ORIGINAL ARTICLE

Evaluation of the predictive value of fetal Doppler ultrasound for neonatal outcome from the 36th week of pregnancy

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Background: Early prediction of adverse neonatal outcome would be possible by Doppler impedance indices of middle cerebral artery (MCA), umbilical artery (UmA), and descending aortal artery (AO) that result in decrease neonatal morbidity and mortality rate. The aim of the present study was a determination of optimal value for the ratio of MCA to descending aorta blood flow (MCA/AO) impedance indices and its comparison with the ratio of MCA to UmA (MCA/UmA) impedance indices and their relationship with neonatal outcome. **Materials and Methods:** This was a prospective cohort study on 212 pregnant women with gestational age 36 weeks or more, in three hospitals in Tehran, from April 2012 to April 2013. We investigated AO, MCA, and UmA impedance indices Doppler ultrasound every 2 weeks till delivery. The mother was monitored for adverse pregnancy outcome (hypertension [HTN], fetal growth retardation, and other maternal complications) then infant birth weight, cord blood of pH, and Neonatal Intensive Care Unit (NICU) admission during the first 24 h after delivery were assessed. Finally, we investigated relationships between Doppler indices and neonatal outcomes include neonatal body weight (NBW), cord blood of pH, and NICU admission. **Results:** MCA/AO resistance index (RI) and MCA/AO pulsatile index (PI) showed an area under the receiver operating characteristics curve (area under the curve) of 0.905 (95% confidence interval (CI): 0.850, 0.959) and 0.818 (95% CI: 0.679, 0.956), respectively. The cutoff values for pH (≥7.2 vs. <7.2) based on MCA/AO RI and MCA/AO PI indices were 0.951 (sensitivity, 80% and specificity, 86%) and 0.853 (sensitivity, 91% and specificity, 83%), respectively. The cutoff value for NBW (≥2500 vs. <2500 g) based on MCA/UmA PI index was 1.467 (sensitivity, 73% and specificity, 63%). The cutoff value of NICU admission of child based on MCA/AO PI index was 1.114 (sensitivity, 73% and specificity, 54%). **Conclusion:** In the end of third-trimester pregnancies with the assessment of MCA and AO artery Doppler ultrasonography, it is possible to prevent many cases of neonatal acidosis caused by prenatal asphyxia as well as inappropriate interventions which are applied on mother. If MCA/AO PI was <0.85, the fetus needs to be evaluated further because it is at risk for acidosis.

Key words: Complicated pregnancy, Doppler indices, neonatal outcome uncomplicated pregnancy

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INTRODUCTION

There are studies to show effectiveness at improving perinatal outcomes with the application of fetal well-being tests result in prediction neonatal outcome.[1] The neonatal outcome contains body weight, cord blood pH at delivery, and admission of Neonatal Intensive Care Unit (NICU) that determinate timing of delivery, places of delivery (first, secondary, or tertiary center), and necessary personnel and equipment to get ready for the delivery high-risk neonate.

In the past decades, color Doppler ultrasound has been employed for fetal surveillance.[2-4] Doppler studies are noninvasive and help to identify the degree of placental insufficiency and also to detect worsening of the situation, thereby decision to intervene can be taken once the need arises.[5] The results of umbilical artery (UmA)

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Doppler is a reflection of the placenta status, whereas the results obtained from a middle cerebral artery (MCA) and aorta artery indicate the state of fetal circulation.[6] Doppler ultrasound is used in high-risk pregnancies, particularly the cases complicated by fetal growth retardation, preeclampsia, or other maternal medical conditions.[7,2] Abnormal MCA Doppler alone showed limited predictive accuracy for compromise of fetal and neonatal well-being.[8-10] Today, according to the evidence available, Doppler study of the umbilical arteries is the only test that has shown to improve the outcome, reducing perinatal mortality, and reducing obstetric interventions.[5]

After the 34th week of gestational age, cerebroplacental ratio is not significantly related with the prognosis and outcome of the pregnancy.[11,12] Therefore, during the 3rd trimester, the ratio of pulsatile index (PI) and resistance index (RI) of MCA to the descending aorta could be used.[11] This is while various studies have shown that, as the gestational age increases, contrary to other vasculatures, the vascular resistance of descending aorta is kept unchanged.[13-17] Hence, Doppler indices of this artery could be used for investigation of the hemodynamic status, especially after the 34th week of pregnancy.

The studies on the ratios of blood flow in the descending aorta and cerebral arteries have tried to carry out better evaluations on the unfavorable fetal conditions and oxygenation level in small-for-gestational-age fetuses.[13] However, no guidelines are currently available on clinical and physiological determination of fetal arterial circulation, particularly around the end of pregnancy.

The aims of the current study are a diagnosis of placental dysfunction and fetal hypoxia and determination of the predictive value of Doppler ultrasound for neonatal outcome in complicated and uncomplicated pregnancies in late pregnancy with regard to the blood flow indices as long as prevent neonatal asphyxia.

MATERIALS AND METHODS

This was a prospective cohort study on pregnant women in three university hospitals in Tehran, from April 2012 to April 2013. This study was approved by the Ethics Committee within Tehran University of Medical Sciences.

All of the pregnant women with gestational age 36 weeks who came to prenatal clinic for prenatal care and completed the consent form were included in the study. Multiple pregnancies and pregnancies with major fetal anomalies were excluded. For each mother, the demographic characteristics were recorded as well as the reason for referral, history of medical disorders before or during the pregnancy, and familial medical history in a datasheet. The gestational age was calculated according to the regular and reliable last menstrual period, which was found consistent with the crown-rump length reported in the first-trimester ultrasound. If a mother had a medical disorder, a complete history of the condition, a list of drugs taken, and the disease history before and during the pregnancy were recorded.

An ultrasound follow-up with biometric measurement and MCA, UmA and descending (abdominal) aorta Doppler studies was scheduled every 2 weeks till delivery by Siemens ultrasound machine, Antares. During the evaluation, RI, PI, and systolic to diastolic standard deviation (SD) ratio of each artery were measured. Moreover, the mothers were followed for complications such as fetal growth restriction (FGR), preeclampsia, placental abruption, and fetal distress until delivery. For all participants, the history of labor, peripartum hypoxic events, the cause of delivery or cesarean section, neonatal UmA pH, and birth weight (BW) and neonatal sex, follow-up during the first 24 h after delivery was recorded.

According to methodology of Doppler assessment of fetal arteries from "Doppler in obstetrics" in ISOUG educational series, the Doppler indices were measured using an abdominal probe while the mother lies in a semi-recumbent position with a slight lateral tilt, and according to evaluation of the UmA, MCA, and abdominal aortal artery (AO) (just below the bifurcation of renal arteries).[18,19]

After collecting the data, the pregnant women were categorized into two groups; 1 - complicated group contains "FGR, hypertensive disorder, and vasculopathy depend on overt diabetes or systemic lupus erythematosus (SLE) or renal disease" and 2 - uncomplicated group (low-risk pregnancy). Results of the Doppler ultrasound (MCA/AO RI and PI and MCA/UmA RI and PI) and neonatal body weight (NBW), cord blood of pH, and NICU admission in these two groups were analyzed. The neonate is poor outcome with pH <7.2 and NBW <2500 g and NICU admission after than birth but if pH ≥7.2 and or NBW ≥2500, she or he can be a good outcome.[20,21]

Statistical analysis

The Kolmogorov–Smirnov (K-S) test was used to evaluate the normality of the quantitative data. Quantitative and qualitative variables were presented as mean ± SD or median and interquartile range (IQR), as appropriate, and number (percent), respectively. Independent Student's *t*-test was used to compare quantitative variables among studied groups. Distribution of study participants in terms of categorical variables was compared between two groups using the Chi-square test. The Pearson correlation coefficient was used to examine relationships between

Doppler indices and neonatal outcomes. Receiver operating characteristics (ROC) curves were used to determine the predictive value of Doppler indices for neonatal outcomes. In addition, odds ratios (ORs) obtained from logistic regression describe associations of Doppler indices with neonatal outcomes. Data analyses were performed using Statistical Package for the Social Sciences software version 21 (SPSS Inc., Chicago, IL, USA).

RESULTS

In this study, 212 pregnant women were evaluated. Among them, 65 (30.7%) were complicated by fetal growth retardation, hypertensive disorder, and vasculopathy due to overt diabetes or SLE or renal disease. The mean age was 28.12 ± 5.11 years (27.98 ± 4.88 and 28.43 ± 5.63 years for uncomplicated and complicated groups, respectively; $P > 0.05$). Median gestational age at delivery was 37 weeks, 4 days (IQR: 36 weeks, 4 days to 38 weeks, 4 days), 37 weeks, 4 days (IQR: 37 weeks, 4 days to 39 weeks, 4 days), and 37 weeks, 4 days (IQR: 36 weeks, 4 days to 37 weeks, 4 days) for uncomplicated and complicated groups, respectively).

About 8% of women were underweight, 28.3% overweight, and 12.7% obese. Family history of diabetes, heart disease, and thrombophilia was reported in 9.5% of women (6.9% and 15.4% for uncomplicated and complicated groups, respectively; $P = 0.053$). Delivery was performed by cesarean section in 67% of women (64.8% and 71.9% for uncomplicated and complicated groups, respectively, $P = 0.318$). Thirty neonates (14.4%) were admitted to NICU (11 (7.5%) and 19 (30.2%) for uncomplicated and complicated groups, respectively $P < 0.0001$. Nearly 57.1% of women were primary gravid (55.1 and 61.5 for uncomplicated and complicated groups, respectively). Median BW was 3100 g (IQR: 2738.75–3500 g); 3250 g (IQR: 2900–3600 gr), and 2650 g (IQR: 2240–3200 g) for uncomplicated and complicated groups, respectively, $P < 0.0001$. There were statistically significant differences between two groups in terms of umbilical cord pH and Doppler indices (MCA/AO PI, MCA/UmA RI, and MCA/UmA PI) ($P < 0.05$) so that mean of mentioned indices in complicated group was lower than the other group [Table 1].

The correlation of analyzed results for assessing the relationship between Doppler indices with umbilical cord pH and NBW was presented in Table 2. Doppler indices (i.e. MCA/AO RI, MCA/AO PI, MCA/UmA RI, and MCA/UmA PI) correlated significantly with umbilical cord pH. Among them, MCA/AO PI had stronger associations with umbilical cord pH ($r = 0.411$ and 0.510 for total sample and complicated group, respectively, $P < 0.01$). MCA/UmA PI index was significantly correlated with NBW ($r = 0.253$ and 0.376 for total sample and complicated group, respectively, $P < 0.01$).

Mean ± SD of Doppler indices according to status of NICU admission is presented in Table 3. Mean of MCA PI/AO PI index for mothers of neonates admitted to NICU was significantly lower than others in total sample and complicated group ($P < 0.05$). Furthermore, mean of MCA/UmA PI index for mothers of neonates admitted to NICU was significantly lower than others in complicated group ($P < 0.05$).

ROC curves for pH (≥7.2 vs. <7.2) based on Doppler indices are shown in Figures 1-4. MCA RI/AO RI showed an area under the ROC curve (area under the curve [AUC]) of 0.818 (95% CI: 0.679, 0.956), 0.966 (0.93, 1.00), and 0.729 (0.53, 0.93) for total sample, uncomplicated, and complicated groups, respectively [Table 4]. The optimal cutoff point was 0.951 (sensitivity, 80% and 100%; specificity, 86% and 88%) for both total sample and uncomplicated group and 0.827 (sensitivity, 69%; specificity, 90% and 88%) for complicated group [Table 4]. MCA/AO PI index showed an area under the ROC curve (AUC) of 0.905 (95% CI: 0.850, 0.959), 0.940 (0.893, 0.986), and 0.870 (0.774, 0.965) for total sample, uncomplicated, and complicated groups, respectively [Table 4]. The optimal cutoff point was 0.853, 0.849, and 0.880 (sensitivity, 91%, 100%, and 86%; specificity, 83%, 84%, and 80%) for total sample, uncomplicated, and complicated groups, respectively [Table 4]. By comparing the ORs of the four indices and their corresponding 95% confidence interval (CI), again MCA/AO PI demonstrates the highest discriminating power compared to other indices for pH (OR: 0.09, 95% CI [0.05–0.15]) [Table 4].

ROC curve analysis for NBW (≥2500 vs. <2500 g) is shown in Figures 5 and 6. MCA/UmA PI showed an AUC of 0.722 (95% CI: 0.625, 0.819) and 0.748 (0.627, 0.869) for total sample and complicated group, respectively [Table 4]. The optimal cutoff point was 1.467 and 1.471 (sensitivity, 73% and 81%; specificity, 63% and 62%) for total sample and complicated group, respectively [Table 4]. In addition, by comparing the ORs and their corresponding 95% CI, MCA/UmA PI demonstrates the highest discriminating power for NBW (OR: 3.39, 95% CI [2.57–4.56]) [Table 4].

ROC curve for NICU admission of the child based on MCA/AO PI is shown in Figure 7. The optimal cutoff point was 1.114 and 1.07 (sensitivity, 73% and 79%; specificity, 54% and 55%) for total sample and complicated group, respectively [Table 4].

DISCUSSION

In this study with investigation of impedance indices of MCA, UmA, and aorta artery Doppler between 36 and

Table 1: Demographic and obstetric characteristics of study participants

Characteristics	Total sample (*n*=212)	Uncomplicated group (*n*=147)	Complicated group (*n*=65)	*P*
Age (years)	28.12±5.11	27.98±4.88	28.43±5.63	0.555
Gestational age (weeks)				
36-37	61 (28.8)	34 (23.1)	27 (41.5)	<0.0001*
37.1-38	73 (34.4)	45 (30.6)	28 (43.1)	
38.1-39	33 (15.6)	28 (19.0)	5 (7.7)	
39.1-40	30 (14.2)	29 (19.7)	1 (1.5)	
40.1-41	15 (7.1)	11 (7.5)	4 (6.2)	
BMI				
Under-weight	17 (8.0)	12 (8.2)	5 (7.7)	0.555
Normal	108 (50.9)	78 (53.1)	30 (46.2)	
Overweight	60 (28.3)	38 (25.9)	22 (33.8)	
Obese	27 (12.7)	19 (12.9)	8 (12.3)	
Family history of diseases				
Yes	20 (9.5)	10 (6.9)	10 (15.4)	0.053
No	190 (90.5)	135 (93.1)	55 (84.6)	
Delivery route				
Caesarean	140 (67.0)	94 (64.8)	46 (71.9)	0.318
NVD	69 (33.0)	51 (35.2)	18 (28.1)	
NICU admission				
Breast feeding	179 (85.6)	135 (92.5)	44 (69.8)	<0.0001*
NICU	30 (14.4)	11 (7.5)	19 (30.2)	
Child's sex				
Female	99 (47.8)	75 (52.4)	24 (37.5)	0.047**
Male	108 (52.2)	68 (47.6)	40 (62.5)	
Gravida				
1	121 (57.1)	81 (55.1)	40 (61.5)	0.391
2	41 (19.3)	29 (19.7)	12 (18.5)	
3	24 (11.3)	17 (11.6)	7 (10.8)	
4	17 (8.0)	15 (10.2)	2 (3.1)	
5	8 (3.8)	4 (2.7)	4 (6.2)	
6	1 (5.0)	1 (0.7)	-	
Birth weight (g)	3100 (2738.75-3500)	3250 (2900-3600)	2650 (2240-3200)	<0.0001*
pH	7.32 (7.25-7.35)	7.33 (7.27-7.35)	7.26 (7.20-7.34)	<0.0001*
>7.2	191 (90.1)	140 (95.2)	51 (78.5)	<0.0001*
7-7.2	13 (6.1)	7 (4.8)	6 (9.2)	
<7.2	8 (3.8)	0	8 (12.3)	
MCA RI/AO RI	1.12±0.22	1.12±0.18	1.11±0.30	0.857
MCA PI/AO PI	1.22±0.54	1.27±0.54	1.10±0.51	0.036**
MCA RI/UM RI	2.50±0.87	2.61±0.91	2.26±0.70	0.007*
MCA PI/UM PI	1.65±0.64	1.74±0.68	1.44±0.48	0.002*

Values are mean±SD, median (IQR) or *n* (%), *P* values from independent samples *t*-test or Pearson χ^2. *P<0.01; **P<0.05. SD=Standard deviation; IQR=Interquartile range; BMI=Body mass index; NVD=Normal vaginal delivery; NICU=Neonatal Intensive Care Unit; MCA=Middle cerebral artery; RI=Resistance index; PI=Pulsatile index; UM=Umbilical; AO=Aortal artery

41 weeks of pregnancy, we understood that cerebroaortic ratio (CAR) is in relation with neonatal acidosis and admission at NICU compared with other impedance indices, especially cerebral-placenta ratio (CPR) but NBW is in more relation with that. Therefore, with the assessment of CAR at the end of third trimester and especially in high-risk pregnancies compromise fetus is predictable. After 36 weeks, MCA/AO PI < 0.85 indicates the possibility of hypoxia in the fetus, which means that the fetus should be placed under special care and should be born early if needed, also the birth should be done at the tertiary center. Hence, with more intervention, neonatal hypoxia and acidosis are preventable.

The studies which have used Doppler indices for adverse pregnancy outcome (APO) are divided into two groups: 1 - the studies which have been done in normal pregnancy[22-24] such as the systematic review done by Alfirevic *et al*. in 2015. In this research, conclusive evidence was not seen for the use of routine UmA Doppler ultrasound in favor of mother and baby.[22] In another research by Akolekar *et al*. in 2015 on 6178 pregnancies between 35 and 37 weeks, it was concluded that the CPR assessment

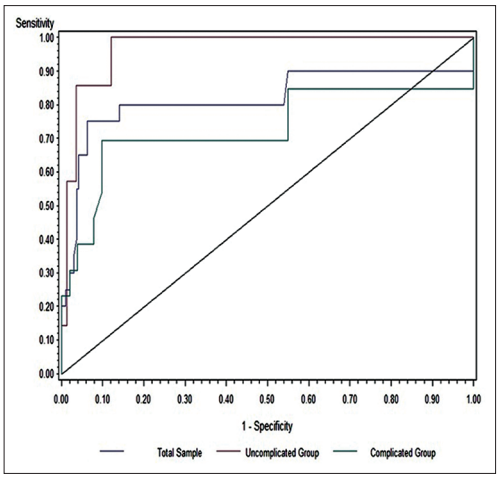

Figure 1: Receiver–operating characteristics curve for pH and middle cerebral artery resistance index/aortal artery resistance index

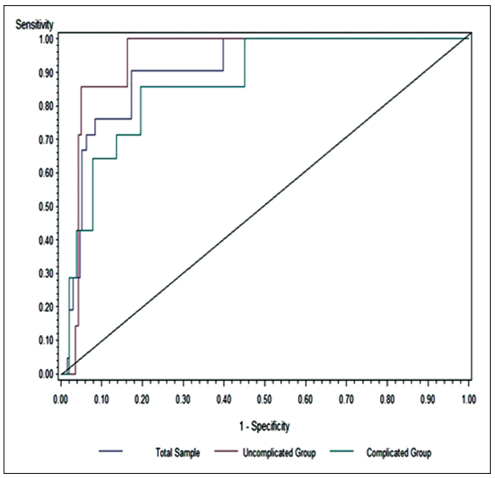

Figure 2: Receiver operating characteristics curve for pH and middle cerebral artery pulsatile index/aortal artery pulsatile index

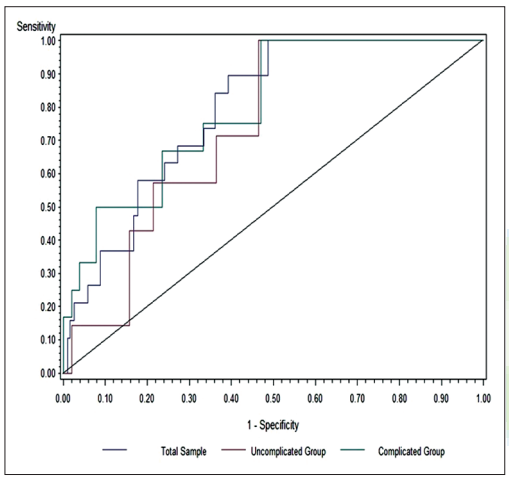

Figure 3: Receiver operating characteristics curve for pH and middle cerebral artery resistance index/umbilical artery resistance index

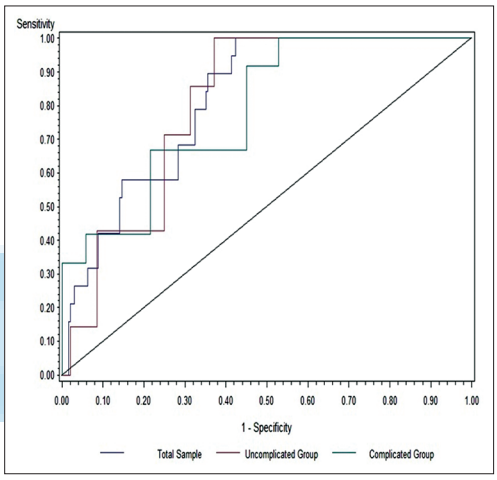

Figure 4: Receiver operating characteristics curve for pH and middle cerebral artery pulsatile index/umbilical artery

Table 2: Pearson correlation between Doppler indices with pH and neonatal body weight

	MCA/ AO RI	MCA/ AO PI	MCA/ UmA RI	MCA/ UmA PI
Total sample				
pH	0.331**	0.411**	0.288**	0.279**
NBW	−0.023	0.142*	0.228**	0.253**
Uncomplicated group				
pH	0.451**	0.363**	0.200*	0.181*
NBW	0.076	0.041	0.106	0.126
Complicated group				
pH	0.299*	0.510**	0.399**	0.397**
NBW	−0.109	0.179	0.34**	0.376**

*P<0.05; **P<0.01. NBW=Neonatal body weight; MCA=Middle cerebral artery; RI=Resistance index; PI=Pulsatile index; UmA=Umbilical artery; AO=Aortal artery

in routine screening for APO is poor at 36-week gestation. However, in a small subgroup, if delivery was done in 2 weeks after Doppler ultrasound, the detection rate of CPR was increased.[24] In our research, the unselected population at the end of the third trimester was the same as the study done by Akolekar. However, CAR was used in our research instead of CPR and was valuable for neonatal outcome.

2 - The studies which have been done in high-risk pregnancies, especially pregnancies with FGR and HTN.[25,26] Alfirevic's research in 2013 suggested that the use of Doppler ultrasound in high-risk pregnancies decreased the risk of perinatal death and resulted in less obstetric intervention, but it did not have any effect on Apgar scores <7 at 5 min of birth.[2] The research was done by Rozeta in 2010 on pregnancies with preeclampsia and gestation HTN.[26] And also, the study was done by Chalubinski in 2012 on FGR pregnancy, CPR was in relation with APO.[25] Most studies of Doppler ultrasound have been done on FGR, but according to Bakalis *et al*. in a research on 30,780 singleton pregnancy between 30 and 34 weeks, it was observed that APO was more related to AGA not SGA, and the cases with umbilical cord pH ≤ 7 or admission to NICU were more seen in AGA group.[27] Therefore, if APO is the result of impaired placentation, prenatal care must be done to identify hypoxic fetus not fetal weight.

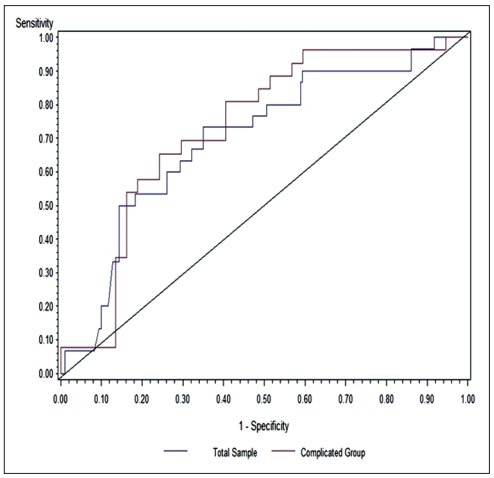

Figure 5: Receiver operating characteristics curve for neonatal body weight and middle cerebral artery resistance index/umbilical artery resistance index

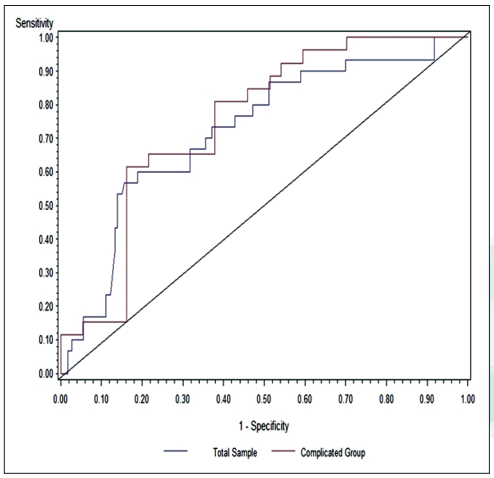

Figure 6: Receiver operating characteristics curve for neonatal body weight and middle cerebral artery pulsatile index/umbilical artery pulsatile index

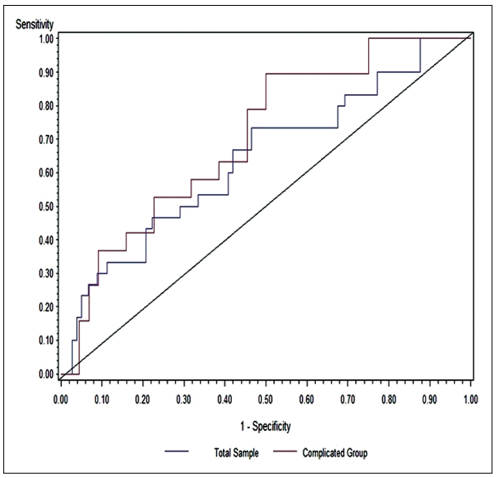

Figure 7: Receiver operating characteristics curve for Neonatal Intensive Care Unit admission and middle cerebral artery pulsatile index/aortal artery pulsatile index

In previous studies, Doppler indices in FGR and HTN pregnancies were into account, but in the present stud, y

Table 3: Comparing mean of Doppler indices according to status of Neonatal Intensive Care Unit admission

Doppler indices	Total sample	Uncomplicated group (*n*=147)	Complicated group (*n*=65)
MCA RI/AO RI			
Breastfeeding	1.12±0.20	1.12±0.18	1.14±0.28
NICU	1.09±0.31	1.11±0.24	1.07±0.36
P	0.527	0.802	0.44
MCA PI/AO PI			
Breastfeeding	1.27±0.54	1.27±0.55	1.23±0.54
NICU	1.02±0.44	1.27±0.51	0.87±0.34
P	0.023**	0.999	0.011**
MCA RI/UM RI			
Breastfeeding	2.54±0.87	2.60±0.91	2.40±0.72
NICU	2.29±0.87	2.74±1.01	1.99±0.63
P	0.155	0.622	0.063
MCA PI/UM PI			
Breastfeeding	1.68±0.65	1.72±0.68	1.53±0.49
NICU	1.50±0.67	1.90±0.78	1.23±0.43
P	0.16	0.431	0.032**

**Significant at 0.05 level. MCA=Middle cerebral artery; RI=Resistance index; AO=Aortal artery; PI=Pulsatile index; NICU=Neonatal Intensive Care Unit; UM=Umbilical

Doppler indices were used to predict neonatal outcome in low-risk and high-risk pregnancies which are almost the same as Akolekar's research in 2015, but the main difference is that, in this study, aortal indices were used and compared with UmA indices at the end of the third trimester.[24] A few studies were done on Aortal Doppler indices and its relation to neonatal outcome and APO such as Aranyosi *et al*.'s research in 2001 which investigated MCA and aortal Doppler between the 28th and 41st week of gestation. It was concluded that if AO/MCA RI was constant during this period of uncomplicated pregnancy, it reflects optimal perinatal results and if this ratio is abnormal, it has a strong association with fetal hypoxia.[13]

This relation is also seen in our study; however, PI has more relation with fetal hypoxia compare to RI. Furthermore, Aranyosi *et al*. did another research on 96 uncomplicated pregnancies between the 38th and 40th weeks of gestation, and they reported the normal AO/MCA RI as 1.06 ± 0.08 and aortic-cerebral RI (ACRI) in normal pregnancies was below 1.2 but ACRI above 1.2 was not assessed.[28] In comparison, in our research, the related cutoff was 1.05 in the entire population and also in the uncomplicated group and was 1.2 in complicated group, which was similar to that of Aranyosis's work. The novel observation in our study was a comparison of CPR with CAR in duration of 2 weeks and the strong relation of CAR with neonatal outcome. As long as UmA impedance indices from 36 weeks on have less value for APO and neonatal outcome; in this gestational age, aortal impedance indices must be used.

Table 4: Odds ratios and diagnostic criteria of receiver operating characteristics curve for Doppler indices

Doppler indices/neonatal outcome	Studied group	OR (95% CI)	AUC (SE)	95% CI (AUC)	Sensitivity	Specificity	Cut-off point
MCA RI/AO RI							
pH (≥7.2 vs. <7.2)	Total sample	0.11 (0.07-0.18)	0.818 (0.071)	0.679-0.956	0.80	0.86	0.951
	Uncomplicated group	0.05 (0.02-0.11)	0.966 (0.018)	0.931-1.000	1.00	0.88	0.951
	Complicated group	0.27 (0.15-0.48)	0.729 (0.102)	0.529-0.930	0.69	0.90	0.827
MCA PI/AO PI							
pH (≥7.2 vs. <7.2)	Total sample	0.09 (0.05-0.15)	0.905 (0.028)	0.850-0.959	0.91	0.83	0.853
	Uncomplicated group	0.04 (0.02-0.12)	0.940 (0.024)	0.893-0.986	1.00	0.84	0.849
	Complicated group	0.20 (0.10-0.40)	0.870 (0.049)	0.774-0.965	0.86	0.80	0.880
NICU admission	Total sample	4.75 (3.30-6.83)	0.640 (0.057)	0.529-0.751	0.73	0.54	1.114
	Uncomplicated group	-	-	-	-	-	-
	Complicated group	2.52 (1.51-4.21)	0.703 (0.068)	0.569-0.838	0.79	0.55	1.07
MCA RI/UM RI							
pH (≥7.2 vs. <7.2)	Total sample	0.34 (0.27-0.43)	0.793 (0.041)	0.713-0.874	0.90	0.61	2.300
	Uncomplicated group	0.27 (0.19-0.39)	0.737 (0.066)	0.607-0.866	0.71	0.64	2.300
	Complicated group	0.46 (0.34-0.64)	0.797 (0.064)	0.672-0.923	0.75	0.67	1.978
NBW (≥2500 vs. <2500 g)	Total sample	2.20 (1.84-2.62)	0.699 (0.051)	0.599-0.799	0.73	0.65	2.253
	Uncomplicated group	-	-	-	-	-	-
	Complicated group	1.28 (1.03-1.60)	0.729 (0.065)	0.602-0.856	0.81	0.60	2.27
MCA PI/UM PI							
pH (≥7.2 vs. <7.2)	Total sample	0.16 (0.13-0.27)	0.814 (0.039)	0.739-0.890	0.90	0.64	1.453
	Uncomplicated group	0.13 (0.07-0.23)	0.803 (0.053)	0.698-0.908	0.86	0.69	1.417
	Complicated group	0.30 (0.18-0.50)	0.784 (0.068)	0.652-0.917	0.92	0.55	1.460
NBW (≥2500 vs. <2500 g)	Total sample	3.39 (2.57-4.56)	0.722 (0.050)	0.625-0.819	0.73	0.63	1.467
	Uncomplicated group	-	-	-	-	-	-
	Complicated group	1.52 (1.07-2.15)	0.748 (0.062)	0.627-0.869	0.81	0.62	1.471

OR obtained from binary logistic regression. AUC=Area under the curve; SE=Standard error; CI=Confidence interval; MCA=Middle cerebral artery; RI=Resistance index; AO=Aortal artery; PI=Pulsatile index; NICU=Neonatal Intensive Care Unit; UM=Umbilical; NBW=Neonatal body weight, OR=Odds ratio

Finally, in normal- and high-risk pregnancies, CAR is in strong relation with cord blood pH at delivery and admission of NICU; however, NBW is in association with CPR.

CONCLUSION

This research showed that, with an assessment of MCA/AO PI in late pregnancy can be prevented of stillbirth due to asphyxia and so neonatal ischemic, hypoxic encephalopathy, on the other side, obstetric intervention is also prevented.

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Conflicts of interest
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