Importance of Ductus Venosus Doppler in Prediction of Perinatal Morbidity and Mortality

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Abstract:-

- ***Introduction:***

The ductus venosus is a vascular shunt situated within the fetal liver parenchyma, connecting the umbilical vein to the inferior vena cava. This vessel acts as a bypass of the liver microcirculation and plays a critical role in the fetal circulation. The ductus venosus allows oxygenated and nutrient rich venous blood to flow from the placenta to the myocardium and brain. Increased impedance to flow in the fetal ductus venosus is associated with fetal aneuploidies, cardiac defects and other ad-verse pregnancy outcomes. This review serves to improve our understanding of the mechanisms that regulate the blood flow redistribution between the fetal liver circulation and fetal heart and the clinical significance of the ductus venosus waveform as generated by pressure-volume changes in the fetal heart.

- ***Materials and Methods:***

A cross sectional study was performed at Fetal Medicine Department, SKNMC, Pune, from August 2021 to December 2022. Total 400 women were screened at routine antenatal visit during this period, out of which 225 were selected. Fetal Doppler was performed using a Siemens Acuson X300 ultrasound machine with a 3.5 MHz convex probe. The umbilical artery, fetal middle cerebral artery and the fetal ductus venosus were sampled. The pulsatility indices were measured. Follow up of these fetuses were done and the perinatal outcome were obtained.

- ***Results:***

An abnormal DV was associated with an overall increased for birth by emergency caesarean (CS). Overall caesarean rate is increased for delivering babies between 28 - 32 weeks gestation irrespective of dv values possibly due to policy of caesarean section in preterm deliveries. Whereas abnormal DV values at 28 - 32 weeks, 32 - 37 weeks & 37 - 42 weeks has shown clear cut increased in caesarean section rate, NICU admission and duration of stay in NICU, intrauterine deaths, low birth weight. We have categorically identified that DV values < 5th centile and >95th centile increases perinatal morbidity & mortality. We have seen that there is substantial increase in intrauterine and neonatal deaths at < 5th centile.

- ***Conclusion:***

In conclusion, the DV acts as a bypass of the liver microcirculation and plays a critical role in the fetal circulation. The DV allows oxygenated and nutrient-rich venous blood to flow from the placenta to the myocardium and brain. Increased impedance to flow in the fetal DV is associated with fetal aneuploidies, cardiac defects and other adverse pregnancy outcomes. Further research is necessary to determine the importance of the DV Doppler assessment in improving perinatal outcomes.

Keywords: *Fetal Hypoxemia, Diastolic Reversal, Ductus Venosus, Perinatal Outcome.*

I. INTRODUCTION

Doppler investigation of the fetal circulation can give important clues to fetal well-being in a number of fetal conditions. At any given gestational age, the perinatal morbidity and mortality is higher for smaller gestational age fetuses and average gestational age fetuses. [1]Balance between intrauterine hostility and post-natal maturity of fetus should be maintained while decision for delivery so has to have good perinatal outcome.[2] Ductus venosus doppler is taken in first trimester tells about prediction of about downs syndrome, second trimester ductus venosus doppler tells about right atrial pressure internal failure due to abnormal circulation.[3] Derangement in third trimester doppler indicates towards failure of fetal head because of increase of peripheral vascular resistance thus ductal venosus doppler starts increases.[4] High pressure resistant flow etiology of deprival of fetus oxygenation and growth. So, in our article we have compared ductal venosus doppler T.I value with perinatal outcome. [5]

Our main aim for Doppler is delivering the baby at the right time before the fetal central damage occurs because of hypoxia. The normal ductus venosus waveform pattern has a peak systolic, a peak diastolic and peak atrial velocity. The average shunting of blood through the ductus venosus normally decreases from 30% at 18-20 weeks to 18% at 31-34 weeks gestation.[6]The ductus venosus is the only venous vessel with forward flow during all phases of the cardiac cycle. The S-wave reflects the pressure gradient between the peripheral venous system and the right atrium. The D-wave represents the opening of the atrial ventricular valves and passive early filling of the ventricles. Between the S and the D wave is a period of isovolumetric relaxation (IVR) when atrial pressure and waning systolic ejection pressure are comparable. [7]

With increasing myocardial hypoxia and acidosis, the cardiac muscle is less compliant and isovolumetric relaxation decreases, may become absent, or even reversed. An evaluation of IVR and the A-wave is a more accurate predictor of fetal outcome then noting the absence or reversal of the A-wave thus can predict early fetal failure and fetal death.[8] The pulsatility index is utilized to quantitate ductus venosus flow. With advancing gestation cardiac compliance increases and placental resistance falls. As a result, the pulsatility index of the ductus venosus normally declines with advancing gestation. An increase in cardiac after-load or decreased cardiac compliance will result in a decrease in forward flow and an increase in the pulsatility index[9]

Abnormal ductus venosus dopplers are associated with significant perinatal mortality. Intact survival of the patient is excellent in normal DV dopplers. Article on DV dopplers by Baschat in 2007 states that DV doppler and Gestational age are the key points for a better perinatal outcome. [10]

The sequence of Doppler events for fetuses that has to be carefully monitored is:

- Initial umbilical artery PI increased and decreased end diastolic volume further progressing to absent or reversed end diastolic volume.
- Brain sparing effect showed by increased MCA PI and increases diastolic volume and increased peak systolic velocity.
- Abnormal venous pulsations or cardiac pulsations leading to increased PI of DV doppler or reversal of DV Doppler leads to pulsatile umbilical vein in the baby usually associated with absent diastolic umbilical vein which is good indicator of fetal distress.[11]

II. MATERIALS AND METHODS

A cross sectional study was performed at Fetal Medicine Department, SKNMC, Pune, from August 2021 to December 2022. Total 400 women were screened at routine antenatal visit during this period, out of which 225 were selected. All patients were screened on Siemens Acuson X300 Ultrasound machine.

➢ *Inclusion Criteria:*
- Pregnant women more than or equal to 25 weeks of gestation.
- Women who are willing to perform the doppler study (written informed consent taken).

➢ *Exclusion Criteria:*
- Pregnant women who are less than 25 weeks of gestation.
- Multifetal pregnancies.
- Diagnosed case of IUGR either clinically or ultrasound.

This visit included recording of maternal characteristics and medical history, and estimation of fetal size from trans abdominal ultrasound measurement of biparietal diameter fetal head circumference, abdominal circumference and femur length. Determination of gestational age was done from menstrual history or measurement of the fetal head circumference at 19–24 weeks. Doppler studies were performed using Siemens Acuson X300 Ultrasound machine by single Fetal medicine specialist using 5-MHz sector transducers with spatial peak temporal average intensities below 50 mW/cm2 and the high-pass filter at 50–100 Hz. In the fetal ductus venosus the flow pattern is a triphasic pattern, with S, D and A waves. In a normal fetus all three points should be in a forward direction and therefore above the baseline[12]. This is in contrast to the flow in the other veins such as IVC where the A wave is below the baseline. The most important a wave which is due to the atrial systole. The interpretation is done as normal a wave, absent a wave or reversal of a wave.

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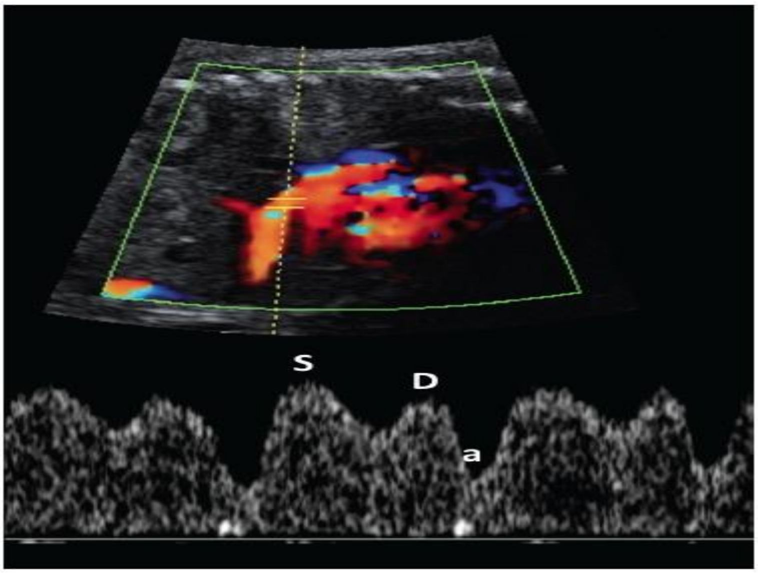

Fig 1 Color Doppler Imaging of the Ductus Venosus (DV) and a Normal Second-Trimester DV Waveform.

- *Timing the Obstetric Intervention:*

If the fetal Doppler was normal, the patients were monitored once in two weeks till confinement. When the abnormality in fetal Doppler showed a severe hemodynamic instability such as absent or reversed umbilical artery flow, immediate termination of pregnancy was undertaken. When the Doppler abnormality was intermediate such as a reduced umbilical artery diastolic flow, if the background fetal maturity was adequate, the patient was taken up for pregnancy termination. In the patients where adequate fetal maturity had not been achieved, close clinical monitoring of the patient with non-stress tests and biophysical profiles were done on a daily basis. Patient was intervened if these tests showed any abnormality at any time. When there was cerebroplacental reversal which indicated preferential shunting of blood to the fetal brain, the pregnancy was immediately terminated [13]. Perinatal outcome was recorded as intrauterine death, neonatal death, Apgar and infant birthweight Outcome of pregnancy was recorded in detail including intrauterine demise, neonatal death, birth weight[14].

III. RESULTS

Maternal and perinatal characteristics were evaluated and sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were calculated. Appropriate for gestational age (AGA) was defined as BW or EFW between 10th and 90th centiles. An abnormal DV was defined as DVPI below the 5th percentile or more than 95th percentile for gestational age on the basis of the nomogram by Baschat and Gembruch. [15].The mean DV was about 0.98, and the 5th and 95th percentile were 0.73 and 1.22(+/- 2SD)[16]. Maternal parameters studied were weeks of gestation, mode of delivery (vaginal or Caesarean section), complications during pregnancy. Neonatal parameters studied were NICU admissions and neonatal death. New-borns were classified as small for gestational age (SGA) if their birth weight was below the 10th percentile for gestational age according to Brenner et al [17].SGA new borns were considered growth retarded if they showed signs of malnutrition (decreased amount of subcutaneous fat, hypoglycaemia, hyperbilirubinemia ,hypocalcaemia, hyperviscocity syndrome) in the immediate neonatal period. Preterm delivery was defined as delivery before 37 completed weeks. Neonatal morbidity was assessed by the length of stay in the neonatal intensive care unit. Because of cost concern and affordability of patient, all babies were not subjected to ABG at birth, but all babies in NICU were subjected to ABG examination as per protocol. We have categorically identified that DV values < 5th centile and > 95th centile increases perinatal morbidity and mortality. We have seen that there is substantial increase in intrauterine and neonatal deaths at < 5th centile. Khalilet al., 2015 [18], also described the association of low DV with both instrumental delivery and cesarean section, Conversely, a normal DV was more likely to be associated with spontaneous vaginal delivery.

Table 1 Amongst the 225 Patients Subjected for Fetal Doppler, Doppler Abnormalities were Observed in 88 %Patients

Total No of IUGR cases	225	Percentage (%)
Normal doppler	26	12
Abnormal doppler	199	88

Table 2 Grading of the Doppler Findings in Ascending Order of Severity

Grade	Doppler findings
0	Normal Doppler
1	Increased umbilical artery PI without other Doppler abnormalities
2	Increased umbilical artery PI with reduced middle cerebral artery PI –cerebroplacental reversal
3	Absent/reversed diastolic flow in umbilical artery with decreased middle cerebral artery PI
4	Absent/reversed diastolic flow in umbilical artery with increased middle cerebral artery PI
5	Altered ‘a’ wave in ductus venosus

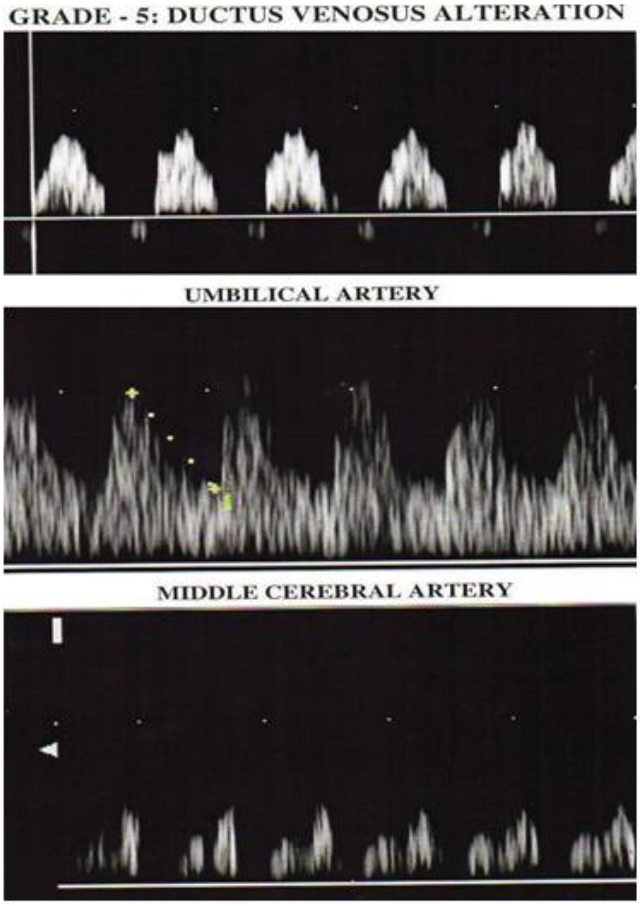

Fig 2 Grade 5 Doppler. Reversed Diastolic Flow in Umbilical Artery, Compensated Low Resistance Flow in the Umbilical Artery, Absent a Wave in Ductus Venosus

Table 3 This Illustrated the Number of Patients Fitting into Each Grade from 0 to 5 Based on the Doppler Findings

GRADES		Number of patients	Corresponding percentage
0	Normal Doppler	26	11.5
1	Increased umbilical artery PI without other Doppler abnormalities	40	17.7
2	Increased umbilical artery PI with reduced middle cerebral artery PI – cerebroplacental reversal	122	54
3	Absent/reversed diastolic flow in umbilical artery with decreased middle cerebral artery PI	18	8
4	Absent/reversed diastolic flow in umbilical artery with increased middle cerebral artery PI	15	6.6
5	Altered ‘a’ wave in ductus venosus	4	1.7

Amongst our 225 patients, abnormal Doppler was observed in 199 patients. Only 26 out of our 160 patients had a normal Doppler pattern (Table 1). Since the timing of obstetric intervention was based on a multifactorial dataset of Doppler abnormalities, to makethe decision simpler, we had done a grading of the Doppler abnormalities in the ascending order of severity[20]. This was done into six datasets from Grade 0 to Grade 5 as shown in Table 2.In our 199 patients with positive Doppler findings, 40 patients were in Grade 1, 122 were in Grade 2, 18 patients were in Grade 3, 15 patients were in Grade 4 and 4 patients were in Grade 5 which indicated irreversible fetal acidaemia (Table

3) Figure 1 demonstrates the normal Doppler waveform of the umbilical artery, MCA and Ductus venosus, that is Grade 0. Figure 2 demonstrates the most severe Grade 5 Doppler waveform of the umbilical artery, MCA and ductus venosus.

➢ *Perinatal Outcome:*

Out of the 225 cases, 206 were live born, 10 were neonatal deaths. There were 6 cases of intrauterine deaths and 3 were stillborn. Of the 225 live born, 41 had increased perinatal mortality which encompassed poor APGAR scores, necrotizing enterocolitis, hypoxic ischemic encephalopathy, meconium aspiration syndrome, hyperbilirubinemia and prolonged admission in NICU (Table 4).

Table 4 The Perinatal Outcome of the 225 Fetuses were Correlated with the Antenatal Doppler Grading

Perinatal outcome	Grade 0	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Total
IUD	0	0	0	0	2	4	6 (2.6%)
Stillborn	0	0	0	0	3	0	3 (1.3%)
Neonatal death	0	0	0	2	4	2	10 (4.4%)
Increased perinatal morbidity	0	0	26	13	2	0	41 (18.2%)
No adverse perinatal outcome	21	32	110	2	0	0	165(73%)

IV. DISCUSSION

Diagnosing IUGR is by B mode biometry. But the fetal hemodynamic status and hence the prediction of perinatal outcome requires a dedicated fetal Doppler study. Ductus venosus Doppler in predicting and preventing fetal acidaemia in confirmed growth restricted fetuses were analysed in our study and we came to a few illuminating conclusions. Amongst the Grade 0 fetuses, that is when the fetal Doppler is normal, there was no adverse perinatal outcome. So, Grade 0 had a negative predictive value of 100%. Amongst the Grade 1 fetuses, when the only abnormality was a decrease in umbilical artery diastolic flow, again none of the fetuses had an adverse perinatal outcome. Hence, Grade 1 too had a negative predictive value of 100%. Grade 2 fetuses showed a cerebroplacental reversal. There was a flow compensation occurring in the fetus with preferential shunting of blood to the brain. Grade 3 fetuses had no forward flow during diastole in the umbilical artery. Out of 18 fetuses in Grade 3, only two infants with adverse perinatal outcome. There was a perinatal morbidity in 14 new-borns with two neonatal deaths. Grade 4 decompensated fetuses had a 100% positive predictive value for adverse perinatal outcome, with both perinatal morbidity and mortality. Grade 5 fetuses, that is once there is increased resistance to flow in the ductus venosus, none of the fetuses survived. This grade therefore had a 100% positive predictive value as well as a 100% mortality[19].It was obvious in our study therefore that all patients with a severe grade of abnormality (Grade 3 and above) had a worse outcome as compared to the patients in the lower grades of abnormality. An inference from this study is a mild fetal hemodynamic compromise (Grade 1, Grade 2) had no significant perinatalmortality. Some Grade 2 fetuses had an increased perinatal morbidity, but survived with management. Grade 3 and Grade 4 fetuses, where the fetus went in for decompensation and hypoxemia, there was a significant increase in perinatal morbidity, with a high mortality rate in Grade 4. All 5 fetuses in Grade 5 did not survive, and this grade indicated fetal acidaemia. The crucial combined role of the radiologist and gynaecologist would be to regularly and closely monitor such high-risk pregnancies with fetal Doppler, and intervene swiftly before the fetus progresses toGrade 4 Doppler abnormalities.

V. CONCLUSION

In conclusion, the DV acts as a bypass of the liver microcirculation and plays a critical role in the fetal circulation. The DV allows oxygenated and nutrient-rich venous blood to flow from the placenta to the myocardium and brain. Increased impedance to flow in the fetal DV is associated with fetal aneuploidies, cardiac defects and other adverse pregnancy outcomes [20]. Further research is necessary to determine the importance of the DV Doppler assessment in improving perinatal outcomes Thus, we conclude, that Doppler can be used as a prognostictool in an IUGR fetus, as it gives an accurate prediction of the potential compromise in varying degrees of severity.

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