Fetal left ventricular myocardial performance index: Defining normal values for Indian population and a review of literature

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ABSTRACT

Objective : **The aim of this study was to determine normal values for fetal left ventricular (LV)-myocardial performance index (MPI) in Indian population and to assess its relation to advancing gestation and fetal heart rate (FHR).**

Materials and Methods : **Two hundred pregnant women without any pregnancy-related complications and whose fetuses were shown to have structurally normal hearts were enrolled in this study. Doppler waveform involving simultaneous display of mitral inflow and LV outflow was obtained in all. Various intervals including isovolumetric contraction time (IVCT), isovolumetric relaxation time (IVRT), and ejection time (ET) were measured and then the MPI was calculated using the formula IVCT + IVRT/ET. Also the correlation between MPI and gestation age and FHR was assessed. We also reviewed the literature on the use of MPI for the assessment of fetal LV function.**

Results : **The normal MPI in second and third trimester fetuses of Indian population was 0.42 ± 0.03. The mean IVCT was 33 ± 4 milliseconds (ms), mean IVRT was 39 ± 5 ms, and mean ET was 169 ± 9 ms. The mean heart rate was 148 ± 8 bpm and the mean PR interval was 111 ± 10 ms. There was no significant association of LV-MPI with either FHR or advancing gestation.**

Conclusion : **MPI is a useful parameter for the assessment global cardiac function. MPI has the advantage of not being affected by FHR, ventricular size, and geometry or image quality. The review of literature shows its significant importance in monitoring complicated pregnancies.**

Keywords : Fetal cardiac function, myocardial performance index (MPI), normal values

INTRODUCTION

The field of fetal cardiology has advanced significantly in the past few decades. From the initial use of fetal echocardiography for cardiac anatomy delineation in fetus by Dolkart and Reimer[1] who documented the normal cardiac anatomy of 52 second and third trimester fetuses. Echocardiography is now used for fetal cardiac anatomy, function, and hemodynamic assessment. Doppler technique is being increasingly used for the functional assessment of the fetal heart. The systolic function has been assessed by various parameters such as ventricular fractional shortening or ejection fraction measured by Simpson's technique.[2] However, the reproducibility of these measurements were poor due to fetal movements or inadequate images. Diastolic function is being assessed by pulsed Doppler of ventricular

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inflows, IVC, ductus venosus, or umbilical vein. An alteration of the velocity or waveform at these sites was an indicator of cardiac dysfunction with imminent heart failure. However, these parameters are often a late marker of ventricular dysfunction.

Recently, there has been particular interest in fetal myocardial performance index (MPI or Tei index) as it gives an evaluation of both systolic and diastolic ventricular functions.[3] In fetus though cardiac failure is less common, implementation of this technique helps in identifying subtle changes in cardiac function in subclinical phase. This in turn helps in identifying the high-risk population and their subsequent management.

MPI is a combined index of global myocardial function and it is independent of ventricular size, geometry, and heart rate.[4] It may get affected by preload. MPI is being increasingly used in pediatric echocardiography. However, its use in fetal cardiac assessment is limited probably because of lack of normal value ranges and awareness of its significance in various fetal conditions. This study was done to determine the normal values for fetal left ventricular (LV)-MPI in second and third trimester fetuses of Indian population.

MATERIALS AND METHODS

Patient selection

This is a prospective study involving 200 healthy pregnant women with singleton pregnancy whose fetuses were shown to have a normal echocardiogram. These women were referred for fetal echocardiography either due to a family history of heart disease or due to some abnormal finding on routine level-two ultrasound. The mean gestational age was 24 ± 3.9 weeks (range 17-37 weeks). The exclusion criteria included women with pregnancy-associated complications such as preeclampsia, diabetes, or intrauterine growth restriction as well as women whose fetuses were diagnosed to have significant structural anomaly.

Echocardiographic evaluation

Two-dimensional fetal echocardiography was performed using the C5-2 curved array transducer and iE33 imaging system (Philips Healthcare) and all images were recorded. For Doppler measurements, the Doppler gate was kept at the minimum size (1 mm) and the angle of insonation was kept below 30°. Faster sweep were used to better define the intervals and gains were kept low. For calculation of MPI, a gated pulsed Doppler sample volume was placed in the left ventricle at the junction of the anterior mitral leaflet and the LV outflow tract in an apical five-chamber view. The following time intervals were measured: Isovolumetric contraction time (IVCT) was measured from the end of the mitral A wave to the onset of the aortic pulsed Doppler tracing, ejection time was measured from the onset to end of the aortic pulsed Doppler tracing, and isovolumetric relaxation time (IVRT) was measured from end of aortic pulsed Doppler tracing to the onset of mitral valve E wave. Three successive measurements of all the parameters were obtained and MPI was calculated from the average of each interval using the formula: MPI = IVCT + IVRT/ET. Fetal heart rate (FHR) and PR interval were also measured. A single observer made all the measurements.

Statistical analysis

Statistical Package for the Social Sciences (SPSS) software (SPSS-Inc., Chicago, IL) was used for the statistical analysis. All numeric data are expressed as mean ± SD. Linear regression analysis was used to evaluate the relationship of the MPI and other parameters to gestational age and heart rate. Statistical significance was defined as $P < 0.05$.

RESULTS

Two hundred pregnant women with single, normal healthy fetuses were enrolled in this study [Table 1]. Fetal IVCT, IVRT, ET, HR, PR interval, and mitral valve inflow E and A velocities were measured in all fetuses [Table 2]. Mean IVCT was 33 ± 4 milliseconds (ms), mean IVRT was 39 ± 5 ms, and mean ET was 169 ± 9 ms. The mean heart rate was 148 ± 8 bpm and the mean PR interval was 111 ± 10 ms. The mean MPI was 0.42 ± 0.03.

The correlation coefficient analysis revealed no correlation between MPI and the gestational age ($R = 0.04$) [Figure 1]. Also there was no correlation between MPI and the FHR [Figure 2]. However, there is a definite correlation of FHR and the mitral valve inflow E/A wave velocity ratio with gestational age.

Table 1: Distribution of patients according to gestational age

Gestational age	No of patients	Mean MPI
Second trimester (13-27 weeks)	32	0.424±0.04
Third trimester (28-40 weeks)	168	0.426±0.04

There was no significant change in the MPI during the second and third trimester ($P = 0.762$)

Table 2: Echocardiographic parameters

Parameters	Time intervals (mean ± SD)
Isovolumetric contraction time	33±4 milliseconds (ms)
Isovolumetric relaxation time	39±5 ms
Ejection time	169±9 ms
Myocardial performance index	0.42±0.03
Mitral valve-E velocity	28±6 cm/s
Mitral valve-A velocity	47±7 cm/s
E/A	0.59±0.08
Fetal heart rate	148±8 beats per min
PR interval	111±10 ms

FHR decreased with advancing gestation [Figure 3] ($r = 0.455$, $P < 0.001$) while the mitral valve inflow E/A ratio increased with advancing gestation [Figure 4] ($r = 0.28$, $P < 0.001$).

DISCUSSION

Our knowledge to assess fetal cardiac function and to predict potential progression to dysfunction is still evolving. The correct assessment of fetal myocardial function is of critical importance while evaluating high-risk fetuses. Early recognition of subtle changes in myocardial performance may be potentially lifesaving for the fetus and helpful in timing the delivery appropriately. The IRT component of MPI is the most important, its derangement indicates a reduced calcium uptake and reduced cardiac function and is the earliest to get affected in diseased states.[9] Multiple studies have been done to determine the normal values of MPI in the fetus [Table 3] and establish its potential clinical application but with varied results.

Tsutsumi *et al.*[4] were the first to use TEI index for the assessment of fetal global myocardial function. They reported a LV-MPI of 0.62 ± 0.07 (18-26 weeks fetuses) and also reported a fall in MPI values to 0.43 ± 0.03 beyond 34 weeks of gestation. According to them, LV myocardial maturational changes accelerate after the late gestation and the changes in global ventricular function are related to these maturational changes. Similar negative correlation of MPI with advancing gestation was also reported by Chen *et al.*[8] In contrast to this, Friedman *et al.*[5] reported that the MPI values did not show any significant correlation with gestational age and heart rate. Similar finding were reported by Parasuraman *et al.*[3] and Russel *et al.*[10] Our study has also shown that the MPI has no correlation with either gestational age or heart rate.

The technique of MPI measurement has also evolved. Initially the time intervals were measured in separate inflow and outflow pulsed Doppler signals. Subsequently, Friedman[5] introduced the measurement of intervals from a single pulsed Doppler recording with simultaneous display of normal LV filling and emptying which was

Table 3: Summary of selected MPI studies

Study	No. of pts	Left ventricular - MPI
Friedman *et al.*[5]	74	0.53±0.13
Eidem *et al.*[6]	125	0.36±0.06
Hani Ghawi *et al.*[7]	420	0.45±0.1
Parasuraman *et al.*[3]	224	0.34±0.14 (second trimester) 0.48±0.12 (third trimester)
Chen *et al.*[8]	225	0.27±0.05 (second trimester) 0.22±0.05 (third trimester)
Tsutsumi *et al.*[4]	135	0.43±0.03
Present study	200	0.42±0.03

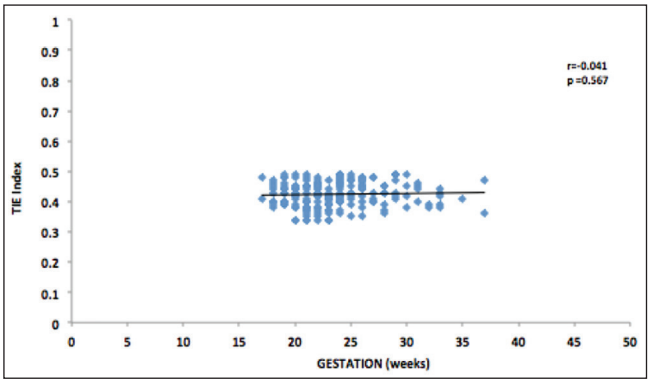

Figure 1: No Correlation between gestational age and Tie index

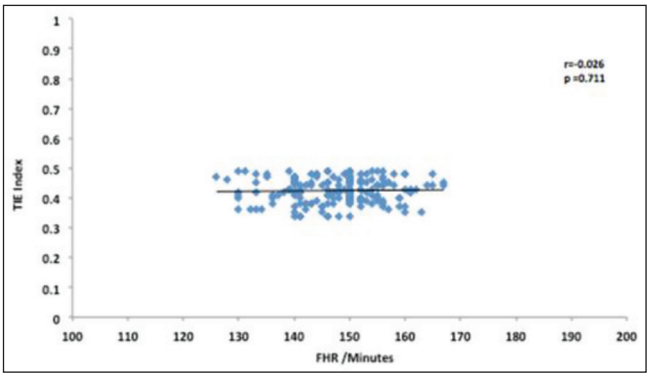

Figure 2: No Correlation between FHR and Tie index

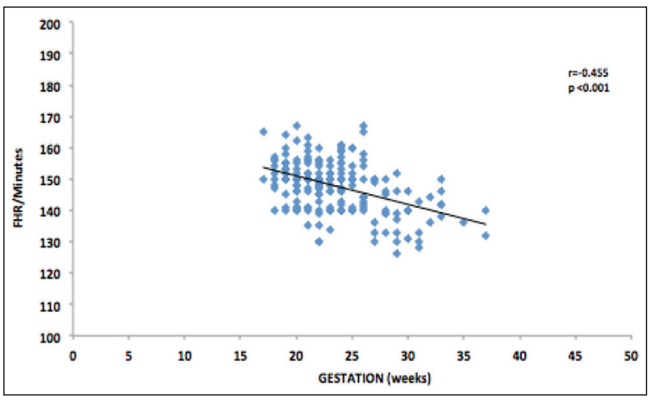

Figure 3: Correlation between gestational age and FHR

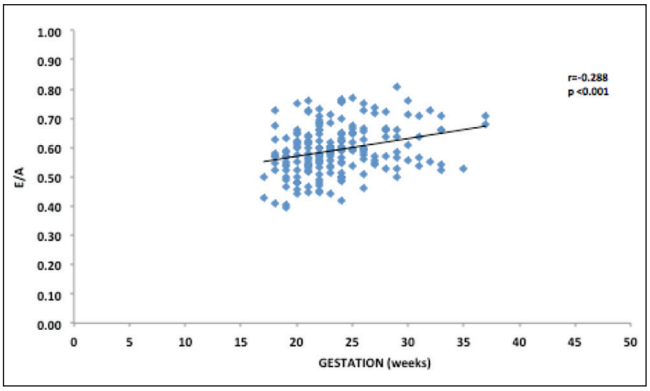

Figure 4: Correlation between gestational age and MV E/A velocity

Table 4: Role of MPI in various fetal disorders

Fetal disease	Study	Result
Twin-twin transfusion syndrome (TTTS)	Stirnemann *et al.*[12]	40% of recipient twins at Quintero stage I[13] already had myocardial dysfunction
	Papanna *et al.*[14]	Recipient twin's MPI was elevated during laser therapy and it remained elevated after the procedure and became normal only 48 h after the therapy
Fetal inflammatory response syndrome (FIRS)	Letti *et al.*[15]	MPI was significantly higher in fetuses showing signs of FIRS suggesting involvement of the fetal cardiac tissue FIRS
Maternal diabetes	Tsutsumi *et al.*[4]	Thirty fetuses of diabetic mothers — Tie index was higher compared to controls especially during the third trimester of pregnancy
	Bhorat *et al.*[16]	MPI was higher while the mitral valve E/A ratio was lower in fetuses of diabetic mother MPI > O.52 was associated with adverse perinatal outcome
	Figueroa *et al.*[17]	MPI was higher in the fetuses of diabetic mother compared to normal fetuses and also in those with associated polyhydramnios, insulin use, or large for gestation fetus
Intrauterine growth retardation (IUGR)	Benavides-Serralde *et al.*[18]	MPI was already affected when the uterine artery waveform still has end-diastolic forward blood flow
	Nassr *et al.*[19]	MPI was significantly higher in IUGR fetuses IUGR fetuses with abnormal MPI had significantly worse perinatal outcome and increased morbidity compared to healthy fetuses Outcome was worst with higher morbidity in IUGR fetuses with abnormal MPI compared to IUGR fetuses with normal MPI

obtained by placing the sample volume at the junction of the anterior mitral valve leaflet and the LV outflow in an apical five-chamber view. Hernandez *et al.* introduced a new approach to measure the time intervals by using the Doppler echos of mitral and aortic valve clicks reported that this technique had lesser intra- and interobserver variation.[11] We had however used the technique described by Friedman.

MPI has been proven to be useful in monitoring the cardiac status in various diseased states of the fetus such as intrauterine growth retardation (IUGR), twin-twin transfusion syndrome (TTTS), fetus of diabetic mother, and fetal inflammatory response syndrome (FIRS) in fetuses with preterm premature rupture of membranes. MPI is also helpful in determining the prognosis. Various fetal disease states and the role of MPI are described in Table 4.

Developments in the technique of image acquisition and definition of ultrasound settings have substantially improved the reproducibility of measurements since its proposal. Several single-center studies have previously evaluated the MPI in complicated pregnancies; however, large multicenter studies using standardized machine settings and technique are still required to evaluate the effect of pathology on the fetal MPI values. A consensus must be reached and universal normal reference ranges should be established to accurately assess the effect on MPI values in complicated pregnancies.

Limitation

The possibility of intraobserver errors cannot be excluded from the study since all the observations were made by a single operator.

CONCLUSION

Our study gives the normal range of MPI in normal fetuses of Indian population and also shows that MPI is independent of gestational age and FHR. Thus, MPI should be used for the initial assessment of the global cardiac function in normal fetuses and fetuses with congenital heart defects as well as for the follow-up of fetuses with cardiac defects. MPI is also potentially useful for the evaluation of the fetal cardiac status in noncardiac disease states.

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Conflicts of interest

There are no conflicts of interest.

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