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Original Article

Radiology Section

Doppler Spectral Wave Patterns of Ductus Venosus: Do they Change with Foetal Position in the First Trimester?

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ABSTRACT

Introduction: The ductus venosus is a branch of the umbilical vein that carries oxygenated blood to the foetus's right atrium. Assessing the ductus venosus during the first trimester is used as one of the soft markers to detect aneuploidy. Since, operators often have to wait for extended periods for the foetus to assume the desired position. Prolonged scanning increases costs and reduces efficiency by extending scan times. Therefore, it is crucial to determine whether the foetal position affects the ductus waveform. In India, where the number of qualified operators is limited compared to the high demand for scans, efficiency is particularly important.

Aim: To observe the spectral flow patterns on colour Doppler of the ductus venosus in supine, prone, and oblique positions of the foetus.

Materials and Methods: The authors conducted a prospective observational study at Kempegowda Institute of Medical Sciences and Delta Diagnostics, Bengaluru, Karnataka, India, between August 2021 and December 2021. The study included 100 pregnant women who underwent routine first-trimester antenatal scans between 11 weeks and 13 weeks and six days. Colour Doppler flow mapping was used to visualise the umbilical vein, ductus venosus, and foetal heart. Spectral flow patterns of the ductus venosus were obtained in the supine, prone, and oblique positions of the foetus. The parameters studied were peak systolic velocity, end-diastolic velocity, and ductus venosus pulsatility index. Friedman's Test followed by Wilcoxon Signed Rank Post hoc test was used to compare the mean values of systolic and diastolic velocity and pulsatility index between different foetal positions.

Results: A total of 100 singleton pregnancies were included, mean gestational age was 12 weeks and four days. There was no difference in the subjective evaluation of the waveforms obtained in different positions. All foetuses exhibited type 1 spectral waveform. There were no false positives in the subjective evaluation for 'a' wave reversal. However, there was a significant difference in the systolic and diastolic velocities of the ductus venosus with different foetal positions, with a p-value of less than 0.001. The mean systolic velocities in supine, prone, and oblique positions were 60.09 cm/s, 51.59 cm/s, and 31.38 cm/s, respectively. The mean diastolic velocities in supine, prone, and oblique positions were 25.23 cm/s, 22.05 cm/s, and 19.05 cm/s, respectively. There was no significant difference in the pulsatility index among the supine, prone, and oblique positions.

Conclusion: Radiologists do not need to wait for the foetus to be in the horizontal position to assess the ductus venosus waveforms. The waveforms can be evaluated in other foetal positions without affecting the assessment of aneuploidy risk.

Keywords: Foetal position, 1st Trimester, Ultrasound

INTRODUCTION

The ductus venosus is a narrow vascular channel that shunts oxygenated blood from the umbilical vein to the caudal inferior vena cava, bypassing the liver. This allows oxygenated and nutrient-rich blood from the placenta to reach vital organs such as the brain and myocardium. Blood from the inferior vena cava is then delivered to the left atrium via the right atrium and the fossa ovalis [1]. Changes in the ductus venosus flow, such as increased impedance, absence, or reversal of flow, serve as indirect markers for cardiac defects and aneuploidies in the first trimester [2].

During liver development, the umbilical vein undergoes compression, and the ductus venosus helps in diverting oxygenated blood to the inferior vena cava. The absence of this shunt can lead to hypoxia and developmental abnormalities in the foetus, which can be indicated by the reversal of the 'a' wave in spectral Doppler [3].

One study reported an incidence of 2.46% (euploidy) and 37.7% (aneuploidy) in foetuses with a reversed 'a' wave in the ductus venosus [4]. A search on Google did not yield any literature or studies on the effect of foetal position on the assessment of ductus venosus waveforms. Therefore, this present study was conducted to observe the spectral waveforms on Doppler in different positions of the foetus (supine, prone, and oblique).

MATERIALS AND METHODS

A prospective observational study was conducted in the Department of Radiodiagnosis, Kempegowda Institute of Medical Sciences and Delta Diagnostics, Bangalore, Karnataka, India, from August 2021 to December 2021. Ethical committee approval (KIMS/IEC/A086/M/2021) was obtained for the study.

Inclusion criteria: The study included a total of 100 singleton pregnancies undergoing routine prenatal first-trimester antenatal screening scans for chromosomal abnormalities between 11 weeks and 13 weeks 6 days.

Exclusion criteria: Pregnancies with maternal age below 18 years, medicolegal cases, and foetuses with abnormal nuchal translucency or major structural abnormalities were excluded from the study.

Procedure

Ultrasound examinations were performed transabdominally. Gestational age was confirmed by measuring the crown-rump length, and foetuses ranging from 45-84 mm were included. Foetal anatomy was carefully evaluated. Ductus venosus waveform analysis was conducted during foetal quiescence. The ultrasound image was magnified to focus on the foetal thorax and abdomen. A right ventral parasagittal view of the foetal trunk was obtained, and the umbilical vein, ductus venosus, and foetal heart were visualised using colour flow mapping. Spectral Doppler waveforms were obtained in the sagittal plane with the foetus in the supine position. For the prone position, a dorsal parasagittal view was obtained. An oblique section was acquired with either anterior or posterior insonation, resulting in waveforms with less control over the angle and absolute velocities.

Colour Doppler was used to identify the area of maximum aliasing. The Doppler gate size was set at 1.0 mm and placed in the aliasing area. The Doppler angle was set at zero degrees for the supine and prone positions, and below 30 degrees for the oblique position. The filter was set at a low frequency range of 50-70 Hz to enhance visualisation of the 'a' wave. The sweep speed was set at 2-3 cm/s. Manual tracing of the waveform outline was performed. The ductus venosus Pulsatility Index of Veins (PIV) was measured by the machine. The status of the 'a' wave was evaluated in all three positions. Waveforms of the ductus venosus were obtained in the supine, prone, and oblique positions of the foetus. Assessment of the waveforms was conducted to determine if there were any changes in the flow patterns of the ductus venosus with changes in foetal position [Table/Fig-1] [5].

Type of wave pattern	S and D PEAKS	a and v nadirs	Others
Type-1- classic wave pattern	Normal	Normal	Reflects atrial pressures in the cardiac cycle
Type-2- monophasic umbilical wave MUV pattern	-	Absent	S/a ratio less than UV Vmax/Vmin
Type-3	-	Less obvious, monophasic	S/a ratio more than UV Vmax/Vmin (<1.80)
Type-4- MUV pattern with intermittent normal waveform component	-	-	Monophasic Umbilical Venous (MUV) pattern
Type-5- normal waveform pattern with intermittent MUV component	-	-	Normal waveform pattern
Type-6- undulant waveform pattern			
Type-7- mixed or unclassified flow pattern			

[Table/Fig-1]: Types of wave patterns [5].

The examinations were performed using a CA1-7A convex transducer with a Samsung RS 80A USG machine and a CA 3-10A curved array transducer with a Samsung HERA W10 ultrasound machine.

All Doppler studies were conducted by a single radiologist with twelve years of experience in foetal ultrasound and venous Doppler sonography.

STATISTICAL ANALYSIS

Statistical analysis was performed using IBM Corp's Statistical Package for the Social Sciences (SPSS) for Windows, version 22.0, released in 2013 (Armonk, NY). Friedman's Test followed by the Wilcoxon Signed Rank post-hoc test was used to compare the mean values of systolic and diastolic velocity and pulsatility index between different foetal positions. The level of significance was set at a p-value of less than 0.05.

RESULTS

The average maternal age was 27.63±4.44 years [Table/Fig-2].

Using Friedman's test, the mean systolic values were compared among different foetal positions, and a significant change in systolic values was observed with a p-value of less than 0.001 [Table/Fig-3].

The mean systolic velocity was significantly higher in the supine position compared to the prone and oblique positions [Table/Fig-4].

There was a significant change in the mean diastolic values with a change in foetal position [Table/Fig-5].

Variable	Category	N
Age (years)	18-20 y	6
	21-30 y	66
	31-40 y	28
		Mean±SD
	Mean	27.63±4.44
	Range	18-39
Gestational age (weeks)	12	11
	13	67
	14	22

[Table/Fig-2]: Age wise and gestational age wise distribution of study subjects.

Position	Mean (cm/s)	SD (cm/s)	p-value
Supine	60.09	23.35	<0.001*
Prone	51.59	22.16	
Oblique	45.75	31.38	

[Table/Fig-3]: Comparison of mean systolic velocity values between different foetal positions using friedman's test.

(I) Groups	(J) Groups	Mean Diff. (I-J)	95% CI for the Diff.		p-value
			Lower	Upper	
Supine	Prone	8.50	2.76	14.25	**0.001***
	Oblique	14.34	6.16	22.52	**<0.001***
Prone	Oblique	5.84	-2.32	14.01	**0.001***

[Table/Fig-4]: Multiple comparison of mean difference in systolic velocity values between different foetal positions using Wilcoxon Signed rank post-hoc test.

Groups	Mean (cm/s)	SD (cm/s)	p-value
Supine	25.23	9.25	<0.001*
Prone	22.05	8.55	
Oblique	19.05	8.38	

[Table/Fig-5]: Comparison of mean end diastolic velocity values between different foetal positions using Friedman's test.

The mean diastolic velocity in the foetal supine position was higher compared to the prone and oblique positions [Table/Fig-6].

There was no significant change in the pulsatility index with a change in foetal position [Table/Fig-7].

(I) Groups	(J) Groups	Mean Diff. (I-J) (cm/s)	95% CI for the diff.		p-value
			Lower	Upper	
Supine	Prone	3.18	0.43	5.93	**0.02***
	Oblique	6.18	3.79	8.56	**<0.001***
Prone	Oblique	3.00	0.58	5.41	**0.01***

[Table/Fig-6]: Multiple comparison of mean difference in end diastolic velocity values between different foetal positions using Wilcoxon Signed Rank post-hoc test.

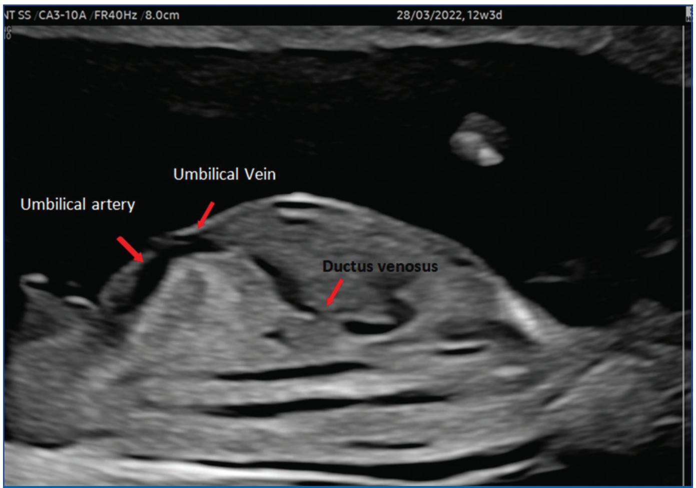
Groups	Mean	SD	Min	Max	p-value
Supine	0.902	0.175	0.50	1.40	0.74
Prone	0.904	0.179	0.10	1.30	
Oblique	0.898	0.172	0.50	1.40	

[Table/Fig-7]: Comparison of mean pulsatility index values between different positions using friedman's test.

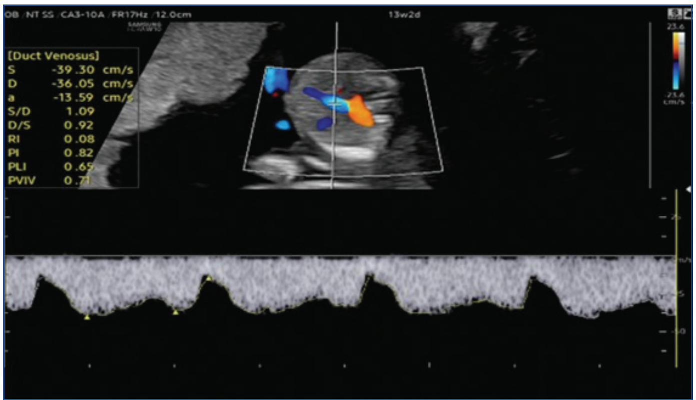
DISCUSSION

Ductus venosus Doppler parameters play an important role in foetal assessment. The normal and abnormal ductus venosus waveforms at 11-14 weeks of gestation are crucial for detecting chromosomal abnormalities, congenital heart disease, or adverse foetal outcomes. Parameters such as Pulsatility Index of Veins (PIV) and absent or reversed flow during atrial contraction are used for this purpose.

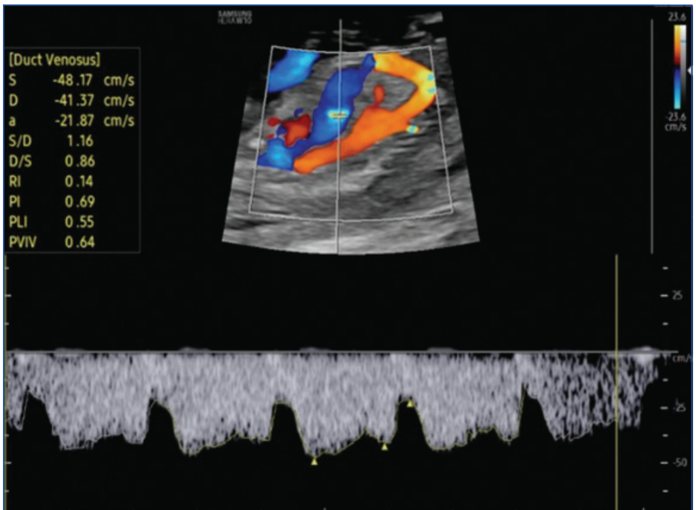
The confirmation of the ductus venosus is done by identifying its triphasic forward wave pattern, which consists of two peaks, 'S' and 'D', representing ventricular systole and diastole, respectively. There is a third nadir 'a' which represents atrial systole and remains antegrade, unlike the inferior vena cava and hepatic veins [6]. Normally, the peak systolic velocity of the ductus venosus is higher compared to the atrial velocity, which explains its role in propelling oxygenated blood into the left atrium through the fossa ovalis [Table/Fig-8-11].



[Table/Fig-8]: Gray scale ultrasound of foetus in sagittal section with magnification of foetal thorax and abdomen.

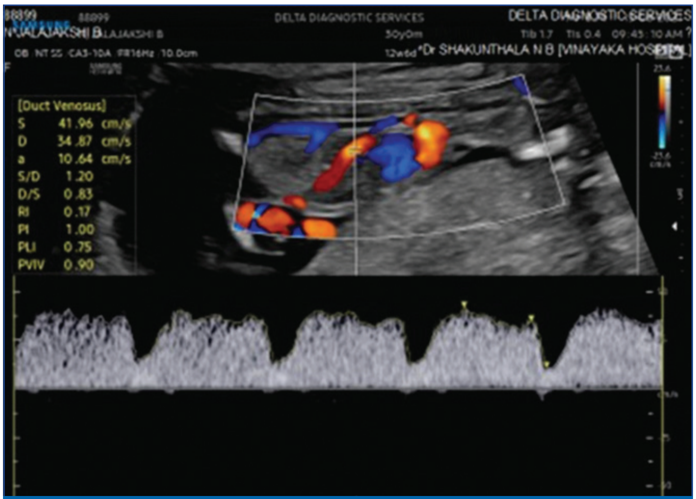


[Table/Fig-9]: Normal ductus venosus spectral wave pattern obtained in supine position.



[Table/Fig-10]: Normal ductus venosus spectral wave pattern obtained in prone position.

Gürses C et al., in their study, found that each trimester corresponds to a classic blood flow pattern [5]. Normal pregnancies can exhibit seven different normal wave patterns, making the assessment of foetal circulation challenging. In this study, all foetuses had type 1 waveforms.



[Table/Fig-11]: Normal ductus venosus spectral wave pattern obtained in oblique position.

The ultrasonographic velocimetry of the foetal ductus venosus was first described by Kiserud T et al., [7,8]. Since then, reference values of absolute flow velocities, which are angle-dependent, or indices, which are angle-independent, have been established for each week of pregnancy.

A study conducted by Pruksanusak N et al., which included 304 foetuses between 11 weeks and 13 weeks six days, reported a significant increase in systolic velocity and diastolic velocity with gestational age [9]. The mean systolic velocity at the 95^{th} percentile was 51.81±0.30, whereas in this study, it was 60.09±23.5, showing a significant difference compared to the previous study.

Similarly, Pruksanusak N et al., reported a diastolic velocity of 44.34±0.29 cm/s, while in the present study, the diastolic velocity was 25.23±9.25 cm/s, also showing a significant difference [9].

Velocities across the ductus venosus depend on various factors such as vessel diameter, pressure gradient, blood viscosity, and Doppler angle. Therefore, there is a statistically significant difference in Peak Systolic Velocity (PSV) and End-Diastolic Velocity (EDV) among the various foetal positions. In addition to these factors, the gravitational force, which has been neglected until now, could also play a role in ductus venosus velocimetry, potentially leading to an increase in mean peak systolic velocity in the supine position compared to other positions. However, there is no statistically significant difference in venous Pulsatility Index (PI), which is a quantitative measurement. This can be attributed to the angle independent of PI. Clinicians can perform scans in any position and do not need to wait for the foetus to be in the horizontal position. Further research on abnormal foetuses is needed in the future to better understand the relationship between foetal position and changes in the flow pattern of the ductus venosus.

Limitation(s)

This study was conducted only in foetuses with normal nuchal translucency and structural anatomy. Therefore, further studies should be conducted in foetuses with abnormal nuchal translucency and structural abnormalities.

CONCLUSION(S)

The subjective evaluation of ductus venosus waveforms, particularly the assessment for 'a' wave reversal, does not appear to be influenced by the position of the foetus, and there were no false positives in any of the cases evaluated. Although there was a significant difference in absolute velocities (as expected with changes in foetal position), this is not clinically significant as absolute velocities are not used in the assessment for aneuploidies. Additionally, the parameter commonly used, Pulsatility Index (PI), also does not appear to be affected by changes in foetal position. Therefore, assessing ductus venosus waveforms in different positions of the foetus may not alter the risk assessment for aneuploidies, potentially reducing examination time.

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