Original Research Article

Doppler velocimetry of middle cerebral and umbilical artery in the diagnosis intrauterine growth retardation

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Abstract

Background: Doppler ultrasound of the uterine, umbilical and middle cerebral arteries offer the potential to study the function and physiological changes in the uteroplacental and fetoplacental circulation. When fetal growth retardation is diagnosed during the third trimester of pregnancy, the obstetrician must decide whether the fetus is constitutionally small or small as a consequence of impaired placental perfusion. **Aim:** To evaluate usefulness of Doppler velocimetry of middle cerebral and umbilical artery in the diagnosis intrauterine growth retardation. **Material and Methods:** The study population comprised of 100 pregnancies out of 100 patients, 50 patients showing normal fetal growth parameters were included in the control group and 50 patients showing abdominal circumference less than 10th percentile for their gestational age were included in the study group. All the 100 patients were then subjected to doppler examination. Flow velocity wave forms were recorded from the umbilical artery and fetal middle cerebral artery. **Results:** Umbilical artery PI ratio had highest sensitivity in prediction of IUGR (82%) followed by umbilical artery S/D ratio (71.79%) with cut off value of 3. AEDF/REDF had lowest sensitivity. The specificity and positive predictive value in prediction was highest with AEDF/REDF and MCA PI/UmA PI with cut off value of 1.08 (100% each) and lowest with MCA PI (81and 69% respectively). **Conclusion:** Doppler velocimetry of the umbilical and middle cerebral arteries proved to be a practicable and relatively quick procedure. With the application of color mode, identification and sampling of the middle cerebral artery was further simplified.

Keywords: intrauterine growth retardation, Doppler velocimetry, middle cerebral artery, umbilical artery

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Received Date: 28/10/2019 Revised Date: 02/12/2019 Accepted Date: 14/12/2019
DOI: https://doi.org/10.26611/101313312

Access this article online	
Quick Response Code:	Website: www.medpulse.in
	Accessed Date: 09 March 2020

INTRODUCTION

The normal growth of fetus during intrauterine life, ability to withstand the stress of labor and healthy development during neonatal period depends to a great extent upon the integrity of the fetoplacental circulation. An important goal of contemporary obstetrics is to identify the growth retarded fetus with compromised uteroplacental circulation and hence at an increased risk for fetal hypoxia. Doppler offers the potential to evaluate the uteroplacental and fetal blood flow in a non-invasive manner. Recently developed methods using real time ultrasound images superimposed with blood flow coded in color have made it possible to delineate vessels like the fetal middle cerebral artery and fetal aorta with great ease and accuracy resulting in more accurate and quicker examination.[1] It is an important technique for distinguishing the compromised small fetus from a constitutionally small fetus who is unlikely to experience serious perinatal complications. Several authors have reported a low end diastolic velocity in the umbilical artery in growth retarded pregnancy and it was considered a consequence of high flow resistance in the capillaries of terminal villi.[2] In the present study we

How to cite this article: Parag Vijaysingh Patil. Doppler velocimetry of middle cerebral and umbilical artery in the diagnosis intrauterine growth retardation. *MedPulse International Journal of Radiology.* March 2020; 13(3): 151-156.
http://www.medpulse.in/Radio%20Diagnosis/

have evaluated usefulness of Doppler velocimetry of middle cerebral and umbilical artery in the diagnosis intrauterine growth retardation.

MATERIAL AND METHODS

The present prospective study was carried out in the Department of Radiodiagnosis, of a tertiary care hospital. The Doppler study was carried out on Aloka Prosound (Model: SSD 4000) Color Doppler machine.

Study subjects

- Those were the clinically suspected cases of intrauterine growth retardation in which fetal weight was below the 10th percentile for its gestational age (Hadlock 1982) and ultrasonic finding of upper abdominal circumference was below the 10th percentile for that gestational age (Hadlock 1982).
- Postnatal confirmation of growth retardation fetuses was done by using Kloosterman's tables, if birth weight was below 10th percentile for that gestational age.[89]

Inclusion criteria

Clinically diagnosed intrauterine growth retarded pregnancies with patient giving history of regular cycles of 3 to 4 days per 28 days with definitive knowledge of last menstrual period.

Exclusion criteria

Patients with clinically diagnosed intrauterine growth retardation having following risk factors -

- Patients with irregular menstrual cycle or not sure of last menstrual period.
- Patients conceived in lactational ammenorrhoea.
- Patients with systemic diseases, viz, heart disease, sickle cell hemoglobinopathy.
- Pregnant patients with congenital anomalies in the fetus.
- Patient who lost to follow up.

The study population comprised of 100 pregnancies out of 100 patients, 50 patients showing normal fetal growth parameters were included in the control group and 50 patients showing abdominal circumference less than 10th percentile for their gestational age were included in the study group. All pregnant women studied were between 31-40 weeks of gestation. Thus, there were 2 groups:

- **Control Group:** Control group comprised of 50 patients with normal fetal parameters and without intrauterine growth retardation.
- **Study Group:** Study group comprised of 50 patients with intrauterine growth retardation and without any obvious risk factor as mentioned previously.

Methodology

Detailed present obstetrical and menstrual history was asked and noted for all 100 patients. Special stress was given on menstrual history, last menstrual period and accordingly expected date of delivery was calculated by Naegle's formula. Patients were then subjected to ultrasound examination. These patients were subjected to follow up ultrasound examination and consistent findings were confirmed. All the 100 patients were then subjected to doppler examination. Doppler examinations were then performed with Aloka Prosound (Model: SSD 4000) Color Doppler machine using a 3.5 MHz transducer with 3 mm sample volume and medium filter with the patient in a semirecumbent position and fetus in a quiet resting state. Flow velocity wave forms were recorded from the umbilical artery and fetal middle cerebral artery. Recordings were obtained from the umbilical artery by placing the sample volume in the lumen of the artery away from the placental and fetal cord insertion.[90] After recording a technically satisfactory doppler waveform, the pulsatility index and S/D ratio was noted. Pulsatility index of the middle cerebral artery was noted using a transverse section of the fetal head at the level of the thalami and the cavum septum pellucidum. By moving the probe caudally, on a plane parallel to the previous one, we identified the pulsation of the middle cerebral artery in the sylvian fissure. The doppler sample was placed in the center of the pulsation to obtain the maximum frequency shift After recording a technically satisfactory doppler waveform, pulsatility index and S/D ratio was noted. The MCA/UA PI ratio and MCA/UA S/D ratio were calculated from the pulsatility indices and S/D ratios of the middle cerebral and umbilical arteries.

Interpretation of Doppler findings:

Doppler study was considered abnormal when-

1. Umbilical artery pulsatility index more than 95 percentile of reference values by Acharya G *et al.*.[3]
2. Umbilical artery S/D ratio more than 3 or more than 95 percentile of reference values by Acharya G *et al.*.[3]
3. Middle cerebral artery pulsatility index less than 5 percentile of reference values by Mari G *et al.*.[4]
4. MCA/UA PI ratio less than 1.08 or less than 2S.D. of reference values by Gramellini D *et al.*.[5]
5. MCA/UA S/D ratio less than 1.

Statistical analysis

All the indices and ratios in the intrauterine growth retardation group were compared with that in the normal study group using the Chi Square Test and Student 't' Test. $P < 0.05$ was significant.

RESULTS

In the present study on the basis of history examination and investigations, the subjects were divided into two groups: study group and control group.

Study group: women in third trimester with clinically diagnosed and confirmed intrauterine growth restriction were included under this group. Control group: women in third trimester without any risk factors and intrauterine growth restriction were included in this group The study population was divided accordingly in 4 groups with class interval of 5 years. In the present study, maximum number of patients were in the age group of 21-25 years (31 in study group and 30 in control group) followed by the age group of 26-30 years (12 in study group and 10 in control group). Mean age for study group was 25±3.7 years while that for control group was 24±3.9 years. The age wise distribution between study group and control group was statistically not significant. Out of 100 subjects, 60 (60%) were primigravida, 29 (29%) were second gravida and 7 (7%), 2 (2%), 2 (2%) were third, fourth and fifth gravida respectively. In the study group, 32 (64%) were primigravida and 18 (36%) were multigravida. While in the control group, 28 (56%) were primigravida and 22 (44%) were multigravida. The gravida wise distribution between study group and control group was statistically not significant. Mean gestational age in study group was 35.3±2.48 weeks and in control group was 36±2.71 weeks. The gestational age wise distribution between study group and control group was statistically not significant.

Table 1: Umbilical artery velocimetry [S/D ratio] study in two groups with a single cut off value of 3

Umbilical artery S/D ratio	Study group		Control group	
	No.	%	No.	%
≥3	35	70	4	8
<3	4	8	46	92
AEDF	5	10	0	0
REDF	6	12	0	0
Total	**50**	**100**	**50**	**100**

$\chi^2 = 59.47$ P= 0.0000 (Highly Significant); $\chi^2 = 12.360$ P= 0.0000 (Highly Significant)

Table 1 shows umbilical artery velocimetry [S/D ratio] study in two groups with a single cut off value of 3. Using a single cut off value of 3, 35 (70%) patients in study group were having abnormal S/D value and 4 (8%) were having normal S/D value. While in control group 4 (8%) patients were having abnormal S/D value and 46 (92%) were having normal S/D value. In study group 5 (10%) patients had absent end diastolic flow (AEDF) and 6 (12%) patients had reversed end diastolic flow (REDF). While in control group none of the patients showed absent or reversed end diastolic flow. The difference between two groups was statistically significant.

Table 2: Umbilical artery velocimetry [S/D ratio] study in two groups with gestational age specific cut of values (AEDF and REDF excluded)

Umbilical artery S/D ratio	Study group		Control group	
	No.	%	No.	%
≥ [mean + 2S.D.]	28	71.80	1	2
< [mean + 2S.D.]	11	28.20	49	98
Total	39	100	50	100

$\chi^2 = 48.587$ P= 0.0000 (Highly Significant)

Table 2 shows umbilical artery velocimetry [S/D ratio] study in two groups with gestational age specific cut off values. 28 patients in study group were having S/D ratio ≥ [mean + 2S.D.] as compared to control group which had only 1 patient having S/D ratio ≥ [mean + 2S.D.]. Among the patients with S/D ratio < [mean + 2S.D.], 11 were from study group while 49 were from control group. The difference between two groups was statistically significant.

Table 3: Umbilical artery velocimetry PI ratio in two groups with gestational age specific cut of values

Umbilical artery PI ratio	Study group		Control group	
	No.	%	No.	%
≥ [mean + 2S.D.]	41	82	6	12
< [mean + 2S.D.]	9	18	44	88
Total	**50**	**100**	**50**	**100**

$\chi^2 = 49.177$; P= 0.0000 (Highly Significant)

Table 3 shows umbilical artery velocimetry PI ratio in two groups with gestational age specific cut off values. In study group, 41(82%) patients were having umbilical artery velocimetry PI ratio ≥ [mean + 2S.D.] while 9 (18%) were having umbilical artery velocimetry PI ratio < [mean + 2S.D.]. but in control group, 6 (12%) patients were having umbilical artery velocimetry PI ratio above the gestational age specific cut off value and 44 (88%) were having umbilical artery PI ratio below the gestational age specific cut off value. The difference between two groups was statistically significant.

Table 4: Middle cerebral artery velocimetry PI ratio in two groups with gestational age specific cut off values

MCA PI ratio	Study group		Control group	
	No.	%	No.	%
< [mean - 2S.D.]	20	40	9	18
≥ [mean - 2S.D.]	30	60	41	82
Total	**50**	**100**	**50**	**100**

$\chi^2 = 14.213$; P= 0.0000 (Highly Significant)

Table 4 shows middle cerebral artery PI ratio in study population using gestational age specific cut off values. In study group, 20 (40%) patients were having MCA PI ratio <2S.D. while 30 (60%) were having PI ratio ≥2S.D. while in control group, only 9 (18%) patients were having MCA PI ratio below the gestational age specific cut off value and 41 (82%) were having PI ratio below the gestational age specific cut off value. The difference between two groups was statistically significant.

Table 5: MCA PI/UmA PI in study population using a single cut off value of 1.08

MCA PI/UmA PI	Study group		Control group	
	No.	%	No.	%
< 1.08	33	66	0	0
≥ 1.08	17	34	50	100
Total	**50**	**100**	**50**	**100**

$\chi^2 = 49.254$; P= 0.0000 (Highly Significant)

Table 5 is showing MCA PI/UmA PI in study population using a single cut off value of 1.08. 33 (66%) patients in study group had MCA PI/UmA PI ratio <1.08 and remaining 17 (34%) had the ratio value more than the cut off value. However, none of the patients in control group had MCA PI/UmA PI ratio less than 1.08. The difference between two groups was statistically significant.

Table 6: MCA PI/UmA PI in study population using gestational age specific values

MCA PI/UmA PI	Study group		Control group	
	No.	%	No.	%
< [mean + 2S.D.]	34	68	3	6
≥ [mean + 2S.D.]	16	32	47	94
Total	**50**	**100**	**50**	**100**

$\chi^2 = 41.227$; P=0.0000 (Highly Significant)

Table 6 is showing MCA PI/UmA PI in study population using gestational age specific values. 34 (68%) patients in study group had MCA PI/UmA PI ratio < 2 S.D. and 16 (32%) had the ratio value ≥ 2 S.D; while 3 (6%) and 47 (94%) patients in control group had MCA PI/UmA PI ratio less than and more than 2 S.D. respectively. The difference between two groups was statistically significant.

Table 7: MCA [S/D]/UmA [S/D] in study population using a single cut off value of 1

MCA [S/D]/UmA [S/D]	Study group		Control group	
	No.	%	No.	%
<1	21	53.85	7	14
≥1	18	46.15	43	94
Total	**39**	**100**	**50**	**100**

χ^2=16.133; P= 0.0000 (Highly Significant)

Table 7 is showing MCA [S/D]/UmA [S/D] in study population using a single cut off value of 1. In study group 21 (53.85%) patients had the ratio < 1 and 18 (46.15%) had the ratio value more than 1. while in control group the respective figures were 7 (14%) and 43 (94%). The difference between two groups was statistically significant.

Table 8: Diagnostic criteria of IUGR: Performance characteristics

Criterion	Sensitivity	Specificity	Predictive value		Accuracy
			Positive	Negative	
UmA PI ≥ [mean+2SD]	82	88	87.23	83.01	85
UmA S/D ≥ 3	71.79	92	87.5	80.70	83.14
UmA S/D≥ [mean+2SD]	64.1	98	96.15	77	86.51
MCA PI < [mean+2SD]	40	81	69	57.75	61
MCA PI/UmA PI < [mean+2SD]	68	94	91.89	74.60	81
MCA [S/D] / UmA [S/D] >1	53.84	86	75	70.49	86.51
AEDF/REDF	22	100	100	56.18	61
MCA PI/UmA PI < 1.08	66	100	100	74.63	83

Table 8 shows performance characteristics of various parameters to evaluate their efficacy in diagnosing intrauterine growth restriction. Umbilical artery PI ratio had highest sensitivity in prediction of IUGR (82%) followed by umbilical artery S/D ratio (71.79%) with cut off value of 3. AEDF/REDF had lowest sensitivity. The specificity and positive predictive value in prediction was highest with AEDF/REDF and MCA PI/UmA PI with cut off value of 1.08 (100% each) and lowest with MCA PI (81 and 69% respectively).

DISCUSSION

Intrauterine growth is an important sign of fetal well-being. The fetal and neonatal implications of intrauterine growth retardation are well documented. Accurate assessment of fetal condition is essential if perinatal morbidity and mortality is to be prevented. Doppler ultrasound of the uterine, umbilical and middle cerebral arteries offer the potential to study the function and hence physiological changes in the uteroplacental and fetoplacental circulation and may help identity small for gestational age fetus suffering from hypoxia. Moreover, the test can be performed simply is non-invasive and relatively inexpensive. When fetal growth retardation is diagnosed during the third trimester of pregnancy, the obstetrician must decide whether the fetus is constitutionally small or small as a consequence of impaired placental perfusion. Doppler flow velocity analysis can be valuable in resolving this question. We have used various doppler indices (and their ratios) of two fetal arteries i.e. umbilical and middle cerebral artery and evaluated their role in prediction of intrauterine growth restriction. We have evaluated the diagnostic and prognostic efficacy of UA PI, UA S/D, MCA PI, MCA PI/UA PI, and MCA (S/D) / UA (S/D).

Table 9: Performance characteristics of umbilical artery velocimetry study in prediction of intrauterine growth restriction

Parameter assessed		Author	Se	Sp	PPV	NPV	Acc
PI	>2SD	Gramellini *et al.*[5]	40	91.1	81.8	60.2	65.5
	>95 percentile	Bahado S *et al.*[6]	54.1	89.4	74	78	-
	>2SD	Ozeren *et al.*[7]	64	92	84	79	81
	>2SD	Doubilet *et al.*[8]	93	91	54	99	-
	>2SD	Banu *et al.*[9]	60.6	93.3	75.2	87.6	85
	>2SD	Zha *et al.*[10]	70.96	88.9	-	-	-
	>95 percentile	**Present study**	**82**	**88**	**87.23**	**83.01**	**85**
S/D	>2SD	Strigini *et al.*[11]	37	97	73	88	-
	>2SD	Ozeren *et al.*[7]	80	89	83	87	85
	>3	Chanprapaph *et al.*[12]	52.96	78.85	74.42	65.08	-
	>2SD	Wang *et al.*[13]	80	83.7	50	-	-
	>3	Doubilet *et al.*[8]	78	83	34	96	-
	>95 percentile	Doubilet *et al.*[8]	68	85	34	96	-
	>3	**Present study**	**71.79**	**92**	**87.5**	**80.7**	**83.14**
	>95 percentile	**Present study**	**64.1**	**98**	**96.15**	**77**	**86.51**

For the diagnosis of intrauterine growth restriction, umbilical artery PI value >95 percentile was 82% sensitive, 88% specific with positive and negative predictive values of 87.23% and 83.01% respectively; the diagnostic accuracy being 85%. These values are in consonance with other studies listed in table 9. Umbilical artery S/D ratio with cut off value of 3 had sensitivity, specificity, positive predictive value, negative predictive value and diagnostic accuracy of 71.8%, 92%, 87.5%, 80.7%, 83.14% respectively. With a cut off value of >95 percentile, the sensitivity in diagnosis was decreased but specificity and positive predictive value did increase. These values are in consonance with previous studies listed in table 9.

Table 10: Performance characteristics of MCA velocimetry study in prediction of intrauterine growth restriction

Parameter assessed		Author	Se	Sp	PPV	NPV	Acc
PI	<2 sd	Gramellini *et al.*[5]	11.1	97.7	83.3	52.3	54.4
	<1.5 sd	Strigini *et al.*[11]	25	96	58	85	-
	<2 sd	Ozeren *et al.*[7]	44	70	50	65	60
	<2 sd	Zha *et al.*[10]	80.64	94.15	-	-	-
	<5 percentile	**Present study**	**40**	**81**	**69**	**57.75**	**61**

With a value less than 5 percentile, MCA PI had sensitivity, specificity, positive predictive value, negative predictive value and diagnostic accuracy of 40%, 81%, 69%, 57.75%, and 61% respectively. Table 10 shows that various authors have reported sensitivities ranging from 11.1 to 80.64%; with an overall low sensitivity of MCA PI in diagnosis of intrauterine growth restriction. However, in all these studies (including the present study), the specificity of MCA PI in diagnosis of intrauterine growth restriction was high and the diagnostic accuracy was almost equal.

Table 11: Performance characteristics of MCA/UA ratios in prediction of intrauterine growth restriction

Parameter assessed		Author	Se	Sp	PPV	NPV	Acc
PI	<1.08	Gramellini *et al.*[5]	40	100	100	62.5	70
	<2sd	Ozeren *et al.*[7]	84	89	84	89	87
	<5 percentile	Bahado S *et al.*[6]	47	90	95	43	-
	<2sd	Banu *et al.*[9]	67.3	97.4	72.9	96.7	94.6
	<2sd	Zha *et al.*[10]	87.09	97.61	-	-	-
	<1.08	**Present study**	**66**	**100**	**100**	**74.63**	**83**
	<2sd	**Present study**	**68**	**94**	**91.89**	**74.6**	**81**
S/D	**<1**	**Present study**	**53.84**	**86**	**75**	**70.49**	**86.51**

In the present study, MCA PI / UA PI ratio with a single cut off value of < 1.08 has achieved the specificity and positive predictive value of 100% each with relatively low sensitivity (66%). These values are in consonance with that reported by Gramellini *et al.* (Table 11). With the use of gestational age specific cut off values (< 2S.D.), sensitivity, specificity, positive predictive value, negative predictive value and diagnostic accuracy did not change much as compared to single cut off value. MCA (S/D) / UA (S/D) ratio had overall low efficacy in prediction of intrauterine growth restriction as compared to MCA PI / UA PI ratio.

CONCLUSION

Doppler velocimetry of the umbilical and middle cerebral arteries proved to be a practicable and relatively quick procedure. With the application of color mode, identification and sampling of the middle cerebral artery was further simplified.

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Source of Support: None Declared
Conflict of Interest: None Declared