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Study of Doppler-derived Myocardial Performance Index in Growth-restricted Fetuses as a Predictor of Adverse Perinatal Outcome

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ABSTRACT

Background: Identifying damaged intrauterine growth restriction (IUGR) fetuses quickly and offering timely intervention is one of the main goals of the prenatal care services that are now in place.

Aim: To compare myocardial performance index (MPI) values among growth restricted and normal growing fetuses and to establish if these values are associated with the severity of growth restriction and poor outcomes.

Patients and Methods: Eighty expectant women participated in this cohort study. Forty were assigned to the study group and were diagnosed with growth-restricted fetal syndrome, while another forty were assigned to the control group and were diagnosed with normally developing fetuses. All expectant women underwent fetal echocardiography in order to evaluate the modified MPI. Ultrasound parameters for the umbilical, middle cerebral, ductus venosus, and uterine artery were assessed using Doppler methods.

Results: IUGR fetuses had a significantly greater myocardial performance index than controls. The admission rates to the neonatal ICU were notably greater in IUGR infants contrasted to control group ($P < 0.001$). At a cutoff value of 0.52, the modified MPI demonstrated a sensitivity of 88.9% and a specificity of 84.1% in its ability to predict adverse outcomes. Birth weights were significantly inversely correlated with modified myocardial performance index values.

Conclusions: MPI values appeared to be associated with the severity of FGR, as they were elevated in FGR pregnancies. A greater MPI value may be predictive of unfavorable outcomes, such as reflex cardiac dysfunction in FGR.

Key words: Cardiac function, Fetal growth restriction, Modified myocardial performance index.

INTRODUCTION

FGR is characterized by approximated fetal weight that falls beneath the 10th percentile for GA of the fetus [(1)]. Enhanced management of fetal growth restriction (FGR) pregnancies is imperative in developing countries to mitigate neonatal mortality [(2)].

Critical procedures that provide information on the date and method of delivery ultimately resulting in improved patient outcomes are monitoring and identifying FGR throughout pregnancy. UA, MCA, as well as venous ductus Doppler measurements have been utilized to assess the condition of fetuses within the uterus. Doppler flow changes in these blood vessels show that the fetal cardiovascular system is getting worse [(3)].

Reducing the occurrence of poor postnatal consequences in these persons can be achieved by evaluating the reduced heart function and determining the most favorable period for delivery [(4)]. An assessment tool for cardiac function, the MPI incorporates both the systolic and diastolic stages of the cardiac cycle. You may hear it called the Tei index as well. Prenatal cardiovascular examinations using the Doppler mode of ultrasonography have also been reported. The term pertains to a global evaluation of embryonic ventricular function acquired through the utilization of Doppler technology [(5,6)]. In IUGR neonates, aberrant MPI occurs early during fetal deterioration prior to atypical Doppler findings, according to **Öcal *et al***. findings [(7)].

The purpose of current research was to compare the MPI values of normally developing and growth-restricted neonates and to determine whether the MPI values are linked to perinatal adverse outcomes and the severity of growth restriction.

PATIENT AND METHOD

A prospective cohort research was conducted between January 2022 to February 2024 on 80 pregnant women attending Menoufia University Hospital (Based on previous studies [(8)], calculated sample size was 52 pregnant women).

Inclusion criteria:

1- Singleton pregnant women aged 20-38 years.
2- Gestational age 28–39 weeks.
3- Growth-restricted fetuses with matched controls.

Exclusion criteria:

1- Pregnant women with coexisting chronic diseases as hypertension and cardiac disease.
2- Obstetric-related problems, as gestational diabetes mellitus and preeclampsia.
3- Major fetal anomalies.

Methodology:

Group (A): As a control group, forty singleton expectant women with sound fetuses were selected at random. The approximated gestational weights were determined utilizing the Hadlock method [(9)]. Each estimated fetal weight fell within the interval of the tenth and ninetieth percentiles.

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Group (B): Forty growth restricted fetuses were categorized as IUGR fetuses if their assessed weight was beneath the 10th percentile for their gestational age and their UA Doppler was either normal or aberrant.

Ultrasound and Doppler Measurements:

GA was evaluated predicated on the last menstrual period and verified by 1st trimester ultrasonographic crown-rump length (CRL) measurements [10].

A highly skilled obstetrician oversaw each sonographic measurement. In order to conduct the sonographic examinations, a VolusonS6 sonographic apparatus voluson S6 (GE healthcare ultrasound, Milwaukee, WI, USA) was employed, which featured a 3.5 MHz curvilinear transducer. Fetal biometric measurements included the following: biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), femoral length (FL), and estimated gestational weight. Furthermore, an assessment and record-keeping of numerous anatomical characteristics were undertaken, as the average uterine artery (UA), fetal middle cerebral artery (MCA), single deepest vertical pocket (SDVP) of amniotic fluid, location of the placenta, and placental structure. Mod-MPI of left ventricle of the neonate was calculated.

Doppler indices:

1. The pulsatility index (PI) of UA was evaluated in a section of umbilical cord that was not located near the areas where the embryo or placenta attach.
2. The pulsatility index of MCA was assessed in the proximal segment of the internal carotid artery, close to its place of origin. The circle of Willis was visualized utilizing color flow mapping.
3. The pulsatility index of ductus venosus (DV): A mid-sagittal image of the fetal trunk was used to calculate the PI of the ductus venosus (DV) or through the upper abdomen in a transverse plane before to its entry into the inferior vena cava, with the Doppler gate positioned at the ductus venosus isthmic part. A conventional sampling location with high velocity at its narrow entry was identified using color flow mapping.
4. The average GA at delivery of control was (37.3 ± 2.3 weeks) and showed a statistically significant variance from that of IUGR group (34.1± 2.3) ($P < 0.05$). A significant variance in birth weight amongst the control and IUGR groups with mean (2829.5±511.0) and (1501.5±412.4) respectively and in adverse outcome (P value < 0.001). When contrasted IUGR fetuses with normal left MPI with IUGR fetuses with elevated left MPI, the elevated MPI group had a worse perinatal outcome (Figure 1).

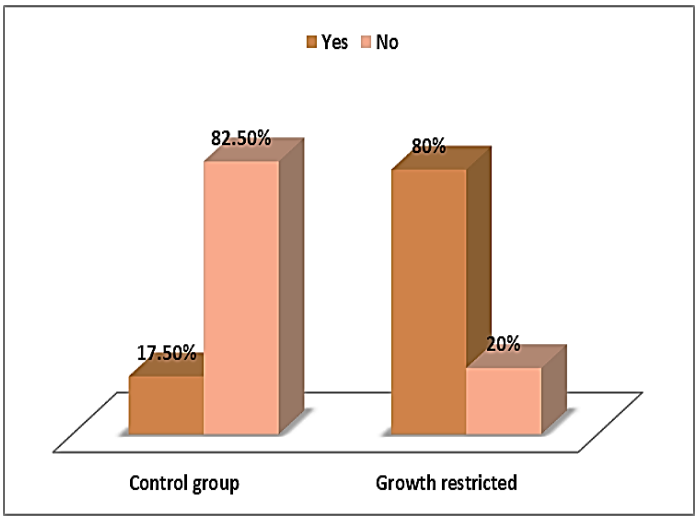

Figure 1: Adverse neonatal outcomes (NICU and respiratory distress among all participants).

Follow-up Procedure

Time and mode of the delivery, as well as the birth weights and perinatal outcomes, were recorded for each newborn. An adverse perinatal outcome was defined according to the need for hospitalization in the neonatal intensive care unit or neonatal resuscitation and/or presence of any of the following findings as: respiratory distress, low birth weight, APGAR score.

Ethical Considerations: For the purpose of taking part in the study, the patient gave written informed consent to Obstetrics and Gynecology Department, Menoufia University, Egypt, and the Research Ethics Committee of the Menoufia University Faculty of Medicine authorized the research's conduct. The purpose of this study was to perform research on humans in compliance with the Declaration of Helsinki, the code of ethics of the World Medical Association.

Statistical Analysis

The data were obtained, organized into tables, and examined utilizing Statistical Package for the Social Sciences (SPSS) version 26 on an IBM compatible personal computer [11].

Two different kinds of statistical analyses were carried out:

a) Quantitative data were presented as mean ($\bar{x}$), standard deviation (SD), and range (minimum-maximum), whilst descriptive statistics were used to describe qualitative data as number (N) and percentage (%) [12].

b) Analytic statistics as.

– The students' t-test (t) was utilized to compare quantitative variables among 2 sets of data that follow a normal distribution [13].

- Fisher's Exact test was utilized to examine relationship among qualitative variables as some of the expected cells were < 5 [14].

- The Receiver Operator Characteristic (ROC) curve, together with the area under the curve (AUC), was used to identify the best threshold values of MPI for predicting negative neonatal outcomes. The area beneath the curve corresponds to the accuracy of a test. The statement was made using a 95 percent confidence interval (CI).

The test findings were reported as two-tailed probability of significance.

- P value greater than or equal to 0.05 was deemed to be statistically non-significant.
- P value less than 0.05 was deemed to be statistically significant.
- P value less than 0.001 was deemed to be statistically highly significant.

RESULTS

Our study included 40 pregnant persons diagnosed with IUGR and an additional forty pregnant individuals who were matched in terms of gestational age. The demographic data revealed that the average age of pregnant women in the study group was 30.4 ± 5.1 years, whereas in control group it was 29.2 ± 6.4 years. The groups did not show any significant variation in mother age (P value 0.377). No significant variance was noted in BMI, gravidity, and parity among the two groups. There was a notable difference in the average gestational age [GA] at enrollment between the study group (31.4 ± 2.5 weeks) and the control group (36.8 ± 2.5 weeks) (P value < 0.001). The research group's fetuses had considerably lower average AC percentile measures compared to fetuses in control group: 23.2 ± 3.1 and 45.8 ± 12.0, correspondingly (P < 0.001). In addition, the EFW measurements were 1324.0 ± 426.6 in study group and 2804.5 ± 543.5 in control group, and the variance was highly significant (P < 0.001).

The Doppler US technique was used to evaluate the blood flow in umbilical and MCA in both groups, with the determination of pulsatility indices. Out of the 40 fetuses diagnosed with IUGR, 32 of them (80%) had aberrant PI in the umbilical arteries. Additionally, six fetuses showed a lowered PI in the MCA, while five fetuses had a reversed DV a wave as in **Table 1.**

Table 1. Doppler US of umbilical artery, middle cerebral artery, and ducts venous (DV) of the studied groups

	Control group (N= 40)		Growth restricted (N= 40)		Test	P-value
	N	%	N	%		
UAPI:						
Normal	39	97.5	8	20.0	FE	**<0.001 (HS)**
Abnormal	1	2.5	32	80.0		
MCAPI:						
Normal	40	100.0	34	85.0	FE	**<0.026 (S)**
Abnormal	-	-	6	15.0		
DVPI:						
Normal	40	100.0	35	87.5	FE	0.055
Abnormal	-	-	5	12.5		

FE: Fisher's Exact test, S: significant, HS: Highly significant. UAPI: umbilical artery pulsatility index, MCAPI: middle cerebral artery pulsatility index, DVPI: Ductus Venosus Pulsatility Index.

The IVRT was longer and ejection time was shorter in IUGR fetuses contrasted to control group. In contrast, no statistically significant disparity was detected in IVCT among control and IUGR groups. The average MPI in the IUGR group was significantly greater than in the control group as in **Table 2.**

Table 2. Time period's components of the MPI amongst the studied groups

	Control group (N= 40)		Growth restricted (N= 40)		T	P-value
	Mean± SD	Range	Mean±SD	Range		
IVRT (msec)	41.7±1.0	40-43	56.0±1.6	54-59	47.63	**<0.001 (HS)**
ET (msec)	172.9±2.2	170-176	153.0±1.2	151-155	49.54	**<0.001 (HS)**
IVCT (msec)	35.1±0.9	34.0-36.5	34.8±0.8	34.0-36.5	1.46	0.150
MPI	0.44±0.01	0.44-0.45	0.62±0.06	0.50-0.70	19.13	**<0.001 (HS)**

SD: standard deviation, Range: minimum- maximum, t: student t test, HS: Highly significant.
IVRT: Isovolumetric relaxation time, ET: ejection time, IVCT: isovolumic contraction time, MPI: myocardial performance index.

Fetal Cardiac Assessment: in 2 groups, MPI was assessed and compared among both groups. To evaluate MPI, a cross-sectional image of the fetal thorax with an apical projection of the fetal heart was taken at the level of the four-chamber view. For measurement of left MPI, the Doppler sample volume was in the left ventricle to include the lateral wall of the ascending aorta and the mitral valve. The Doppler sample was opened to 4 mm. Moreover, the minute spikes of blood flow related to valve click corresponded with the aortic valve's opening and closing **(Figure 2)**. They had to be observed to confirm the correct measurement. The isovolumetric relaxation time (IVRT), isovolumetric contraction time (IVCT), and ejection time (ET) were measured utilizing the clicks of the aortic valve as landmarks. The MPI was calculated as follows: (IVCT + IVRT)/ET **[10].**

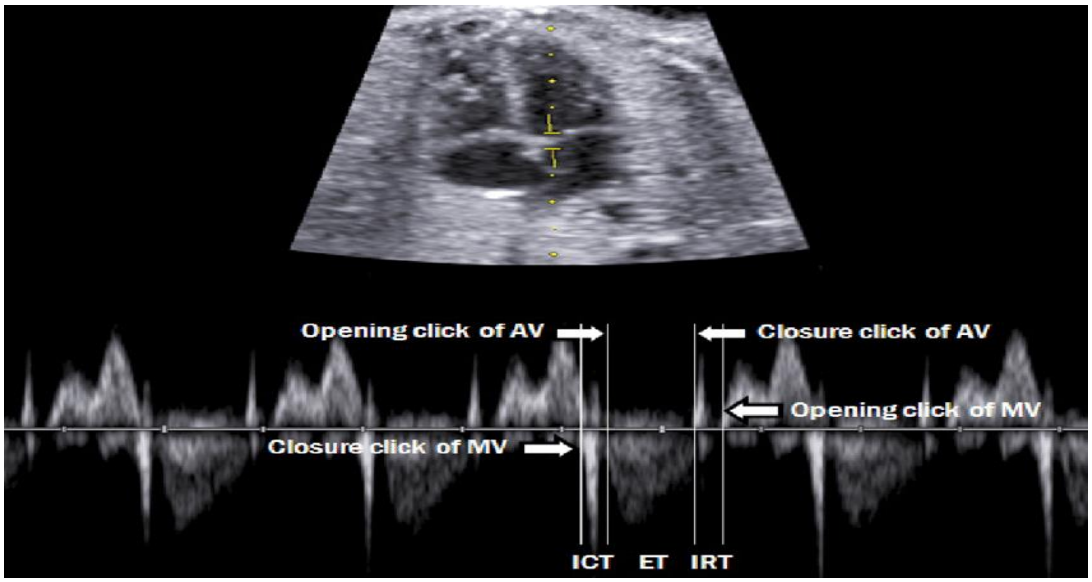

Figure 2: Measurement of the fetal modified MPI. AV, aortic valve; MV, mitral valve; ICT, isovolumetric contraction time; IRT, isovolumetric relaxation time; ET, ejection time.

At a cutoff value of 0.52, the modified MPI demonstrated a sensitivity of 88.9% and a specificity of 84.1% in its ability to predict adverse outcomes **(Table 3 and Figure 3).**

Table 3. ROC curve for Doppler-derived MPI as a predictor of adverse neonatal outcomes in the participants (N= 80)

Cutoff point	AUC	Accuracy	Significance	Sensitivity	Specificity	95% CI (Lower-Upper)
≥ 0.52	0.837	78.2%	**<0.001 (HS)**	88.9%	84.1%	0.74-0.93

AUC: Area under curve, CI: Confidence interval, HS: Highly significant.

Figure 3: ROC curve for Doppler- derived MPI as a predictor of adverse neonatal result including respiratory distress (RD) and NICU.

Univariate and multivariate regression analysis showed that abnormal UAPI and MPI were significant predictors of adverse neonatal outcomes among all participants (**Table 4).**

Table 4. Univariate and multivariate regression model for Doppler US parameters and MPI as predictors of adverse neonatal outcomes among all participants (N= 80)

Independent variables	Adverse neonatal outcomes among all participants (outcome)					
	Univariate regression			Multivariate regression		
	B	P-value	OR (95% CI)	B	P-value	Adjusted OR (95% CI)
Abnormal UAPI	2.9	**<0.001 HS**	18.3 (5.7-58.9)	1.2	**0.006 S**	7.2 (1.8-28.9)
Abnormal MCAPI	1.8	0.114	5.9 (0.7-52.8)			
MPI	3.8	**<0.001 HS**	22.2 (7.0-70.4)	3.1	**0.002 S**	9.1 (2.9-36.1)

S: significant, HS: Highly significant. UAPI: umbilical artery pulsatility index, MCAPI: middle cerebral artery pulsatility index, MPI: myocardial performance index.

DISCUSSION

In our research we found that no significant variance in maternal age (P value 0.377) was noted among groups. That was in agreement with **Nguyen *et al.*** [8] study on two groups: control (n=97) and fetal growth restriction group (n= 73), P value 0.205, and with **Ali *et al.*** [15] study on two groups: control (n equals 30) and IUGR group (n equals 30), P value 0.804. In contrast with **Henry *et al.*** [16] who noted a significant variance among examined groups (FGR group n equals 52 and control group n equals 52) in maternal age with (P < 0.001). No significant variance in BMI, gravidity and parity was observed among both groups. Those outcomes agreed with **Öcal *et al.*** [7] who studied forty females had growth-restricted fetuses and forty females had fetuses of normal weight (controls) at 29–39 gestational weeks. Also, this is in accordance with **Nguyen *et al.*** [8] and **Ali *et al.*** [15]. It is also, in agreement with **Şimşek and Köse** [4] who reported that no statistically significant variance was noted.

The average AC percentile measures of fetuses in study group were substantially lesser than those of fetuses in control group: 23.2 ± 3.1 and 45.8 ± 12.0, respectively (P < 0.001). That was concurred with **Ali *et al.*** [15] who reported that mean AC percentile for control and case groups was 50.62 ± 23.12 and 2.51 ± 0.73 correspondingly (P < 0.001). This is also in accordance with **Eslamian *et al.*** [17] who stated that significant difference was noted among the case (n=47) and the control groups (n=47) with (P < 0.001). The average AC differed considerably between the case and control groups, with values of 4.3±1.8 and 38.3±17.6, respectively. Moreover, the EFW measurements were 1324.0 ± 426.6 in the study group and 2804.5 ± 543.5 in control group, and the variance was significant (P < 0.001). This agreed with **Öcal *et al.*** [7] who reported a significant variance (P <0.015) between control group (mean fetal weight 2293.5) and case group (mean fetal weight 1868.5). Also, this agreed with **Henry *et al.*** [16] who reported a significant variance amongst both studied groups (FGR group n equals 52 and control group n equals 52) in EFW 1.400 ± 0.6 and 2.0 ± 0.8 correspondingly with (P < 0.001). Also, this is in accordance with **Eslamian *et al.*** [17] who stated that a significant difference was noted among the case and the control groups (P < 0.001), EFW (1625.6±502.4 versus 2313.4±552.1).

A highly significant variance in UAPI was noted among both groups with P value <0.001. This was aligned with **Henry *et al.*** [16] who found a significant difference among two studied groups (FGR group n equals 52 and control group n equals 52) with (P value < 0.001). Furthermore, in accordance with **Nguyen *et al.*** [8] who found that UAPI in FGR group was significantly greater than that in control group (P 0.01).

Furthermore, this is in accordance with **Eslamian *et al.*** [17] who stated that the average UAPI was determined to be atypical in 26 (56.5 percent) of the patients and 7 (16.7 percent) of the control group. The disparity among both groups was statistically significant, with a p-value of 0.001. Also, this is in contrast with **Öcal *et al.*** [7] who reported that UA Doppler was not significantly different among both groups (P value 0.411).

A significant variance was noted in MCAPI among both groups with P value <0.026, that was aligned with **Henry *et al.*** [16] who found a significant difference among two studied groups (FGR group n=52 and control group n=52) with (Pvalue < 0.02). in contrast, **Eslamian *et al.*** [17] reported that no significant variance was noted between case and control groups; 1.9 ± 0.2 and 1.8 ± 0.2 respectively (P value 0.370). In contrast with **Nguyen *et al.*** [8] who reported that there was no significant variance in MCA-PI levels among normal and FGR fetuses (P 0.21).

No significant variance was noted in DVPI among both groups with P value 0.055. This was consistent with **Henry *et al.*** [16] who stated that no significant variance was noted among two examined groups (FGR group n equals 52 and control group n equals 52) with P value 0.49. Also, this is in agreement with **Nguyen *et al.*** [8] who noted that no significant variance in DV-PI levels among normal and FGR fetuses (P 0.38). Also, it is in accordance with **Öcal *et al***. [7] who reported that no significant variance was found in DV Doppler among both groups (P Equal 0.471).

In our research we noted that IVRT was longer (mean 56.0 ± 1.6) and ejection time was shorter (mean153.0 ± 1.2 SD) in IUGR fetuses in comparison to control group. However, the IVCT did not exhibit any noteworthy variances among control and IUGR groups. This was consistent with research conducted by **Zhang *et al.*** [18] who stated that ventricular dysfunction is associated with elevated MPI values, which are attributed to the extension of IVRT. Consequently, the IVRT (isovolumic relaxation time) is the main measure of MPI that shows abnormality at an early stage of dysfunction. Also, with respect to **Ali *et al.*** [15] who noted that in IUGR fetuses, IVRT was longer (average 54.3 ± 3.3) and ejection time was shorter (mean 151 ± 4.47 SD) compared to control group. However, the IVCT did not exhibit any notable variances between control and IUGR groups, as indicated by a P value of 0.886. That was concurring with **Davutoglu *et al.*** [19] who stated that significantly elevated Mod-MPI values are indicative of prenatal cardiac dysfunction in FGR neonates. Furthermore, this is in accordance with the findings of **Bravo-Valenzuela *et al.*** [20] who observed that diastolic dysfunction caused an increase in preload. As the MPI parameter with the highest degree of stability, an increase in IVRT typically corresponds to a decrease in ET.

This is also, in contrast with **Henry *et al.*** [16] who reported that no significant variance was found among two examined groups (case group versus control) regarding IVRT component (46.5 ± 6.4 versus 46.4 ± 6.4 respectively) with p value 0.11.

It is also in contrast with **Henry *et al.*** [16] who reported that there was no significant variance among two examined groups (case group versus control) regarding ET component (165.6 ± 9.4 versus 169.0 ± 10.5 respectively) with P value 0.87. Also, this is contrasting **Öcal *et al.*** [7] who revealed that no statistically significant was noted among-group variances in IVRT and ET (P > 0.05).

Furthermore, it was observed that the growth restricted group exhibited higher Mod-MPI values in comparison to control group (P < 0.001). That was in concurrence with **Eslamian *et al.*** [17] who stated that MPI was 0.4 ± 0.1 and 0.3 ± 0.1 in case and control groups, correspondingly, which was significantly variant among the both groups (P < 0.001). Also, this is in accordance with **Ali *et al.*** [15] who stated that the average cardiac PI was 0.58 ± 0.02 in the group with IUGR, whereas in the control group, it was 0.44 ± 0.01. The observed outcome was highly statistically significant, with a p-value of less than 0.001. Also, this is in accordance with **Chawengsettakul *et al.*** [21] who stated that most of the MPI of IUGR fetuses were higher than normal fetuses with P value < 0.05.

The average MPI value for FGR in this investigation was consistent with that found in the previous research by **Bhorat *et al.*** [22] who reported that MPI was 0.57 IUGR vs 0.37 controls (P <0.001), MPI increases with increasing IUGR severity and MPI correlates with adverse outcome.

The study found that the average length of pregnancy at delivery for the control group was close to full term (37.3 ± 2.3 weeks), which was significantly different from the IUGR group (34.1 ± 2.3 weeks) (P < 0.001). This finding is consistent with the results of an earlier study conducted by **Ali *et al.*** [15], which reported that the control group had an average gestational age of approximately 38 ± 1.0 weeks, which was nearly at full term, in contrast to the IUGR group (34 ± 0.9 weeks) (P < 0.05).

Moreover, this finding aligns with the research conducted by **Henry *et al.*** [16], which revealed that the mean gestational age at delivery for the control group was nearly at full term (39.3 ± 1.5), whereas this was considerably different from the IUGR group's gestational age (34.6 ± 3.8). Extremely high statistical significance characterizes the result; the p-value was below 0.001. Furthermore, this is in line with the findings of **Chawengsettakul *et al.*** [21] who observed that infants born with IUGR had an average gestational age of 36±2.0 weeks, which is in close proximity to full term. This finding indicated a significant deviation from the control group, (P < 0.05).

There was significant variance in birth weight among the control and IUGR groups with mean (2829.5±511.0) and (1501.5±412.4) correspondingly (P < 0.001) in our research, which concurred with **Chawengsettakul *et al.*** [21] who stated that the mean fetal weight of adequate gestational age and IUGR fetuses were 3096± 306 and 2024 ±335 g, correspondingly, and revealed a significant variance amongst groups (P < 0.05). Also, that was in agreement with **Henry *et al.*** [16] who stated that the birth weight of the control was (3400 ± 0.5), which showed a statistically significant variance from that of IUGR group (1700 ± 0.6) (P < 0.001).

In our study we found that MPI was useful as predictor in Doppler indices for adverse perinatal outcome with P value <0.001 between groups that had adverse outcome (like respiratory distress and NICU) and those, which had no adverse outcome. This was with in agreement **Ali *et al.*** [15] who reported a significant variance in adverse neonatal outcome among the normal MPI group and elevated MPI with P value <0.016. These results were in accordance with those of **Al Bellehy *et al.*** [23] who found a correlation among the progression of fetal compromise in IUGR and the deterioration of fetal cardiac function.

The sensitivity of MPI as a predictor of adverse neonatal outcomes in our study was (88.9%) and the specificity was (84.1%) (cutoff value of >0.52 area under curve 0.837, P value <0.001), which was consistent with **Nguyen *et al.*** [8] who stated that MPI level (cutoff value 0.52) has a sensitivity of 89.7 percent, specificity of 46.4 percent, the area under the ROC curve (AUC) was 0.707 (P 0.018). Also, this is in line with **Eslamian *et al.*** [16] who found that the sensitivity of MPI for IUGR detection surpassed its specificity. With a cutoff point of 0.2850 and a curve area of 0.929 (P = 0.001), the specificity and sensitivity were 87 percent and 69.4 percent respectively.

A multivariate logistic regression analysis revealed an independent association between elevated levels of UAPI and MPI and adverse outcomes, with a P value of 0.006 and 0.002, respectively. This was in line with **Nguyen *et al.*** [8] who found that P values were 0.015 and 0.018 for UAPI and MPI respectively.

CONCLUSION AND RECOMMENDATION

Modified MPI is a contemporary method employed to assess heart function. The initial phases of cardiac adaptation in growth-restricted fetuses, characterized by the rise in placental vascular resistance, can be seen by alterations in the MPI and its temporal components. The MPI values showed an elevation in pregnancies with FGR and seem to be associated with the extent of FGR severity. An elevated level of MPI might be indicative of unfavorable results.

STRENGTHS AND LIMITATIONS

The research has several strengths, involving the use of prospective enrollment and the performance of all MPI computations by a skilled operator. EFWs in FGR group were determined to be beneath the 10th percentile. Moreover, there was a statistically significant disparity in the EFWs (P < 0.001) among both groups.

One additional advantage of the research was the implementation of the modified approach as outlined by **Hernandez-Andrade *et al.*[10]**. Implementing this modified approach enhanced the consistency of the observations and reduced the variability across different observers.

The limited number of IUGR fetuses included in the sample was a limitation of this study. Additional support is required for a longitudinal research design utilizing a larger sample size of IUGR cases. Nonetheless, obstetricians should be aware that cardiac dysfunction has already begun in these patients. Therefore, the assessment of MPI and UAPI may prove beneficial in the early detection of cardiac dysfunction.

During ultrasound tests, we faced several challenges, such as suboptimal picture quality caused by maternal habits, obesity, and a preexisting abdominal scar. Inappropriate fetal positioning might contribute to the challenges encountered during ultrasound examinations. Nevertheless, this issue has the potential to be resolved.

DECLARATIONS

- **Consent for publication:** I certify that each author has granted permission for the work to be submitted.
- **Funding:** No fund
- **Availability of data and material:** Available.
- **Conflicts of interest:** No conflicts of interest.
- **Competing interests:** None.

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