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Does maternal hyperoxygenation have any effect on the fetal circulatory system in normal growth and late-onset IUGR fetuses?

Deniz Kanber Acar[a,*], Nijad Bakhshaliyev[b], Can Yilmaz Yozgat[c]

[a] *Kanuni Sultan Suleyman Training and Research Hospital, Department of Maternal Fetal Medicine, Istanbul, Türkiye*
[b] *Bezmialem Vakif University, Department of Cardiology, Istanbul, Türkiye*
[c] *Istanbul Maltepe University, Faculty of Medicine, Istanbul, Türkiye*

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Abstract

Aim: Maternal hyperoxygenation (MHO) has been recommended as an alternative treatment for fetuses with IUGR. We wanted to evaluate the effect of MHO treatment on ductus venosus (DV) and pulmonary vein (PV) doppler flow measurements in fetuses with late-onset IUGR.

Materials and Methods: A total of 63 pregnant women were enrolled in the study (32 pregnant women diagnosed with IUGR and 31 women with normal growth). The control group comprised 31 randomly selected age-matched and gestational-age-matched healthy pregnant women who presented to the antenatal clinic on the exact dates as the women in the study group.

Results: In the IUGR group, MHO significantly increased the PI value of DV (0.50 (0.40, 0.58) to 0.62 (0.60, 0.65). p<.001). The DV-S, DV-D, and S/a values of the DV increase significantly for the IUGR group. DV- a value of DV decreased significantly from 52.00 (49.25, 52.75) to 41.50 (38.50, 42.75) p<.001. Comparison of Doppler findings in healthy fetuses before and after oxygen inhalation did not change significantly. Also, The PI value in the PV did not change significantly following maternal hyper oxygenation in the IUGR group (pre-O2: 0.80 (0.73, 0.88) and post-O2: 0.80 (0.70, 0.90)).

Conclusion: We detected a statistically significant increase in both DV and PV blood flow during MHO administration in late-onset IUGR fetuses. Since increased DV and PV blood flow is associated with increased cardiac output, we think that it will reduce hypoxia in fetuses with IUGR.

Introduction

Oxygen transport to the fetus through the placenta may be impaired due to placental insufficiency. Intrauterine growth retardation (IUGR), a severe cause of neonatal mortality and postnatal morbidity that may affect 1% of pregnancies, is linked to impaired placental perfusion [1-3]. Hypoxemia and hypoglycemia are just two of the metabolic abnormalities that define IUGR. Maternal hyperoxygenation has been recommended as an alternative treatment for placental insufficiency since oxygen is crucial for active placental transport and the proper utilization of fetal nutrients. Numerous studies [4,5] have looked into this matter. Maternal hyperoxygenation is the most crucial way to properly diagnose the clinical situation of fetuses with IUGR. The effect of oxygen on fetal circulation and its potential for outcome prediction was established by all pertinent research.

As a result, the most crucial reason for the formation of IUGR is the low amount of oxygenated blood thrown into the systemic circulation. The amount of oxygenated blood thrown into the systemic circulation depends on the left ventricular preload. DVblood flow carries 30% of blood from the umbilical vein from the foramen ovale, and PV to the left atrium constitutes the most significant part of the left ventricular preload. In addition, these two flow characteristics are that they have the highest oxygen saturation and pressure. An increase in DV and PV blood flow after MHO in IUGR patients correlates with an increase in blood flow with high oxygen saturation circulating in the fetal circulation. We based our study on this hypothesis. We wanted to show the usability of MHO in IUGR patients by directing the possible increase in DV and PV currents after MHO in IUGR patients. Current studies

*Corresponding author:
Email address: deniz.k.acar@gmail.com (Deniz Kanber Acar)

have been primarily on the right ventricle due to being the most crucial ventricle in fetal life. The use of MHO in patients with IUGR, where most of the total cardiac output is supplied by the right ventricle, has mainly been related to right ventricular parameters in the literature. The most commonly used are PA, aortic isthmus, MCA and umbilical artery flow traces. To the best of our knowledge, our study is the first study to investigate DV and PV current to demonstrate MHO efficacy in IUGR patients.

Thirty percent of the highly oxygen-saturated blood coming from the placenta via the umbilical vein (UV) is transmitted directly to the left atrium via the DV without being desaturated and is used for the coronary circulation and nutrition of the upper half of the body. DV blood flow is, therefore, of vital importance. The DV flow pattern is typically antegrade throughout the cardiac cycle. Different wavelengths formed by the effect of the cardiac cycle can be measured quantitatively with pulsed wave (PW) doppler. Four-wave traces have been identified describing the DV stream's major cardiac events. S wave is associated with ventricular systole, v descent, end-systolic ventricular relaxation, D wave is related to early and rapid filling of ventricular diastole, and a wave is associated with atrial contraction. In recent years, the evaluation of fetal cardiac functions with DV blood flow has been based on this association. A maximum of 25% of the cardiac output goes through the lungs in the fetus. At the same time, most blood flow into the left atrium passes through the foramen ovale since variations in the left atrium can be seen in the fetal pulmonary vein waveform. Therefore, with a forward triphasic flow throughout the heart cycle, the waveform of the fetal pulmonary vein is strikingly similar to that of the DV [6,7]. The Fetal pulmonary veins' normal Doppler flow velocity waveform displays a pulsatile forward flow. It has three peaks: one during ventricular systole (i.e., during atrial relaxation) (S), another during the ventricle's early diastolic filling (D), and a minimum during atrial contraction (A). On this premise, we hypothesized that maternal hyperoxygenation would cause Doppler-detectable alterations in fetal venous circulation. To achieve this goal, Doppler blood flow velocity waveforms were captured from the ductus venosus of healthy third-trimester fetuses and late-onset IUGR fetuses before and during maternal oxygen administration.

Materials and Methods

The study was conducted from January 2021 to March 2022 at Istanbul Kanuni Sultan Suleyman Training and Research Hospital, Turkey. This study was planned as a pilot study due to the lack of data regarding the effect of MHO on fetal doppler findings of fetuses with IUGR. Ethical approval for this study was obtained from the local committee. Written informed consent was obtained from all participants for the study following the Declaration of Helsinki. A total of 63 pregnant women were enrolled in the study (32 pregnant women diagnosed with IUGR and 31 women with normal growth). The eligible criteria for the high-risk group were pregnant women with IUGR fetuses (below the 5th percentile); other criteria were 33-35 weeks in gestation. The control group comprised 31 randomly selected age-matched and gestational-age-matched healthy pregnant women who presented to the antenatal clinic on the same dates as the women in the study group. The women in the control group had no medical, obstetrical, or surgical complications. Patients were excluded for chronic maternal disease, pre-gestational diabetes, hypertension, multifetal pregnancy, or Fetal anomalies. The gestational age was determined based on the last day of the menstrual period and confirmed by the first-trimester crown-rump length (CRL) measurement. We first evaluated the effect of MHO therapy on DV blood flow and PV blood flow via Doppler flow velocity waveform both the patient group and the control group. Then, the results of both groups before and after MHO treatment were compared statistically with each other, and the effect of MHO treatment on DV and PV flow traces were investigated.

Study design

For each woman, Doppler flow measurements were obtained while breathing room air, Voluson E6 (GE Medical Systems, Zipf, Austria) ultrasound machine with a RAB4-8-D/OB D/4D 8-MHz transabdominal transducer imaging system. Following baseline measurements, each woman received 60% eFiO2 and then were assessed after 10 min. Doppler measurements were then repeated. All measurements were performed by a single Maternal Fetal Medicine specialist. Care was taken to perform measurements only during fetal apnea. Doppler blood flow velocity waveforms were obtained from the ductus venosus and pulmonary venous vein. At least four good quality waveforms were included in the calculations both of them. peak systolic velocity (S), peak diastolic velocity (D), atrial contraction (a), pulsatility index for veins (PIV), as well as peak velocity index for veins (PVIV) of ductus venosus were calculated. Fetal pulmonary vein peak amplitudes of S- and D-waves were recorded as peak systolic and peak diastolic velocities and pulsatility index for veins (PIV), as well as peak velocity index for veins (PVIV), were calculated.

Study procedures

The examinations were performed with a Voluson E6 (GE Medical Systems, Zipf, Austria) ultrasound machine with a RAB4-8-D/OB D/4D 8-MHz transabdominal transducer imaging system. All Doppler recordings were obtained using the lowest high-pass filter level (100 Hz), and the spatial peak temporal average power output for color and pulsed Doppler was kept at < 100 mW/ cm [8]. An angle of $\leq 15^{\circ}$ between the vessel being studied and the Doppler beam was deemed acceptable and used for analysis. All participants underwent a standard ultrasound examination for estimation of fetal weight, amniotic fluid volume measurements, fetal heart rate and DV, PV Doppler assessment. A fetal echocardiogram was performed according to the International Society of Ultrasound in Obstetrics and Gynecology (ISUOG) guidelines for fetal echocardiography [9] on fetuses between 32- and 37-weeks' gestation.

Statistical analysis

The homogeneity of the data was assessed using the Shapiro-Wilk test and visual inspection of histograms, and

the equality of variances was checked with the Levene test. As the data was non-homogeneous, variables were reported as the median and the 25th-75th percentile range. The Mann-Whitney U test was utilized to compare independent variables (comparison of fetal doppler parameters between healthy fetuses and IUGR fetuses). Besides, the Wilcoxon Signed Rank test was performed to analyse related variables (comparison of fetal doppler parameters before and after MHO). For all statistical analyses, a p-value of < 0.05 was considered indicative of a significant difference between groups, and 95% confidence intervals were provided for all relevant analyses. All statistical analyses were conducted using SPSS 22.0 software (IBM Inc., USA).

Results

All the patients had their measures taken successfully, and all the women finished the evaluation. No overtly harmful effects on either the mother or the fetus were noticed during or after oxygen administration in either group. Comparison of baseline characteristics and fetal doppler parameters of patients and healthy controls before and after MHO treatment was shown in Table 1 and Table 2. In the IUGR group, maternal hyperoxygenation significantly increased the PI value of DV, (0.50 (0.40, 0.58) to 0.62 (0.60, 0.65). p<.001). The PI value in the PV did not change significantly following maternal hyperoxygenation in the In the IUGR group (pre-O2: 0.80 (0.73, 0.88) and post-O2: 0.80 (0.70, 0.90)).The DV-S,DV-D, DV-S/a value of the DV increase significantly for the IUGR group, from 74.5 (71.25, 78.00) to 78.00 (77.00, 80.00) p<.001, from 69.00 (66.25, 70.00) to 77.00 (74.00, 77.00)p<.001, from 1.48 (1.39, 1.54) to 1.91 (1.86, 2.00) p<.001respectively. DV-a value of DV decreased significantly from 52.00 (49.25, 52.75) to 41.50 (38.50, 42.75) p<.001 (Table 3). Also, the PV-S, PV-D, PV-A, PV- S/A value of the PV increases significantly for the IUGR group from 22.00 (21.25, 22.75) to 26.00 (25.00, 28.00) p<.001, from 16.50 (16.00, 17.00) to 21.00 (19.25, 22.00) p<.001, from 1.33 (1.29, 1.41) to 0.80 (0.70, 0.90) p<.001respectively (Table 3). Comparison of Doppler findings in healthy fetus before and after oxygen inhalation did not change significantly (Table 4).

Table 1. Comparison of baseline characteristics and fetal doppler parameters of patients and healthy controls before MHO treatment.

Parameters	Patients (n=32) Median (IQR)	Healthy controls (n=31) Median (IQR)	%95 CI Lower-Upper	P value
Age	27.00 (22.00, 29.75)	28.00 (24.00, 29.00)	0.861-0.874	0.870
GA	33.00 (32.00, 34.00)	34.00 (34.00, 34.00)	0.000-0.000	**0.09**
DV-S	74.5 (71.25, 78.00)	58.00 (56.00, 61.00)	0.000-0.000	**<0.001**
DV-D	69.00 (66.25, 70.00)	58.00 (55.00, 60.00)	0.000-0.000	**<0.001**
DV-a	52.00 (49.25, 52.75)	42.00 (41.00, 45.00)	0.000-0.000	**<0.001**
DV-S/a	1.48 (1.39, 1.54)	1.38 (1.31, 1.45)	0.000-0.004	**0.003**
DV-PI	0.50 (0.40, 0.58)	0.42 (0.40, 0.50)	0.728-0.745	0.742
DV-PVIV	0.43 (0.40, 0.44)	0.38 (0.38, 0.38)	0.000-0.000	**<0.001**
PV-S	22.00 (21.25, 22.75)	42.00 (39.00, 42.00)	0.000-0.000	**<0.001**
PV-D	16.50 (16.00, 17.00)	29.00 (28.00, 32.00)	0.000-0.000	**<0.001**
PV-S/A	1.33 (1.29, 1.41)	1.36 (1.29, 1.48)	0.188-0.194	0.19
PV-PI	0.80 (0.73, 0.88)	0.91 (0.85, 0.91)	0.000-0.000	**<0.001**
PV-PVIV	0.80 (0.80, 0.90)	0.92 (0.89, 0.95)	0.000-0.000	**<0.001**

GA: Gestational Age; DV: Ductus Venosus; PV: Pulmonary Vein ; PVIV: Peak velocity index for veins; PI: Pulsatility Index; IQR: Inter Quartile Range; CI: Confidence Interval. *A p value < 0.05 is statistically significant. *Bold values are statistically significant.

Discussion

During the cardiac cycle, the S wave in DV flow corresponds to ventricular systole, the V descent corresponds to end-systolic ventricular relaxation, the D wave corresponds to early and rapid filling of ventricular diastole, and the a wave corresponds to atrial contraction. These so-called wave velocities are measured in cm/s. The nomograms of each wave velocity according to the pregnancy patient were published, and flow velocities above (+2) a standard deviation or 95% and above according to the gestational week were defined as abnormal [10]. Abnormal DV flow velocities may occur not only due to cardiac dysfunction (contraction, relaxation, ventricular compliance) but also due to changes in preload and afterload of the heart. The routine use of DV flow velocities may enable us to understand fetal cardiovascular physiology better. Good ventricular compliance is manifested by the slight pressure difference between the three waves or the presence of less collapse in the wave. Initially, Doppler indices obtained by mathematical calculation, DV peak velocity index (DV-PVIV), and Pulsatility index (PI) were used to evaluate DV blood flow. In recent years, in the study of Sanopa et al., it was reported that PVI, which is the most widely used DV Doppler index, does not fully reflect DV 'v' and 'D' wave flow changes, so its use in the evaluation of cardiac functions is limited [11,12]. In another study, Smrcek et al. reported that the DV S/D ratio is a better indicator than the DV PVI index in tricuspid regurgitation [13]. Therefore, in recent years, Özhan et al. used the ratios of DV flow velocities to each other [14]. In our study, we used the S/a ratio, the active diastolic filling ratio of ventricular systole, which is one of the best indicators of cardiac output, and the classical Doppler indexes of DV (PVIV, PI). In the IUGR group, maternal hyperoxygenation significantly increased the PI value of DV, (0.50 (0.40, 0.58) to 0.62 (0.60, 0.65). p<.001). The DV-S, DV-

Table 2. Comparison of fetal doppler parameters of patients and healthy controls after MHO treatment.

Parameters	Patients (n=32) Median (IQR)	Healthy controls (n=31) Median (IQR)	%95 CI Lower-Upper	P value
DV-S	78.00 (77.00, 80.00)	56.00 (56.00, 59.00)	0.000-0.000	**<0.001**
DV-S/a	1.91 (1.86, 2.00)	1.36 (1.33, 1.41)	0.000-0.000	**<0.001**
DV-PI	0.62 (0.60, 0.65)	0.40 (0.40, 0.42)	0.000-0.000	**<0.001**
DV-PVIV	0.60 (0.50, 0.60)	0.40 (0.39, 0.45)	0.237-0.254	<0.001
DV-a	41.50 (38.50, 42.75)	42.00 (41.00, 43.00)	0.177-0.192	0.190
DV-D	77.00 (74.00, 77.00)	56.00 (56.00, 59.00)	0.000-0.000	**<0.001**
PV-S	26.00 (25.00, 28.00)	37.00 (36.00, 38.00)	0.000-0.000	**<0.001**
PV-S/A	2.17 (2.02, 2.43)	2.12 (2.00, 2.24)	0.296-0.307	0.300
PV-PI	0.80 (0.70, 0.90)	0.85 (0.85, 0.85)	0.021-0.027	**0.026**
PV-PVIV	0.71 (0.70, 0.72)	0.90 (0.88, 0.91)	0.394-0.413	<0.001
PV-A	26.00 (25.00, 28.00)	37.00 (36.00, 38.00)	0.000-0.000	**<0.001**
PV-D	21.00 (19.25, 22.00)	26.5 (24.5, 26.5)	0.000-0.000	**<0.001**

GA: Gestational Age; DV: Ductus Venosus; PV: Pulmonary Vein ; PVIV: Peak velocity index for veins; PI: Pulsatility Index; IQR: Inter Quartile Range; CI: Confidence Interval. *A p value < 0.05 is statistically significant. *Bold values are statistically significant.

D, S/a value of the DV increase significantly for the IUGR group, but DV- a value of DV decreased significantly from 52.00 (49.25, 52.75) to 41.50 (38.50, 42.75) p<.001. In our study, we found that DV-S, DV-D wave velocities increased, while DV-a wave velocity decreased significantly. These results in our study showed us that when the diastolic phase of the late-onset IUGR Fetal left ventricle was considered, the early and rapid filling phase of the left ventricular diastole after MHO increased excessively (venous return increased). Still, with atrial contraction, the other diastole phase, the blood excreted into the left ventricle decreases. Especially in these patients, excessive increase in the S/a ratio (the active diastolic filling ratio of ventricular systole) showed us that the left ventricle empties almost entirely, and the cardiac output of the left ventricle increases. As we stated in our hypothesis, an increase in left ventricular output suggests that late-onset IUGR Fetal hypoxemia may improve.

Nicolaides et al. published one of the earliest types of research on MHO in IUGR human fetuses in 1987. Five pregnant women with IUGR and aberrant aortic and umbilical artery flow received continuous humidified oxygen (55%) through a facemask. This groundbreaking study demonstrated that the blood flow in the thoracic aorta increased significantly due to MHO under these circumstances. The researchers concluded that the impact of MHO on fetal pO_2 may help determine placental function and can be used as a therapy in IUGR fetuses [15]. The cardiac outflows in the responding fetuses had larger peak velocities. Another investigation calculated the time to peak velocity of the pulmonary artery and ascending aorta in 38 IUGR fetuses before and after MHO. The aorta's reported parameters dropped, and there were little modifications to the pulmonary artery, based on the main findings of Fetal echocardiography [16]. De Rochambeau et al. performed an MHO test in 20 small-for-gestational- age fetuses (SGA) using 8 L/min of 70% humidified oxygen administered to the patients for 20 min. In the study population and control group (n = 78) with normal heart anatomy, the fetal blood flow velocity and the placental resistance index, cerebral resistance index, and cerebroplacental ratio were assessed. The test was positive when the velocity indices

Table 3. Comparison of fetal doppler findings of pregnants with IUGR fetuses before and after MHO treatment.

Parameters	Before MHO treatment Median (IQR)	After MHO treatment Median (IQR)	%95 CI Lower-Upper	P value
DV-S	74.5 (71.25, 78.00)	78.00 (77.00, 80.00)	0.000-0.000	**<0.001**
DV-D	69.00 (66.25, 70.00)	77.00 (74.00, 77.00)	0.000-0.000	**<0.001**
DV-a	52.00 (49.25, 52.75)	41.50 (38.50, 42.75)	0.000-0.000	**<0.001**
DV-S/a	1.48 (1.39, 1.54)	1.91 (1.86, 2.00)	0.000-0.000	**<0.001**
DV-PI	0.50 (0.40, 0.58)	0.62 (0.60, 0.65)	0.000-0.000	**<0.001**
DV-PVIV	0.43 (0.40, 0.44)	0.60 (0.50, 0.60)	0.000-0.000	**<0.001**
PV-S	22.00 (21.25, 22.75)	26.00 (25.00, 28.00)	0.000-0.000	**<0.001**
PV-D	16.50 (16.00, 17.00)	21.00 (19.25, 22.00)	0.000-0.000	**<0.001**
PV-A	22.00 (20.00, 25.00)	28.00 (26.00-32.00)	0.000-0.000	**<0.001**
PV-S/A	1.33 (1.29, 1.41)	2.17 (2.02, 2.43)	0.000-0.000	**<0.001**
PV-PI	0.80 (0.73, 0.88)	0.80 (0.70, 0.90)	0.942-0.951	0.915
PV-PVIV	0.80 (0.80, 0.90)	0.71 (0.70, 0.72)	0.000-0.000	**<0.001**

DV: Ductus Venosus; PV: Pulmonary Vein ; PVIV: Peak velocity index for veins; PI: Pulsatility Index; IQR: Inter Quartile Range; CI: Confidence Interval; MHO: Maternal Hyperoxygenation; IUGR: Intrauterine growth retardation. *A p value < 0.05 is statistically significant. *Bold values are statistically significant.

Table 4. Comparison of fetal doppler findings in healthy individuals before and after MHO treatment.

Parameters	Before MHO treatment Median (IQR)	After MHO treatment Median (IQR)	%95 CI Lower-Upper	P value
DV-S	58.00 (56.00, 61.00)	56.00 (56.00, 59.00)	0.134-0.148	0.142
DV-D	58.00 (55.00, 60.00)	56.00 (56.00, 59.00)	0.368-0.387	0.364
DV-a	42.00 (41.00, 45.00)	42.00 (41.00, 43.00)	0.404-0.423	0.403
DV-S/a	1.38 (1.31, 1.45)	1.36 (1.33, 1.41)	0.748-0.757	0.751
DV-PI	0.42 (0.40, 0.50)	0.40 (0.40, 0.42)	0.053-0.062	0.057
DV-PVIV	0.38 (0.38, 0.38)	0.40 (0.39, 0.45)	0.000-0.000	**<0.001**
PV-S	42.00 (39.00, 42.00)	37.00 (36.00, 38.00)	0.000-0.000	**<0.001**
PV-D	29.00 (28.00, 32.00)	26.5 (24.5, 26.5)	0.000-0.000	**<0.001**
PV-S/A	1.36 (1.29, 1.48)	2.12 (2.00, 2.24)	0.000	**<0.001**
PV-PI	0.91 (0.85, 0.91)	0.85 (0.85, 0.85)	0.000-0.001	**<0.001**
PV-PVIV	0.92 (0.89, 0.95)	0.90 (0.88, 0.91)	0.000-0.000	**0.004**

DV: Ductus Venosus; PV: Pulmonary Vein ; PVIV: Peak velocity index for veins; PI: Pulsatility Index; IQR: Inter Quartile Range; CI: Confidence Interval; MHO: Maternal Hyperoxygenation; IUGR: Intrauterine growth retardation. *A p value < 0.05 is statistically significant. *Bold values are statistically significant.

increased by more than 10% [17]. To our knowledge, our study is the first to investigate DV and PV current to demonstrate MHO efficacy in IUGR patients. We could not compare the results of our research with the literature since no other study existed in the literature on IUGR fetuses.

According to the results of our study, we detected more than a 10% increase in our Doppler indexes in fetuses with IUGR. Therefore, we concluded that the MHO in fetuses with IUGR causes an increase in fetal DV blood flow and this association may help the correction of fetal hypoxemia and can be used as a therapy in IUGR fetuses.

Fetal blood sampling by cordocentesis and Fetal transcutaneous $P0_2$ measurements have shown that maternal hyperoxia causes significant changes in Fetal oxygenation, and concurrent Doppler studies have revealed significant changes in blood flow velocity waveforms in Fetal arterial vessels, particularly in Fetal pulmonary veins [18-20]. Based on this, we hypothesized that maternal hyperoxia might also cause Doppler-detectable alterations in the Fetal venous circulation. In order to prove our point, pulmonary vein blood flow velocity waveforms from healthy third-trimester fetuses and late-onset IUGR fetuses were compared by a MFM specialist before and after MHO.

The early research concentrated on the peak velocities of the pulmonary veins' S-, D-, and A-waves [21]. The suction effect induced by atrial relaxation and the downward migration of the mitral valve during ventricular systole is reflected in the systolic peak. These two occurrences can sometimes be separated, resulting in a double systolic peak. During ventricular relaxation, the diastolic peak corresponds to the rapid emptying of the left atrium. The A-wave shows the ventricular filling pressure during atrial contraction; flow towards the end of diastole is usually low but positive in the fetus. The pulmonary venous blood flow pattern is thought to be regulated by changes in left atrial pressure [22]. To our knowledge, no study evaluated pulmonary vein flows after the MHO test in fetuses with IUGR in literature. However, throughout our search in the literature, only some studies have been researched on Fetal pulmonary veins after MHO test in fetuses in congenital cardiac and pulmonary pathologies other than IUGR patients have been reported in the literature. Zarkowska-Szaniawska et al. investigated various fetal diseases that might result in pulmonary hypoplasia, such as cardiomegaly, hydrothorax, and congenital cystic adenomatoid malformation. Based on alterations in the fetal pulmonary vein Doppler index caused by MHO, they claimed that MHO helped predict defective fetal lung development, fetal lung hypoplasia, and neonatal respiratory failure [21]. Another study, conducted by Mardy C. et al., revealed that the difference in pulmonary vein velocity (P vein VTI) (velocity time integral) prograde and retrograde flows (P vein VTI net) would better distinguish fetuses that had emergent atrial septoplasty (EAS) after birth [22]. As a result of our study, we hypothesized that pulmonary vein Doppler evaluation can be used to evaluate prognosis and fetal well-being in various fetal pathologies. Also, the PV-S, PV-D, PV-A, and PV- S/A value of the PV increases significantly for the IUGR group. Therefore, we concluded that receiving MHO in fetuses with IUGR has caused an increase in fetal pulmonary vein blood flow in fetuses, which may help the correction of fetal hypoxemia in IUGR fetuses.

Conclusion

On this premise, we hypothesized that maternal hyperoxygenation would cause Doppler-detectable alterations in fetal venous circulation. To achieve this goal, blood flow velocity waveforms were captured from the ductus venosus of healthy third-trimester fetuses and before and late-onset IUGR foetuses during maternal oxygen administration. In conclusion, we detected a statistically significant increase in both DV and PV blood flow during MHO administration in late-onset IUGR fetuses. Since increased DV and PV blood flow is associated with increased cardiac output, we think that it will reduce hypoxia in fetuses with IUGR.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will

not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

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Ethical approval

For this study, ethical approval was received from Health Sciences University Istanbul Bakirköy Dr. Sadi Konuk Training and Research Hospital Clinical Research Ethics Committee.

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