited, studied and analyzed.

In Table I, there was no statistically significant difference in the overall socio-demographic characteristics of the participants with normal or abnormal cerebroplacental ratio. The age range of the respondents was 20-42years with a mean of 30.38±5.79, while the median age was 30.6 years and modal age was 30.3years. Majority were married in both categories 79(79%) and 16(16%) respectively, most respondents with normal CPR had tertiary level of education 47(47%) compared with 7(7%) of those with abnormal CPR and the participants belonged predominantly to the Esan tribe 48(48%) with normal CPR and 8(8%) with abnormal CPR.

Table I: socio-demographic characteristics of study participants

Variables	NORMAL CPR (N=81)	ABNORMAL CPR (N=19)	X^2	P-VALUE
Age (in years)				
20-24	9 (9.0%)	4 (4.0%)	1.541 (df=3)	0.673
25-29	27 (27.0%)	6 (6.0%)		
30-34	28 (28.0%)	6 (6.0%)		
≥ 35	17 (17.0%)	3 (3.0%)		
Marital status				
Married	79 (79.0%)	16 (16.0%)	2.808 (df=2)	0.246
Single	1 (1.0%)	3 (3.0%)		
Separated	1 (1.0%)	0 (0.0%)		
Socio-economic class				
1	25 (25.0%)	4 (4.0%)	2.189 (df=4)	0.701
2	20 (20.0%)	5 (5.0%)		
3	17 (17.0%)	3 (3.0%)		
4	11 (11.0%)	4 (4.0%)		
5	8 (8.0%)	3 (3.0%)		
Level of education				
Primary education	9 (9.0%)	5 (5.0%)	6.458 (df=2)	0.253
Secondary education	25 (25.0%)	7 (7.0%)		
Tertiary education	47 (47.0%)	7 (7.0%)		
Tribe				
Esan	48 (48.0%)	8 (8.0%)	7.560 (df=4)	0.109
Bini	16 (16.0%)	2 (2.0%)		
Etsako	9 (9.0%)	5 (5.0%)		
Igbo	4 (4.0%)	1 (1.0%)		
Others	4 (4.0%)	3 (3.0%)		

In Table II, the multiparous women made up the largest proportion of study participants 62(62%) compared to 34(34%) of nulliparous respondents. While 31(31%) had a history of PIH or preeclampsia, majority of participants have no prior history 69(69%). However, majority had a family history of hypertension 68(68%) as against 32(32%) with no similar family history while most 16(16%) were assessed to have normal body mass index (BMI) others had various degrees of obesity with majority being obesed 38(38%).

Table II: Risk Factors and Gynaecological History

Variable	Frequency (N=100)	Percent
Parity		
Nulliparity	34	34.0
Multipara	62	62.0
Grand multipara	4	4.0
Previous history of *PIH/pre-eclampsia		
Yes	31	31.0
No	69	69.0
Family history of hypertension		
Yes	68	68.0
No	32	32.0

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Body mass index (BMI)		
Normal	16	16.0
Overweight	18	18.0
Obese	38	38.0
Moderate obesity	24	24.0
Morbid/severe obesity	4	4.0

*PIH: Pregnancy-induced hypertension

In Table III, it is shown that majority of study participants were booked 81(81%) and majority were not admitted in the index pregnancy 84(84%). There were varying degrees of proteinuria, majority 40(40%) had 3+ and the mean SBP at contact was 150(±15.1) mmHg at contact compared to 134.6(±21.1) at booking while the mean DBP at contact was 93.5(±12.7) mmHg compared to 85.4(±17.7) mmHg at booking.

Table III: Subjects' Characteristics in Current Pregnancy

Variable	**Frequency (N=100)**	**Percent**
Booking status		
Booked	81	81.0
Unbooked	19	19.0
Admission in index pregnancy		
Yes	16	16.0
No	84	84.0
Proteinuria		
+	28	28.0
++	32	32.0
+++	40	40.0
Mean booking SBP: 134.6 (±21.1) mmHg		
Mean booking DBP: 85.4 (±17.7) mmHg		
Mean SBP at current contact: 150 (±15.1) mmHg		
Mean DBP at current contact: 93.5 (±12.7) mmHg		

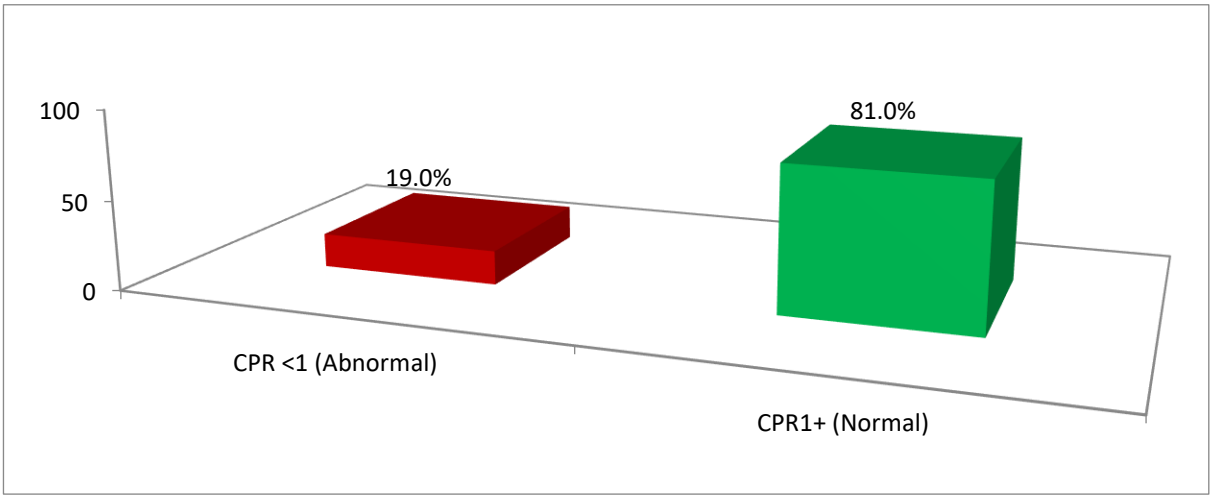

Figure 1: Distribution of subjects according to CPR

Figure 1 shows that 81% of subjects had fetuses with normal CPR

In Table IV, majority of women in this study had fetuses with normal CPR 81(81%) while abnormal CPR was found in the others 19(19%). The middle cerebral artery pulsatility index and the umbilical artery pulsatility index were less than the 95th percentile in 95(95%) of the study population.

Table IV: Ratio of MCA PI And UA PI

Variable	Frequency	Percent
MCA PI (95th percentile =2.5)		
<95th percentile	95	95.0
>95th percentile	5	5.0
UA PI (95th percentile =1.86)		
<95th percentile	95	95.0
>95th percentile	5	5.0
CPR		
<1.0 (Abnormal)	19	19.0
≥1.0 (Normal)	81	81.0

In Table V, it is indicated that over one-third of the study participants had emergency CS due to prelabour fetal compromise 39(39%) while 24(24%) had elective CS. Vaginal birth was spontaneous and induced successfully in 20(20%) and 12(12%) of the women respectively. While 5(5%) had a failed induction and subsequent Caesarean delivery, there were however no maternal complications in most of the participants 98(98%).

Table V: Pregnancy Outcome (Mode of Delivery) and Maternal Complication

Variable	Frequency	Percent
Mode of delivery		
Emergency Caeserean delivery due to prelabour fetal compromise	39	39.0
Elective Caesarean delivery	24	24.0
Spontaneous labour and delivery	20	20.0
Successful induction of labour	12	12.0
Failed induction of labour and emergency Caesarean delivery	5	5.0
Maternal Complications		
None	98	98.0
Eclampsia	0	0.0
Acute kidney injury	1	1.0
ICU admission	1	1.0

Table VI, shows that majority of the participants71(71%) had their deliveries at 37 weeks of gestation and birth weight of 3.0 to 3.99 kg was recorded for more than half of the babies 51(51%) while 37(37%) had birth weights between 2.0 – 2.99kg, while 10 babies had weights less than 2kg, two babies weighed above 4kg. Quite more than half 57(57%) of the babies had APGAR scores of 7-10 in the first minute with 93(93%) in total having APGAR scores up to 7-10 in the fifth minute.

Table VI: Fetal Outcomes

Variable	Frequency (N=100)	Percent
Gestational age at birth (in weeks)		
34	11	11.0

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35	2	2.0
36	15	15.0
37	71	71.0
38	1	1.0
Birth weight at birth (in Kg)		
< 1.0	1	1.0
1.0 – 1.99	9	9.0
2.0 – 2.99	37	37.0
3.0 – 3.99	51	51.0
≥4.0	2	2.0
Apgar score in 1st minute		
< or = 4	15	15.0
5-6	28	28.0
7-10	57	57.0
Apgar score in 5th minute		
< or = 4	1	1.0
5-6	6	6.0
7-10	93	93.0

In Table VII, 29 (29%) of the neonates required Special Care baby unit admissions while majority of the babies born to the study participants did not require SCBU admission 71(71%) and there were 6(6%) early neonatal deaths (ENND) and 2(2%) intrauterine fetal deaths (IUFD) with no perinatal mortalities recorded in majority of the cases 92(92%).

Table VII: Other Outcomes

Variable	Frequency	Percent %
Placental weight (in Kg)		
0.0-0.19	0	0.0
0.20-0.39	9	9.0
0.40-0.59	48	48.0
0.60-0.79	39	39.0
0.80-1.00	4	4.0
SCBU Admission		
Yes	29	29.0
No	71	71.0
Perinatal mortality		
None	92	92.0
IUFD	2	2.0
ENND	6	6.0

Table VIII, shows that normal CPR was significantly associated with higher first minute APGAR scores (X^2=40.443, df=2, P<0.001). A far larger proportion of subjects with normal CPR, 56(56%) had APGAR scores of 7-10 compared to those with abnormal CPR in the first minute.

Table VIII: Association Between CPR And APGAR Score At 1st Minute

CPR	APGAR score			Total (%)	Statistics
	≤4	**5-6**	**7-10**		
	Frequency (%)	Frequency (%)	Frequency (%)		

Abnormal	11 (57.9)	7 (36.8)	1 (5.3)	19 (100)	X^2=40.443
Normal	4 (4.9)	21 (25.9)	56 (69.1)	81 (100)	df=2
Total	15 (15.0)	28 (28.0)	57 (57.0)	100 (100)	P<0.001

In table IX, it was demonstrated that more subjects with normal CPR 79(97.5%) had better APGAR scores of 7-10 in the 5th minute compared with those with abnormal CPR 14 (73.7%). This association was statistically significant (X^2=17.311, df=2, P<0.001).

Table IX: Association Between CPR and APGAR Score at 5th Minute

CPR	**Apgar score**			**Total (%)**	**Statistics**
	≤4	**5-6**	**7-10**		
	Frequency (%)	Frequency (%)	Frequency (%)		
Abnormal	0 (0.0)	5 (26.3)	14 (73.7)	19 (100)	X^2=17.311
Normal	1 (1.2)	1 (1.2)	79 (97.5)	81 (100)	df=2
Total	1 (1.0)	6 (6.0)	93 (93.0)	100 (100)	P<0.001

Table X, shows that there were statistically significant associations between CPR and abnormal fetal outcomes. Most subjects with normal CPR did not have SCBU admissions(p<0.001), poor APGAR scores(p<0.001) nor perinatal mortalities (p= 0.001).

Table X: Association between CPR and abnormal Fetal Outcomes

Characteristics	**CPR**		**Statistics**
	Abnormal	**Normal**	
	Frequency (%)	**Frequency (%)**	
SCBU admission			
Yes	18 (62.1)	11 (37.9)	X^2=49.23
No	1 (1.4)	70 (98.6)	df=1, p<0.001
Poor 1st minute Apgar score			
Yes	18 (41.9)	25 (58.1)	X^2=25.62
No	1 (1.8)	56 (98.2)	df=1, p<0.001
Poor 5th minute Apgar score			
Yes	5 (71.4)	2 (28.6)	X^2=13.44
No	14 (15.1)	79 (84.9)	df=1, p<0.001
Perinatal mortality			
No	13 (14.1)	79 (85.9)	X^2=14.118*
IUFD	1 (50.0)	1 (50.0)	df=2, p=0.001
ENND	5 (83.3)	1 (16.7)	

*Chi square likelihood ratio

Table XI, shows that a higher proportion of participants with normal CPR had spontaneous deliveries compared to those with abnormal CPR. However, this relationship was not statistically significant (X^2=3.184, df=1, p=0.074).

Table XI: Association between CPR and mode of delivery

Mode of delivery	**CPR**		**Statistics**
	Abnormal	**Normal**	
	Frequency (%)	**Frequency (%)**	
Spontaneous	1 (5.0)	19 (95.0)	X^2=3.184

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Interventional	18 (22.5)	62 (77.5)	df=1, p=0.074

DISCUSSION

The early detection of the fetus at risk of death or compromise remains a subject of great importance in modern obstetrics to ensure early intervention and avoid delay in management that could have serious perinatal consequences, this study was conducted to evaluate the relationship between cerebroplacental ratio (CPR) and fetal outcome among women with Preeclampsia in Irrua, Edo State, Nigeria; in order to determine the association between CPR and perinatal outcome.

The women recruited for the study were one hundred (100) consecutive women over a period of seven months between May 2020 and November 2020, who were consenting adults with preeclampsia between 34 completed weeks and 37 completed weeks of gestation during which the CPR was determined and they were followed up till delivery noting APGAR scores, birth weight, need for Special Care Baby Unit admissions, perinatal mortality and mode of delivery.
The age range of the respondents was 20-42years with a mean ± standard deviation of 30.38±5.79, the median age was 30.6 years and modal age was 30.3years. These were a little lower than the values in a prospective study on the prediction of adverse pregnancy outcomes using umbilical artery Doppler in women with hypertensive disorders in AKTH Kano Nigeria by Ayuba et al, in which, a mean age of 31.33±5.92 and a median age of 31.5years were documented, although the age range in the study was 18-40 years *(Ayub et al, 2015)*. This suggests that the age at conception is similar across the nation and the slight reduction in this study could be as a result of societal efforts in reducing marital, hence maternal age irrespective of career pursuit among women.

The participants (29%) in the first socio-economic class were in the majority, probably due to the fact that this group of women as expected, seek skilled antenatal care compared to their counterparts who despite having this complication (preeclampsia) might have other pathologies that excludes them from the study, or they're not available for specialist hospital management and are lost to peripheral or unskilled care. More than half of the participants (56%) belonged to the Esan tribe which is the predominant tribe in the study environment giving a degree of homogeneity to the population of study.

Among the respondents, 19% had a pathologic CPR <1 while 81% had a normal CPR ≥1 which was in keeping with the findings in a similar study that evaluated CPR among low risk pregnancies *(Anand et al, 2020)*. In this study, 19.65% and 80.34% of those evaluated had pathologic CPR and normal CPR respectively, suggesting that abnormalities in CPR are not limited to preeclampsia and the effect of other conditions that could adversely affect fetal well being can be evaluated using the CPR.

Among the 19 women with abnormal CPR, 18(94.7%) of them had a first minute APGAR score <7 while among the 81women with a normal CPR, 25(30.8%) of them had a APGAR score of <7 which was statistically significant (X^2=40.443, df=2, P<0.001). The fifth minute APGAR score showed a similarly statistically significant difference (X^2=17.311, df=2, P<0.001) with 5 (26.3%) fetuses of participants with Abnormal CPR having a APGAR score of <7 as compared to 2 (2.4%) fetuses among those with Normal CPR having a similar score of <7 in the fifth minute. This demonstrates a significant association between an abnormal CPR and low APGAR scores in the

first and fifth minute, which was in keeping with a significant association between pathologic CPR and low APGAR scores also established in previous studies *(Fiolna et al 2019 and Gruttner et al 2019)*. The vasculopathy associated with preeclampsia and brain sparing effect as a result of fetal hypoxia in utero is reflected in the first minute APGAR score in those with abnormal CPR while the fifth minute APGAR score shows a higher percentage of those <7(26.3%) compared to those with normal CPR (2.4%) probably due to a more challenging resuscitative efforts in these group of neonates with CPR abnormalities.

The First and fifth minutes' APGAR scores however, <7 in 30.8% and 2.4% of fetuses respectively with normal CPR also suggests that there are indeed other factors responsible for a low APGAR score apart from an abnormal Doppler scan as alluded by other authors *(Indiramani et al, 2016)*.

There were a total of 29 Special care baby unit (SCBU) admissions out of the 100 participants, 18(62.1%) of whom had an abnormal CPR while 11(37.9%) of the admissions were for fetuses who had a normal CPR which showed a statistically significant association between an abnormal CPR and SCBU admission (X^2=49.23, df=1, P<0.001). One case of intrauterine fetal death (IUFD) was recorded among those with abnormal CPR and another among those with a normal CPR while 6 fetuses had Early Neonatal Death, out of which 5(83.3%) had prior abnormal CPR and 1(16.7) had a normal CPR. This depicts that a significant association exists between perinatal mortality and abnormal CPR (X^2=14.118, df=2. p=0.001).

A higher proportion of those with pathologic CPR had interventional deliveries compared to those with normal CPR however this was not statistically significant (X^2=3.184, df=1, p=0.074) which was in contrast to the study by *Gruttner et al* in which a statistically significant difference (p<0.001) was found as more of those with normal CPR had spontaneous delivery. The mode of delivery being not statistically significant in this study is likely due to the high risk nature of all the pregnancies being patients with preeclampsia irrespective of the CPR unlike in the study by *Gruttner et al* in which a mixture of high risk and low risk pregnancies were evaluated. The reason for a statistically insignificant difference in interventional deliveries in this study could be due to the fact that preeclampsia in itself being a high risk pregnancy has an established risk of interventional deliveries irrespective of CPR results.

In conclusion, there is a significant relationship between cerebroplacental ratio and adverse perinatal outcomes in terms of low APGAR scores, SCBU admission and perinatal mortality in neonates of women with preeclampsia without any significant difference in the mode of delivery. It is therefore recommended, that subsequent studies on cerebroplacental ratio and delivery outcome should ensure a standard Doppler scan delivery interval among the participants to ensure uniformity. However, where this varies, the Z-score should be determined to obviate this limitation. Also, in high risk pregnancies where routine Doppler scans are inconclusive in taking management decisions, CPR should be considered in such cases.

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Authors Contributions

Conceptualization of the study and study design was done by Olugbenga OE and Isabu P, Literature review was done by Olugbenga OE and Omorogbe F, data collection and analysis were done by Olugbenga MA and Okome GBO.

The Doppler scans were under the tutelage of Eigbefoh J, while Alika Sylvester supervised the assessment and management of the neonates. The final editing was done by Momoh M and Olugbenga OE. All the authors reviewed and approved the manuscript for publication.

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