

Color Doppler Ultrasonographic Evaluation of the Intrauterine Hepatic and Portal Venous System

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Introduction: We aimed to determine the changes, varieties, and differences of the Doppler index of the umbilical, uterine and fetal middle cerebral artery (MCA) and umbilical vein (UV), ductus venosus (DV), inferior caval vein (ICV) of normal pregnancies among the 18-37th weeks and the term to determine the normal values of our population.

Materials and Methods: Umbilical, uterine, and fetal MCA with UV, DV, and ICV Doppler examinations were performed following the routine obstetric ultrasonographic evaluation once throughout the pregnancy and at the delivery of 163 normal pregnant with no maternal or Fetal complications at 18-24 (66 patient), 25-30 (53 patients) and 31-37 weeks (44 patients). The Systole/Diastole (S/D) rate for the arteries and the ICV, preload index for the DV, and mean velocity for the UV were used as the Doppler indexes. All color Doppler ultrasonographic examinations were performed by only one operator using Siemens Acuson Antares machine and the CH4-1 MHz convex probe.

Results: During the following weeks of the pregnancy, the S/D Doppler index and DV preload index were found to be decreased. No significant changes were found for the UV mean velocity. Results were statistically evaluated.

Conclusion: As a result, venous structures and arterial parameters should be evaluated during the obstetric color Doppler ultrasonographic examination. The evaluation of these structures can be important for the early diagnosis of the conditions such as intrauterine growth retardation and hypoxia.

Keywords: Obstetric doppler, umbilical artery, uterine artery, fetal middle cerebral artery, umbilical vein, ductus venosus, inferior caval vein

Introduction

Fetal growth and development depend on the normal fetomaternal circulation, which ensures adequate oxygen and nutrient uptake from the maternal circulation. Duplex ultrasonography systems, consisting of a combination of B-Mode and Doppler, are increasingly being used in determining the changes in uteroplacental

and fetal circulation during pregnancy, since they are reproducible and noninvasive. Doppler ultrasonography is an important auxiliary diagnostic method in detecting fetal distress in risky pregnancies, including intrauterine growth retardation, placental insufficiency and preeclampsia. Doppler ultrasonography is a fast, reliable and noninvasive method that can

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be used to evaluate fetal & maternal physiology and pathophysiology (1). Especially the close relationship between the fetal distress and abnormal Doppler waveforms expands the usage areas of the test. The time between the appearance of abnormal Doppler results and the development of severe fetal distress varies according to the underlying cause. While this period is 5-6 weeks for intrauterine growth retardation (IUGR), it can be as short as 24-48 hours for severe preeclampsia (2, 3).

Usually, renal artery Doppler measurements are made at the level of renal hilum. In recent years, thanks to color coding, examination time has been shortened and it has been possible to evaluate very small fetal or uteroplacental vessels. With the widespread use of colour coding, the vascular structures that make up the Willis polygon can be easily evaluated. Diastolic flow in fetal renal arteries gradually increases with advancing weeks of gestation in normal pregnancy. In infants with developmental delay, pulsatility indexes in the renal arteries were found to be significantly higher, and this finding is thought to be associated with reduced blood flow to the kidneys due to redistribution. In addition, it is stated that the increase in renal artery Doppler indices is more pronounced in cases with growth retardation and oligo-hydramnios (4, 5).

In this study, we determined the changes in the Doppler indexes of the fetal umbilical vein (UV), vena cava inferior (VCI) & ductus venosus (DV) according to the weeks of gestation, as well as the umbilical, uterine, fetal middle cerebral arteries during the pregnancy period, and determined the normal for our population. It was aimed to create values and thus to popularize the use of Color Doppler Ultrasonography (CDU) in high-risk pregnancies.

Materials and Methods

Ethical Statement

Our study was carried out with the permission of Gaziantep University Faculty of Medicine,

Medical Ethics Committee decision number 05-2009/146.

Study Design

Our study included 175 pregnant women who were sent from the Obstetrics Clinic to Gaziantep University Medical Faculty Radiology Department between January 2009 and March 2010. However, 12 pregnant women who had various problems during Doppler US were excluded from the study. Among the detected problems were twin pregnancy, single UmA, meningocele, enlarged lateral ventricles. No problem was found in any of the other pregnant women whose clinical examination and laboratory results were normal.

In this study, pregnant women were 18-37. CDUS was performed by following up between weeks. The ages of the pregnant women ranged from 17 to 45. Examinations with CDUS were carried out in 3 different groups consisting of 66 pregnant at 18-24 weeks, 53 at 25-30 weeks, and 44 at 31-37 weeks. A total of 163 cases were included in the study. All CDUS examinations were performed by a single practitioner on the Siemens Acuson Antares instrument. During the examinations, a CH4-1 MHz convex probe was used.

First of all, routine obstetric evaluation was performed in the pregnant women included in the study. Fetal age and growth, amniotic fluid amount, number of fetuses, fetal heart activity, fetal presentation, placenta location and structure, and fetal anatomy were evaluated. In addition, the presence of uterine fibroids or adnexal mass lesions was investigated. After this examination, CDUS evaluation was started. In the examination, the flow patterns of three vessels belonging to the arterial system were evaluated and Doppler indexes were measured. Arterial vessels examined; 1-Umbilical artery (UmA), 2-Uterine artery (UtA), 3-Fetal middle cerebral artery (MCA). Doppler index measured to evaluate the flow in vessels was determined as Systolic velocity/Diastolic velocity ratio (S/D).

Doppler indexes were measured by evaluating the flow patterns of the three main vessels of the venous system.

1-Umbilical vein (UV)

2-Ductus venosus (DV)

3-Vena cava inferior (VCI)

In the measurements made from vessels, flow velocity and flow form in UV, and the preload index in DV were examined. Preload index was found by calculating Ventricular systole (S)-Atrial contraction (A)/Ventricular diastole (D). Ventricular systole (S)/Ventricular diastole (D) ratio and flow form were measured in the inferior vena cava. During the measurement of all Doppler indices, the absence of the fetal respiration or movement was observed. Measurements made during respiration were then repeated. After observing that the obtained waveforms remained constant for at least 4 seconds, measurements were made from three different cycles and their averages were calculated.

In the measurements made from the umbilical artery, attention was paid primarily to the structure of the cord, the presence of 2 arteries and one vein and its location. All measurements were made from either of 2 arteries and the middle 1/3 section. Measurements were not made from localizations close to the fetus and placenta. For uterine artery measurements, first of all, the location of placenta was examined. Measurements were made from the UtA on the side where the placenta was located. In cases where the placenta was located in the midline, either of two UtA was evaluated or the average was taken by measuring from both sides.

In fetal MCA measurements, after determining the vascular structures belonging to the Willis polygon with the help of color coding, Doppler indices were measured from any of them. Measurements made from the umbilical vein were made from the middle 1/3 section. Measurements made during fetal respiration were repeated and evaluated.

Measurements made from DV were made from the place where UV ends in liver and evaluated. Measurements from VCI were measured between renal and subdiaphragmatic hepatic veins (HV).

Statistical Analysis

Doppler index measurements of three different groups were recorded separately for each pregnant woman, and the changes observed in the measurements of the arteries and veins examined were statistically entered into the SPSS 13.00 package program in line with the data obtained. The minimum and maximum values, mean and standard deviations of arteries and veins were tabulated by descriptive statistical method.

Results

It was observed that the Doppler index values obtained in the later stages of pregnancy in the arterial and venous vessels examined in our study showed changes and did not remain constant. A total of 163 cases between the ages of 17 and 45 were included in the study. The umbilical, uterine, MCAs and UV, DV, VCI measurements were made and compared in the cases. Different arterial and venous Doppler indices of the cases were examined, and the amount of change according to weeks was examined.

Umbilical artery (UmA)

S/D velocity ratios were measured in umbilical artery measurements. A decrease was observed in UmA Doppler indexes with the progression of the gestational week, and the decrease observed in all 3 Doppler indexes was found to be significant in the statistical evaluation. S/D velocity ratio: Mean and standard deviation from 3.35 ± 0.86 at 18–24 weeks, to 3 ± 0.61 at 25–30 weeks, 31–37. decreased to 2.67 ± 0.62 weeks (Figure 1). In the analysis of variance applied, the change was found to be significant ($P < 0.001$). When the groups were evaluated within themselves, the change between 18-24

and 25-30 weeks was significant ($P < 0.05$). The change between 18-24 weeks and 31-37 weeks was significant ($P < 0.001$). However, in the evaluation made between 25-30 and 31-37 weeks, difference was not significant ($P > 0.05$).

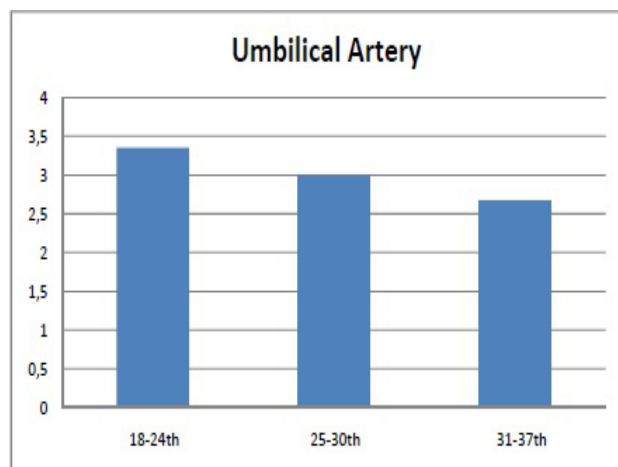


Figure 1. Umbilical artery measurements by weeks

Uterine artery (UtA)

Systolic/Diastolic velocity ratios were measured in uterine artery measurements. A decrease was observed in the UtA Doppler indexes with the progression of the gestational week, and the decrease observed in all three Doppler indices was significant. Systolic/Diastolic ratio: Mean and standard deviation of 2.28 ± 0.54 , 25-30, measured between 18-24 weeks. decreased to 2.10 ± 0.38 at Weeks 31-37 and to 1.97 ± 0.22 at Weeks 31-37 (Figure 2).

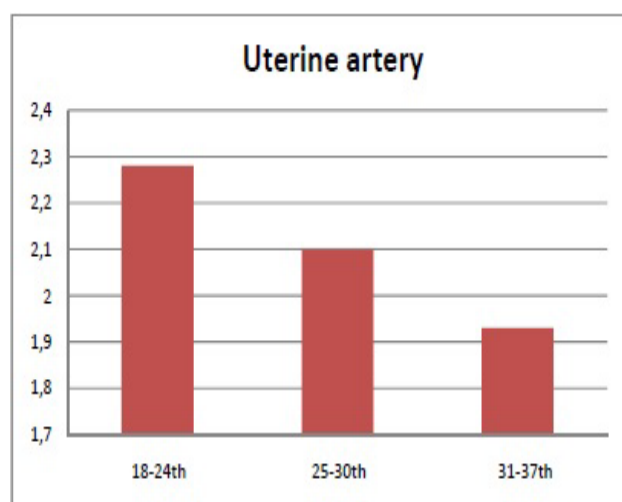


Figure 2. Uterine artery measurements by weeks

In the analysis of variance applied, the change was significant ($P < 0.001$). When the groups were evaluated within themselves, the change between 18-24 weeks and 25-30 weeks was not statistically significant ($P > 0.05$). The change between 18-24 weeks and 31-37 weeks was significant ($P < 0.001$). In the evaluation made between 25-30 weeks and 31-37 weeks, the difference was not significant ($P > 0.05$).

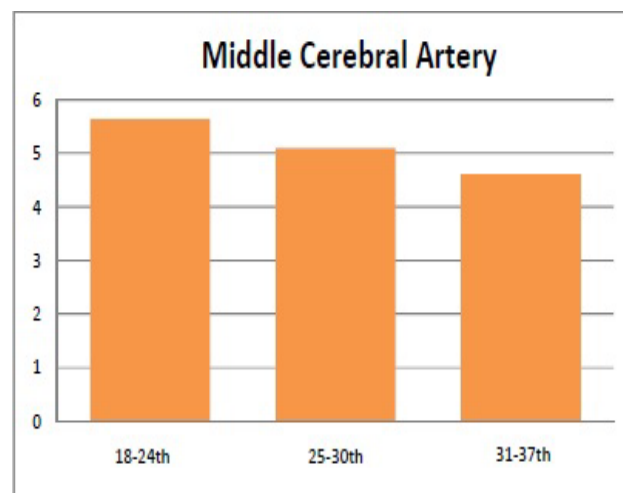


Figure 3. Middle cerebral artery measurements by weeks

Middle Cerebral Artery (MCA)

Systolic/Diastolic velocity ratios were examined in the MCA measurements. A decrease was observed in MCA Doppler indices with the progression of the gestational week, and the decrease observed in all three Doppler indices was found to be significant in the statistical evaluation. Systolic / Diastolic velocity ratio: The mean and standard deviation of measurements performed between 18-24 weeks decreased from 5.64 ± 1.69 to 5.09 ± 1.5 at 25-30 weeks and to 4.61 ± 1.59 at 31-37 weeks (Figure 3). In the analysis of variance applied, the change was significant ($P < 0.001$). When the groups were evaluated within themselves, change between 18-24 and 25-30 weeks was not significant ($P > 0.05$). The change between 18-24 and 31-37 weeks was significant ($P < 0.05$). In the evaluation made between 25-30 and 31-37 weeks, the difference was not significant ($P > 0.05$).

Umbilical vein (UV)

Average velocity values were measured in umbilical vein measurements. There was no difference in UV-Doppler indices as the gestational week progressed, and the changes observed in all three Doppler indices were not significant in the statistical evaluation. Systolic/Diastolic velocity ratio: It was observed that the mean and standard deviation increased from 18.2 ± 3.7 to 19 ± 4.57 between 25-30 weeks, and 19 ± 3.72 at 31-37 weeks in measurements made between 18 and 24 weeks. No change was found in the analysis of variance ($P > 0.05$). Umbilical vein flow Doppler waveform showed pulsation with fetal respiration in 13 cases. Pulsations disappeared during fetal apnea in measurements made after 5 minutes.

Ductus venosus (DV)

Preload index ratios were evaluated in ductus venosus measurements. With the progression of gestational week, a decrease was observed in DV Doppler indices and it was determined that the decrease observed in all three Doppler indices was not significant in the statistical evaluation. Preload index ratio: Mean and standard deviation decreased from 0.91 ± 0.2 at 18-24 weeks, to 0.87 ± 0.16 at 25-30 weeks, and to 0.85 ± 0.14 at 31-37 weeks. No change was found in the analysis of variance ($P > 0.05$).

Vena Cava Inferior (VCI)

S/D velocity ratios were measured in the inferior vena cava measurements. With the progression of the gestational week, a decrease was observed in VCI Doppler indices, and the decrease observed in all three Doppler indices was found to be significant in the statistical evaluation. S/D velocity ratio: The mean and SD of measurements performed between 18-24 weeks decreased from 3.57 ± 1.14 to 3.13 ± 0.68 at 25-30 and 3 ± 0.79 at 31-37 weeks (Figure 4.). In the analysis of variance applied, the change was significant ($P < 0.001$). When the groups were evaluated within themselves, change between 18-24 weeks and 25-30 weeks was found to be

significant ($P < 0.05$). The change between 18-24 and 31-37 weeks was significant ($P < 0.05$). In the evaluation made between 25-30 and 31-37 weeks, the difference was not significant ($P > 0.05$). When we evaluated the inferior flow form of the Vena Cava, the reverse flow pattern observed during atrial contraction was not detected in a total of 24 patients (14.72%). In other cases, reverse flow was present.

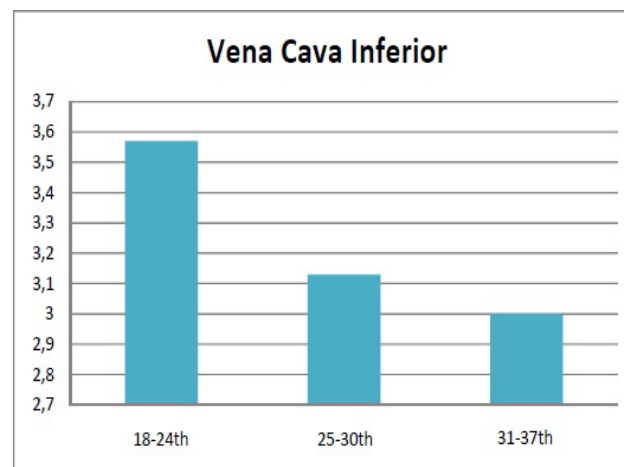


Figure 4. Inferior vena cava measurements by weeks

Discussion

Doppler sonography allows rapid and reliable noninvasive evaluation of the physiological and pathophysiological changes of the fetomaternal circulation. Significant advantages of Doppler sonography can be considered in the early diagnosis of fetal distress, as it can be found before other tests, is reproducible, non-invasive, does not contain radiation, and is easy to apply.

In obstetrics, UmA is the vessel that has the most Doppler ultrasonographic study and can be examined easily. Whatever technique is used, the typical sawtooth Doppler waveform can be easily obtained. In normal pregnancy, after approximately 16-20 weeks of pregnancy, that is, after the trophoblast invasion in the placental vascular bed occurs and placental resistance decreases, a significant increase in the end-diastolic velocities is observed with advancing weeks of gestation. Due to this low

resistance pattern; A progressive decrease is observed in S/D, Resistance index (RI) and Pulsatility index (PI) values. The most commonly used indexes are S/D ratio and PI. S/D ratio and PI have similar predictive values in adverse perinatal events. Since S/D is the most common used area index to describe umbilical artery waveforms (6-8), the ratio was used in the study.

Umbilical artery Doppler indices may also vary depending on the localization of the cord from which the measurement is made. In all segments of the cord, the Doppler waveform is not uniform (1, 6). Generally, indices are found to be slightly lower on the side close to the placenta, and slightly higher in the localization near the fetal abdominal wall. While difference is not significant in normal pregnancy, it becomes more evident especially in cases where resistance to flow increases in the fetoplacental and uteroplacental circulation. In the literature, measurements made from the middle part of the cord were used most frequently. In our study, measurements were made from the middle 1/3 of the cord as in the literature (9, 10).

In the study conducted by Trudinger et al (11) in UmAs in normal pregnant women, the S/D ratios were measured between 3-7 at 20 weeks and their mean was 4.5, and it decreased below 3 after 30 weeks. In the study of Şener et al., S/D ratios were reported as 3.46 at 20 weeks, 2.89 at 30 weeks, and 2.60 at 35 weeks (12). Kurjak et al., on the other hand, presented the average values according to the weeks in a graphic form (13). In the UmA Doppler study conducted by Flescher et al. in 189 high-risk pregnant women, it was shown that the S/D ratio increased as the birth weight decreased. Sensitivity and specificity were 78% and 85%, respectively, in cases with a S/D ratio above 3.0 after the 30th week (14, 15). In our study, the S/D ratio was 3.35 ± 0.86 in the first group, which included pregnant women between 18–24 weeks, and 3.00 ± 0.61 in the second group, which included

pregnant women between 25–30 weeks, 31-37. It was found to be 2.67 ± 0.62 in the 3rd group, which included pregnant women between 3 and 5 weeks of gestation. Similar results were obtained in different studies and our findings were evaluated in accordance with literature.

When taking a Doppler sample, it is very important to determine the appropriate vessel. As a result of the measurements made by Matthews et al. (13), S/D ratios according to gestational weeks are presented graphically. Deutinger et al. (16) calculated the S/D ratio in the measurements they made in UtA in normal pregnancies until delivery. The mean values were 3 at 20 weeks, 2.7 at 24 weeks, 2.1 at 32 weeks, and 2 at 36 weeks. In our study, the UtA S/D averages varied according to the weeks as follows; The S/D ratio was calculated as 2.28 ± 0.54 in the first group between 18-24 weeks, 2.10 ± 0.38 in the group between 25-30 weeks, and 1.93 ± 0.22 in the group between 31-37 weeks. The first group measurements were lower than the rate reported by Deutinger et al. (16), but higher than the findings of Matthews et al. (13). When we evaluate the average of the measurements we made in these weeks (18-24 weeks), the findings are within the normal percentile range. The measurements we made in the other weeks were found to be compatible with the literature.

Quantitative analysis of umbilical blood flow velocity and calculation of its volume are problematic. Because small fluctuations in blood flow values lead to wide variations in blood flow values. The umbilical vein waveform shows a monophasic pattern with an average flow rate of 10-15 cm/sec (17). In our study, UV measurements were made from intraamniotic segment. Respiratory pulsation was present in 13 cases, but the pulsation disappeared in measurements made after 5 minutes. In other cases, a monophasic, non-pulsatile flow pattern was observed. The mean umbilical vein flow velocity varied according to the weeks as

follows; The mean rate was 18.2 ± 3.70 in the first group between 18-24 weeks, 19 ± 4.57 in the 25-30 weeks group, and 19 ± 3.72 in the 31-37 weeks group. The mean blood flow velocities we found were higher than the study by Andelija et al. (18). There are limited studies on this subject. However, this result is due to small fluctuations in UV blood flow values causing wide variations in blood flow values.

Under normal conditions, the blood flow in the DV is forward and biphasic throughout the entire cardiac cycle. The first peak flow corresponds to ventricular systole (S wave), the second occurs during ventricular diastole (D wave). Following these two waves, there is a slowing of the flow rate during atrial contraction (wave A). D wave may not be evident in 11% of cases and A wave may not be seen in 3% (19). Bahlmann et al. (20) calculated preload index in their study. $\text{Preload index} = S (\text{Ventricular Systole}) - A (\text{Atrial contraction}) / D (\text{Ventricular Diastole})$. They found preload index between 0.74-1.07 at week 18 and between 0.36-0.77 at 37 weeks. In our study, the DV preload index averages varied according to the weeks as follows; It was calculated as 0.91 ± 0.20 in the first group between 18-24 weeks, 0.87 ± 0.16 in the group between 25-30 weeks and 0.85 ± 0.14 in the group between 31-37 weeks. Our findings were consistent with the literature findings between 18-24 weeks. However, although the measurements we made between 31-37 weeks are higher than the study by Bahlmann et al. (20), they are below the 95th percentile. In our study, VCI measurements were made just distal to the junction of the DV and proximal to the junction of the renal veins. VCI S/D ratio averages varied according to weeks as follows; The mean S/D was 3.57 ± 1.14 in the first group between 18-24 weeks, 3.13 ± 0.68 in the 25-30 weeks group, and 3 ± 0.79 in the 31-37 weeks group. Compared to the study by Govender et al., S/D ratios in our study were found to be above the 50th percentile, but between the 5th and 95th percentile values (21).

Conclusion

As a result, the S/D index values in UmA, UtA and fetal MCA in normal pregnant women in whom no maternal or fetal abnormality was detected during pregnancy, at birth and immediately after delivery; UV mean velocity values, DV preload index, and changes in VCI S/D values in the later stages of pregnancy were calculated. These normal values, which we obtained for our own population, were assessed together with the literature information. CDUS is an important modality in diagnosis and follow-up in many pathological conditions that complicate pregnancy, especially IUGR and preeclampsia. The main purpose of performing arterial and venous Doppler in practice is to evaluate the well-being of the fetus and to decide on the indication for delivery.

In the follow-up of fetuses who are far from term, especially younger than 32 weeks, and at risk with IUGR, arterial Doppler measurements such as UmA, UtA and MCA should be performed together with venous Doppler measurements. Fetals with abnormal arterial Doppler findings should also be considered in the direction of delivery if abnormal venous Doppler results are also obtained, especially in the presence of progressive increase in resistance or reverse flow in DV, or in the presence of pulsations in UV, since the findings indicate severe fetal distress. If delivery will not be performed, the frequency of biophysical profile follow-ups should be increased, as these findings may herald the impending sudden worsening of the biophysical profile. The results of studies conducted in recent years indicate that abnormal findings occur in venous structures before arterial findings.

Author Contributions

The study conception, designed, statistical analysis, data collection, wrote and edited the manuscript by Mehmet Akif Sarica. Resat Kervancioğlu supervised and participated in data interpretation and manuscript writing.

Conflict of Interest

The authors declare no conflict of interest for the present study.

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