Spectral Doppler Evaluation of Myocardial performance index in Small for Gestational age and Growth Restricted fetuses

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Abstract

Aim: The objective of the study is to determine the importance of the Myocardial Performance Index (MPI) in fetuses with growth restriction and small size for gestational age and how it relates to vascular Doppler results in the identification ofcardiacdysfunction**.**

Method: This is an observational prospective study for evaluation of the value of Myocardial Performance Index in Intrauterine Growth Restricted and Small for Gestational Age fetuses , and its correlation to Umbilical and Middle cerebral artery Doppler findings in detection of cardiac dysfunction.It was carried on 260 singleton pregnancies with gestational age more than or equal to 28 weeks . the population was divided into three groups : SGA (n=60) who had fetal weight centile below 10 and normal Um.A. and MCA RI., IUGR(n=100) who had fetal weight centile below 10 and abnormal Um.A. and MCA RI.,both groups are compared with the third Control (n=100) appropriately grown fetuses with normal doppler. The examination evaluated Isovolumetric contraction time ,Isovolumetric relaxation time and ejection time of the left side of the heart. Myocardial performance index was calculated.

Result: Statistical analysis of the results revealed that both SGA and IUGR fetuses had significantly higher MPI (p= 0.000) than normally grown fetuses The results suggest that MPI could be used to more effectively detect early cardiac dysfunction and fetal compromised in SGA and IUGR fetuses.

Conclusion: Fetal myocardial performance deteriorates with the intrauterine growth restriction. MPI can be applied for early detection of myocardial dysfunction in SGA fetuses more effectively than prior fetoplacental Doppler

methods, and shows considerable potential for a wide range of research purposes and clinical applications.

Key words: Myocardial performance index, MPI, fetal cardiac function, small for gestational age, growth restricted fetuses

Introduction

One of the main concerns regarding prenatal assessment is fetal circulation, particularly the assessment of cardiac activity, which may provide more helpful information about the fetus in the antenatal period[1].

Over the last 30 years, fetal echocardiography has grown up as the dominant noninvasive method for assessing fetal cardiac anatomy, hemodynamics, and function[2].

The myocardial performance index (MPI), which is a ratio of isovolumetric to ejection time cardiac time intervals, is a noninvasive pulsed-wave Doppler-derived measure of global myocardial function that has been studied in fetal cardiology[3]. With death being eight times greater when weight is below the 10th percentile and almost 20 times higher when weight is below the 3rd percentile for gestational age[4], [5], intrauterine growth restriction (IUGR) continues to be a significant cause of perinatal morbidity and mortality.

The main characteristic of intrauterine growth restriction (IUGR) is cardiovascular dysfunction and remodeling[6].

The typical fetal heart works at close to maximal capacity and is very sensitive to afterload increases, which makes it more susceptible to episodes of severe hypoxemia[5], [7].

Growing fetuses with placental insufficiency show increasing hemodynamic alterations brought on by higher placental resistance[8].

As hypoxia worsens, the heart and brain get a preferential rearrangement of blood vessels, and the left ventricle receives a preferential diversion of cardiac output[9].

The cardiac changes include decreased ventricular filling (lower E/A ratios), decreased aortic and pulmonary time to peak velocity, increased aortic and decreased pulmonary time to peak velocity, and a relative increase in left cardiac output associated with decreased right cardiac output, improving cerebral perfusion[10].

These circulatory alterations continue until infancy and manifest as thicker vascular walls, hypertension, and modified, less effective globular hearts[6].

Because it makes it easier to identify mild myocardial dysfunction throughout development, can direct care, and improves newborn outcomes, functional cardiac evaluation with MPI is becoming more and more valued[11].

The objective of this research is to determine the importance of the Myocardial Performance Index (MPI) in fetuses with growth restriction and small size for gestational age and how it relates to vascular Doppler results in the identification of cardiac dysfunction..

Patient and method

Thisstudy was conducted in the Fetal Medicine Department, KasrEl-Ainy Hospital, Cairo University during the period from May 2017 toApril2019.

260 Singleton pregnancies with Gestational age more than or equalto 28 weeks and with estimated fetal weight less than the 90th percentileregarding thegestational agewereincludedinthestudy,beingrecruitedfrompregnantwomenwhocametot heFetalmedicinedepartment for antenatal ultrasonography and patients who were admittedas a caseofIUGR toeitherthewardortheemergencydepartment.

CaseswererecruitedconsecutivelyfromallIUGRandSGAfetuses during the study period, controls were selectedrandomly fromlowrisk pregnanciesat thesamegestationalage.

InclusionCriteria:

SingletonfetuseswithGestationalagemorethanorequalto28weeks and Fetusesofmotherseitherprimigravidaormultigravida.

ForControlGroup:Estimatedfetalweightbetween10thto90thpercentileregardi ngthegestationalage

Normal Doppler study findings (Middle Cerebral Artery andUmbilicalarteryresistanceindex,andCerebralPlacentalRatio)

ForStudyGroup:Estimated fetal weight less than the 10th percentile regardingthegestationalage.

NormalandabnormalDopplerstudyfindings(MiddleCerebralArteryandUmbilicalarteryresistanceindex,cerebral PlacentalRatio)

Exclusioncriteria:

- Gestationalagelessthan28weeks
- Estimatedfetalweightmorethanthe90thpercentileregardingthegestationalage
- Fetusesofmultiple gestation
- Fetuseswithcongenitalmalformations
- **<u>ForControlGroup</u>:**

  - ❖ Fetuses of mothers with any known medical or pregnancyrelateddisorderswhichinterferewithpregnancylikeDiabetes,Preeclampsia,Hypertensive,cardiacorrenaldisease,SLE..
  - ❖ Historyofprevious pregnancywithcongenitalanomalies.
  - ❖ Abnormal Doppler study in the form ofbrain sparing effectand /orreversed cerebralplacentalratio.

Methodologyin details

Verbal informed consent was obtained from all participants, andprocedureswerepreviouslyreviewedandapprovedbytheethicalcommitteeofthedepartment.

Allparticipantsweresubjectedtothefollowing:

1) At first history was taken from all participants in the form of age ,gravidity andparity, last menstrual period, obstetric disorders inthecurrentpregnancyintheformofPreeclampsiaGestationalHTN,GDM, and the past medical history (hypertension , Diabetes ,SLE,APSorany otherdisorders).

2) 2D ultrasonography was done by Voluson 730® Expert ultrasoundsystem(GEHealthcare,Zipf,Austria)to:

- Confirm the Gestational age of admission.(In all pregnanciesgestationalagewascalculatedbasedonCrownrumplength measurementon1st trimesterultrasound and/orLMP).

- EstimationoffetalweightusingHadlockformula,andthenestimationoffetalweightcentileforgestationalage.

- Exclusionofassociatedcongenitalanomaliesincludingcardiacstructuralanomalies.

- Amniotic FluidIndexestimation.

- Doppler data which includedUmbilical artery resistance index(Um.A-RI) ,middle cerebral artery resistanceindex(MCA – RI)andCerebroPlacentalratio(CRP).

- Fetalcardiacstructureandfunctionwasassessedbytwodimentional conventionalDopplerechocardiography.

This involved capturing a clear four-chamber view in an apical orbasalview ,magnifying tooccupyabout75%ofthescreen.Pulsed waveDopplerwasapplied.

Pulse repetition frequencywas increased, Gainwas reduced to thelowestpossiblelevelsaswerethefilter settings.

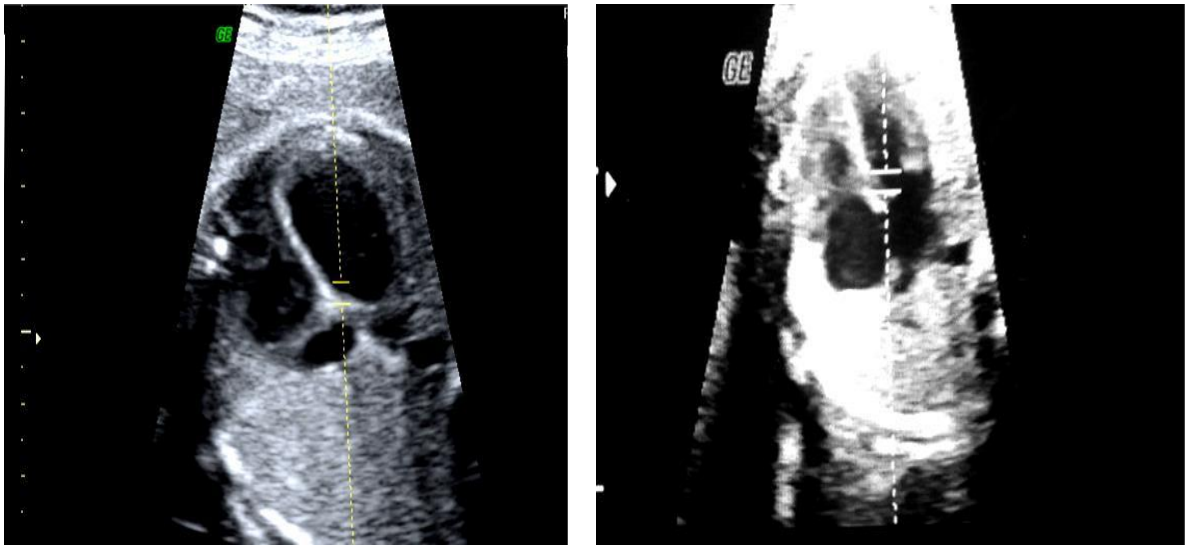

Fig.11a&b; Fourchamberview showingthesiteof placementof thesamplevolume

3mm Doppler sample volume was placedon the lateral wall of theascending aorta below the aortic valve and just above the mitralvalve (Fig.12). Valvular clicks in the Doppler waveform were usedaslandmarkstocalculateeachtimeperiod(Fig.13).Placementof timecursorwas atthebeginningoftheclick(Fig14).

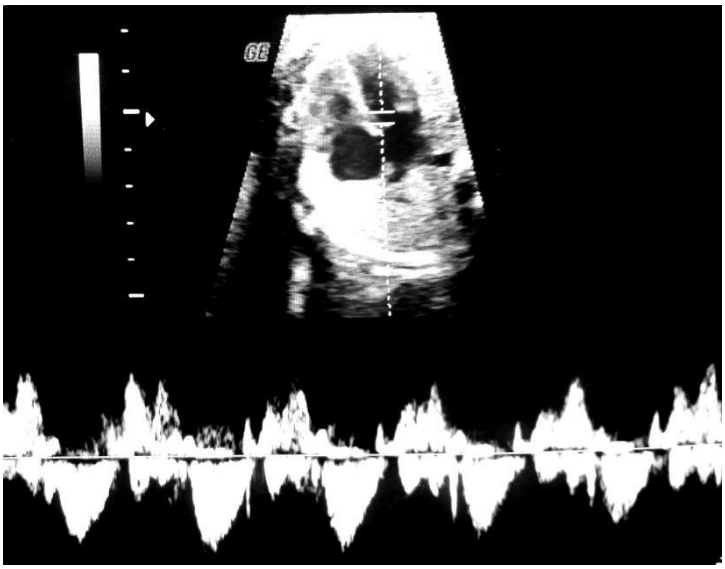

Fig.12: SonographicimageshowingMitralandAorticwaveformsandsite ofsamplevolume

Isovolumetriccontractiontime(ICT),Isovolumetricrelaxationtime (IRT) andventricular ejection time (ET) weremeasuredforallstudygroupbythesameoperator.

ICT:fromthebeginningofmitralvalveclosureclicktothebeginning ofaorticvalveopeningclick.

IRT:from the beginning of aortic valve closure click to thebeginning of mitral valveopeningclick.

ET:fromthebeginningofaorticvalveopeningclicktothebeginning ofaorticvalveclosureclick.

Myocardial performance index (MPI)of the Lt side of the heart was thencalculatedbythesumofICTandIRTdivided bytheET.

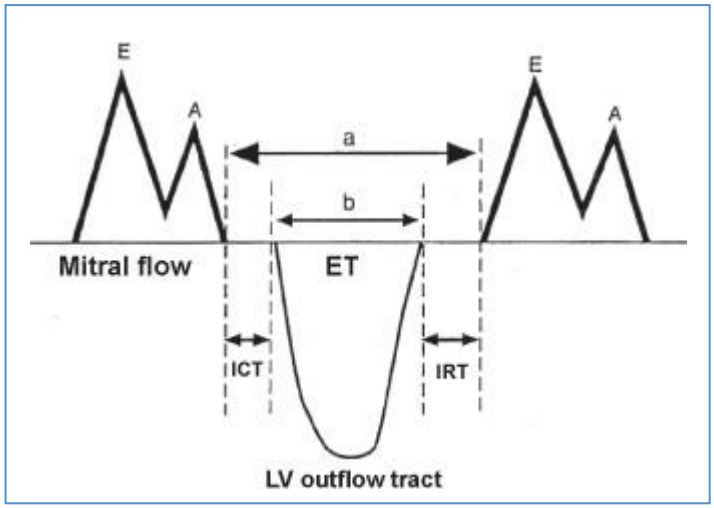

Fig. 13: DiagramShowingTimeintervalsandMitralandAorticwaves.a=tot

3) Thepopulationofstudywas subdividedintothreecategories:

I. **100** controls, defined byestimated fetal weightbetween 10th and90th percentile regarding the gestational age , with no pregnancycomplicationandwithnormalDopplerstudy(MiddleCerebralArteryandUmbilicalarteryresistanceindex,andcerebralPlacentalRatio).

II. **60**SmallforGestationalagefetuses(SGA),definedbyestimatedfetalweight<10th percentilewithnormalDopplerstudy.

III. **100** IUGR fetuses , defined by estimated fetal weigh<10th percentilewithabnormalDopplerstudy.

4) All data was collected for each participant then analyzedstatistically.

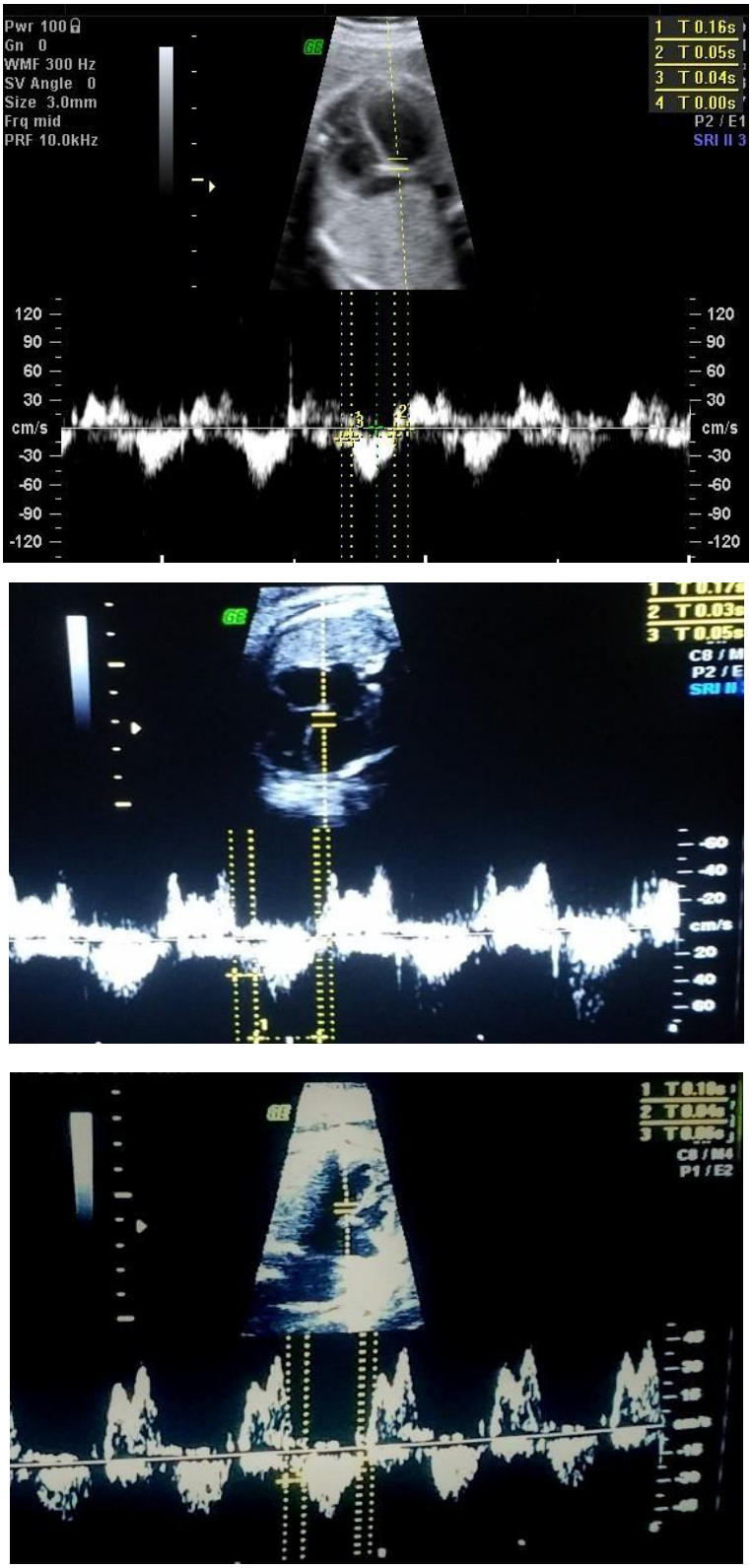

Fig.14;Sonographicimagesshowplacementoftimecursersandmeasurementof ICT,IRTandET

StatisticalAnalysis

Data were statistically reported using the mean, standard deviation (SD), median, and range, or, where applicable, frequencies (number of occurrences), and percentages. A one-way analysis of variance (ANOVA) test was used to compare numerical variables across the research groups, along with post-hoc multiple 2-group comparisons. Using the Chi-square (x2) test, categorical data were compared. When the anticipated frequency is less than 5, an exact test was utilized in its place. For the linear relationship of normally distributed variables, the Pearson moment correlation equation was used, while the Spearman rank correlation equation was used for non-normal variables and non-linear monotonic relationships. Statistical significance was defined as two-sided p values less than 0.05.

RESULTS

A total of 260 patients were enrolled in the study.They weresubdividedintothreegroups-control(100),SGA(60)andIUGR(100).

Table1;Maternalcharacteristicsofthepopulationofstudy.

	Control(100)	SGA(60)	IUGR (100)	P value
Agemeans(□SD)	30.74(□6.72)	30.68(□5.92)	28.54(□4.78)	0.015
Parity				
0	17(17%)	12(20%)	28(28%)	
1	29(29%)	15(25%)	32(32%)	
2	24(24%)	19(31.6%)	23(23%)	
≥3	30(30%)	14(23.3%)	17(17%)	
MedicalandObstetricaldisorders				
None	100(0%)	14(23.3%)	10(10%)	0.022
Preeclampsia	0	23(38.3%)	61(61%)	0.005
Chronic HTN	0	10(16.7%)	14(14%)	0.647

Gestational HTN	0	10(16.7%)	11(11%)	0.304
Dm	0	10(16.7%)	24(24%)	0.272
SLE andothers	0	3(5%)	1(1%)	0.117

Maternal age with a mean 30.74, 30.68, 28.54 in control, SGA and IUGR group respectively showed no statistically significant difference between groups (p = 0.015).

Regarding medical and pregnancy related disorders among mothersoftheSGAandIUGRgroupsresultsshowedstatisticallysignificantdifference in mothers with preeclampsia (p =0.005). While there was nosignificant deference in mothers without known medical or pregnancyrelated disorders (p=0.022) ,nor in mothers with either Gestational HTN (p=0.304)Chronic HTN(p=0.647) ,DM(p=0.272) ,SLE(p=0.117).

From theultrasonographicdatawhich wastaken during scan ,resultsshowedthatgestationalageamongstudygroupswerenearlysimilar (p=0.549), with a mean 31.72 weeksin the control group , 31.66inthe SGAgroup and 34.06 intheIUGRgroup(Table4). Incontrastweight,weightcentileandAFIshowedstatisticallysignificant difference (p=0.000)for each. Among the control group themeanoffetalweightwas1830.84gm(□481.53SD),weightcentile 53.69 % (□19.74 SD) and AFI 14.033(□3.01 SD). In the SGA groupresultswere1158.56gm(□374.39SD),7.46%(□1.42),and10.89(□3.13SD)respectively.WhileintheIUGRgroupthemeanofweight was 1125.04 gm (□294.08 SD) , weight centile 7.407 %(□1.38SD)andAFI10.077(□2.87).

(Table 2;) Ultrasonographiccharacteristics results.

By mean(SD)	Control(100)	SGA(60)	IUGR(100)	P value
GAbywk.a tscan	31.72(2.51)	31.66(2.48)	34.06(2.7)	0.549
Weight at scanbygm.	1830.84(481.53)	1158.56(374.39)	1125.04(294.08)	0.000
Weight centile	53.69(19.74)	7.46(1.42)	7.407(1.38)	0.000
AFI	14.033(3.01)	10.89(3.13)	10.077(2.87)	0.000
Dopplerstudymeans(SD)				
Umb.A RI	0.639(0.05)	0.658(0.04)	0.737(0.01)**	0.000
MCARI	0.817(0.07)	0.831(0.08)	0.768(0.03)	0.000
CPR	1.283(0.14)	1.269(0.14)	1.041(0.04)	0.000
**13caseofIUGRgroupwithAEDF/REDFsoUm.ADoppler andCPRcouldn'tbe measured.				

Doppler study results showed also significant statistical difference(p=0.000) between groups. In the control group the mean of Um.a.RI was0.639 (0.05) ,MCA RI 0.817(0.07) , CPR 1.283 (0.14) . in theSGAgroup Um.a.RI was 0.658(0.04),MCA RI 0.831(0.08), CPR 1.269(0.14). IntheIUGRgroupUm.a.RIwas0.737(0.01),MCARI0.768(0.03), CPR 1.041(0.04). 13out of the 100 cases ofthe IUGR grouphadAEDF/REDFsoUm.ADopplerandCPRcouldn'tbemeasured(Fig16). Myocardial performance index of the left side of the heartwasmeasuredinthe3groupsbythesumofICTandIRT,dividingitbyET.A highly significant difference (p=0.000)was observed between groups(Table3).

(Table 3)MPIandTimeintervalsresultsofthestudygroups.

	Control	SGA	IUGR	Pvalue
ICTbysec.	0.037□0.008	0.039□0.008	0.044□0.008	0.000
IRTbysec.	0.044□0.01	0.052□0.012	0.058□0.009	0.000
ETbysec.	0.167□0.012	0.169□0.012	0.173□0.01	0.003
MPI	0.489□0.09	0.543□0.11	0.589□0.075	0.000

In the control group the mean of ICT was 0.037 (□0.008), IRT0.044(□0.01),ET0.167(□0.012)andtheMPI0.489(□0.09).Ther esults oftheSGAgroupwere0.039(□0.008)fortheICT, 0.052(□0.012)fortheIRT,0.169(□0.012)forETandfinallytheMPIwas0.543(□0.11). TheIUGRgroupshowedhigherresults:0.044(□0.008)forICT, 0.058 (□0.009) for IRT, 0.173 (□0.01) for ET and the MPI was0.589 (□0.075).

Table4;CorrelationbetweenGaandMPI(pvalues)

	Control	SGA	IUGR
GA	0.618	0.889	0.560

Correlationbetweengestationalageandthemyocardialperformance index in each of the three groups showed no significantdifference. Table 4

Table5;CorrelationbetweenDopplerresultsandMPI(pvalues)

	Control	SGA	IUGR
Um.a	0.379	0.07	0.565
MCA	-0.079	0.991	0.186
CPR	-0.137	0.192	0.086

Myocardial performance index in each of the three study groups also showed

no significant difference when correlation was done with the Doppler results (umbilical and MCA). Table 5

DISCUSSION

Fetuses that are regarded to be "small-for-gestational age" (SGA) have weights that are below the 10th percentile for the gestational week that they are in. Additionally, SGA fetuses are split into two main categories based on specific reasons. The first kind is constitutional SGA, which is brought on by physiological elements like a person's genetic potential. The second reason is intrauterine growth restriction (IUGR), which is a term for a variety of clinical disorders mostly brought on by utero-placental insufficiency[12].

Significant prenatal morbidity and death rates are linked to IUGR. Doppler velocimetry has been suggested as a potential supplement to methods like nonstress testing or biophysical profile[13] in the identification of fetal growth limitation.Growing fetuses with placental insufficiency exhibit increasing hemodynamic alterations brought on by higher placental resistance. As hypoxia worsens, the heart and brain get a preferential redistribution of blood vessels, and the left ventricle receives a preferential diversion of cardiac output. The heart is important for fetal adaptations to placental insufficiency and hypoxia because it redistributes more oxygenated blood to the coronary arteries[5].

A time interval measure generated from Doppler called the myocardial performance index (MPI) was created to combine systolic and diastolic cardiac performance in order to characterize heart function. The three time periods, ejection time (ET), isovolumetric contraction time (ICT), and isovolumetric relaxation time (IRT), which are used to calculate MPI (MPI = [ICT + IRT])/ET), are clearly defined by the opening and shutting clicks of the mitral and aortic valves. The MPI has benefits, such as being able to determine heart rate, arterial pressure, and ventricular shape independence[14].

ICT = commencement of mitral valve closure to aortic valve opening; ET = aortic valve opening to closure; and IRT = aortic valve opening to mitral valve opening; MPI = (ICT+ IRT)/ET[14].

Perez-Cruz et al. found a significant difference in preeclampsia in moms ($p = 0.005$), with 5% in the SGA group and 6% in the IUGR group[6].

Preeclampsia prevalence was 11.1% in the IUGR group and undetected in the SGA group in the research by Suphang et al. On the other hand, in the SGA group, 7.3% had ChHTN, 2.4% previous DM, 7.3% GDM, and 68.3% had no identified medical issue. None of the pregnant women with IUGR babies had Ch HTN, preexisting, or gestational DM. from the scan-related ultrasonographic data that was collected.Discussion was held between our findings (using RI) and those of Perez-Cruz et al., research who utilize PI in

their measures, in agreement with Strikumar et al., (2017) pilot study in which they observed that there was a substantial association between MCA PI and UmA PI with their respective RI values. In this research, umbilical artery end diastolic flow in 13 instances of the IUGR group was either reversed or nonexistent, hence CPR was not detected. In addition, 2 of the 13 cases also lacked a wave of the ductus venosus. The CPR outcomes were as follows. For the control group, 1.28 0.14; for the SGA and IUGR groups, 1.27 0.14; and for the other groups, 1.04 0.04; respectively. Lower CPR findings were also seen in the IUGR group, according to Perez-Cruz et al. The findings for the control group were 2.100.51; for the SGA and IUGR groups, they were 1.800.35 and 1.600.54, respectively. ICT, IRT, and ET MPI indicators are compared between this research and Perez-Cruz et al. In this investigation, there was a very significant difference (p=0.000) between the groups, and in the study by Perez-Cruz et al., there was also a significant difference in the MPI findings (p0.001). This was shown in the research by Bhorat et al., where MPI was 0.37 0.01 in the control group and 0.59 0.07 in the IUGR group (p 0.001, [6], [10]). A study done by Pedersen et al. (2016) found that in IUGR fetuses, corticosteroids altered the right but not the left MPI.Mod-MPI levels are much greater in fetuses from DM moms, as shown in studies by Figueroa et al. [15] and Cem et al. [14].In this investigation, the association between gestational age and the myocardial performance index (MPI) p value was 0.618, 0.889, and 0.560 in the control, SGA, and IUGR groups, respectively. This was consistent with the findings of Nair & Radhakrishnan and Khandoker et al, who also found no relationship between GA and MPI[1], [16].

Conclusion

With the intrauterine growth limitation, fetal cardiac performance declines, with considerably high myocardial performance index outcomes. Small for gestational age fetuses showed some degree of myocardial performance degeneration, which was shown by greater than normal myocardial performance index, even if they seemed to have normal Umbilical and Middle cerebral artery resistance index and normal Cerebroplacental ratio.

Compared to previous fetoplacental Doppler techniques, MPI may be used to diagnose cardiac dysfunction in SGA fetuses earlier. MPI also has significant promise for a variety of clinical and research applications.

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