The role of modified myocardial performance index (Tei index) in exploring fetal cardiac function

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Abstract

The aim of this study is to determine the normal values of myocardial performance index, measured by two different methods in the examination of fetal Doppler echocardiography in the second and third trimester of pregnancy, and to compare them with other values quoted in the literature. Doppler evaluation of the myocardial performance index (MPI) and modified myocardial performance index (Mod-MPI) by measuring the isovolumic contraction time, isovolumic relaxation time, ejection time, and calculation of the myocardial performance index (MPI/Mod-MPI). The normal values of MPI for the second and third trimester of pregnancy (18-31 weeks gestation) were 0.51±12 ms, and the normal values of the Mod-MPI for the second and third trimester of pregnancy (18-31 weeks gestation) were 0.40±4, consistent with the values quoted by the literature. The myocardial performance index is an indicator of fetal cardiac systolic function that can be easily measured and reproduced, without the need to obtain detailed anatomical images. The modified Mod-MPI could become a useful tool in exploring the fetal cardiac function in different clinical situations, and could be introduced as a standard measurement for the fetal echocardiography evaluation because it provides a higher accuracy as compared to MPI, in assessing the systolic function.

Keywords: *Doppler, fetal echocardiography, myocardial performance index, Tei index*

Introduction

The myocardial performance index (MPI) is a simple, reproducible method of assessing the global performance of the left ventricle in adults, introduced in 1995 by Tei and his collaborators. It is defined as the sum of isovolumic contraction time (ICT) and isovolumic relaxation time (IRT) divided by ejection time (ET) of the left ventricle (LV). It is determined by the equation: Tei Index= ICT+IRT/ET, where ICT=isovolumic contraction time, IRT= isovolumic relaxation time, and ET=ejection time(1).

The myocardial performance index (Tei index) has been successfully extrapolated to echocardiographic evaluation of fetal cardiac function. Practice revealed that it is a reproducible, simple index, independent of cardiac frequency or gestational age and that it does not present intra-/inter-observational variability(2).

Evaluation of MPI is important for defining the normal as well as the pathological physiological characteristics, as a prognostic marker of fetal cardiac adaptive changes in high risk pregnancies, delayed intrauterine development, and feto-fetal (twin to twin) transfusion syndrome, but it is important to first establish the normal values of this index, as reference for comparison to other values obtained in the literature, in view of setting a standard for this evaluation. This is also the purpose of the present study.

Methods

The study starts from the possibility to measure the value of myocardial performance index for the fetal heart by the Pulsed Doppler method, both the one advanced by Friedman and the one proposed by Raboisson and confirmed by Hernandez- Andrade, i.e the modified myocardial performance index (Mod-MPI), so as to establish which method generates values that are closer to the ones proposed as reference by the literature. By simultaneously measuring the flow through the mitral valve and the flow through the aorta, the time intervals ICT, IRT and ET, necessary for the calculation of the myocardial index, can be obtained. The studies conducted on adult, pediatric and fetal populations show that MPI is independent of ventricular geometry and the precise anatomical positioning of the Doppler caliper (gate)(3).

The study was done retrospectively for a period of 4 months, between January and April 2013, involving a cohort of 69 women with monofetal pregnancies, having an average gestational age of 24 W±3.2 (the range was between 18-31 weeks of gestation), who presented for routine clinical visits and gave their written agreement to be included in the study.

MPI was evaluated both in the Friedman variant (MPI) and in the Hernandez - Andrade variant (Mod- MPI). Echographic evaluations were performed with a Voluson 730 Expert machine (GE Medical Systems), using a 4-8 MHz convex probe. The study included only pregnant women who had an ultrasound screening for fetal abnormalities to exclude the cases of congenital cardiac anomalies and fetuses with delayed intrauterine growth. The measurements were taken in the absence of fetal movement and with the mother in voluntary apnea. To get a clear image of the Doppler waveform, the highest velocity (15 cm/s) was used and the angle of insonation was kept at less than 20°. The wall motion filter was set at over 200 Hz to avoid artifacts.

For MPI evaluation, the sample volume caliper was placed in the left ventricle under the mitral valve, tangent to the

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aortic ejection cone, under the semilunar valves in an apical five chamber view (Figures 1 și 2). In this way, the recorded Doppler flow includes the positive E- (rapid filling phase) and A-wave (atrial contraction) and the negative aortic flow at the same time.

To evaluate Mod-MPI, the pulsed Doppler volume caliper (with an opening of 3 mm) was placed in the left ventricle at the level of the junction between the anterior mitral valve leaflet and the aortic ejection cone under the semilunar valves in an apical five chamber view (Figure 3).

In this way, the recorded Doppler flow includes both the positive E/A wave (transmitral flow) and the wave with the negative aortic flow, but the different positioning of the caliper allows the recording of the Doppler signal produced at the closing/aperture of the mitral valve and of the semilunar aortic valve, facilitating the designation of clear reference points for the measurement of time intervals defining Mod-MPI.

To evaluate MPI, the following time intervals were measured: ICT the interval from the end to the onset of the transmitral diastolic flow, delimited by the end of the E/A wave and the onset of the transaortic flow. ET, the interval from the onset to the end of the transaortic systolic flow; IRT, the interval between the end of transaortic flow to the onset of E/A wave (Figure 2).

To evaluate Mod-MPI, the following time intervals were measured: ICT, the time interval from the end to the onset of transmitral diastolic flow, delimited by the Doppler- signaled click of mitral valve closure and the click of semilunar valves aperture. ET, the interval delimited by the click of semilunar valves aperture and the click of their closure; IRT, the interval delimited by the click signaling semilunar valves closure and the click of mitral valve aperture (Figures 3 and 4).

Three successive measurements were done, every time obtaining all the proposed intervals. Cardiac frequency was also measured three successive times to obtain a final average. Myocardial index was calculated in both variants using the average value of the three successive measurements for each measured interval.

Statistical analysis

The data are presented as average values ± standard deviation (σ) for the myocardial index, as well as for ICT, IRT, ET

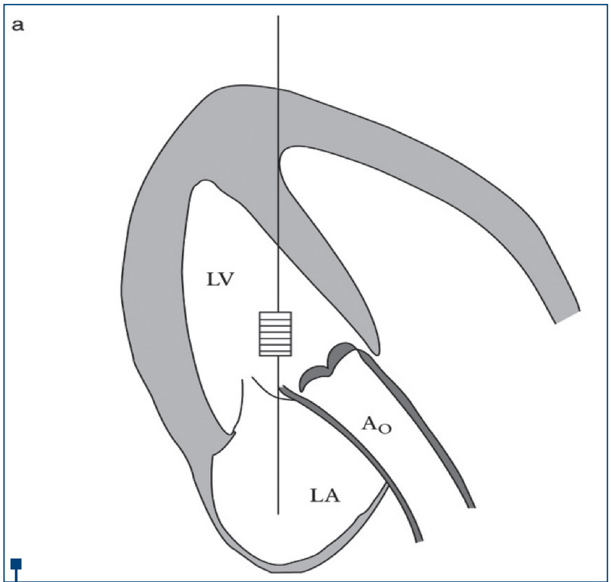

Figure 1. ***Positioning of volume caliper to measure MPI***

and cardiac frequency. The relation between the value of the myocardial index, the other intervals measured (ICT, IRT, ET), cardiac frequency and gestational age was analyzed using simple linear regression. The soft for statistics used was Windows Excel (Microsoft Corp, Redmond, WA, USA) and Student t test /ANOVA. P <0.05 is considered statistically significant.

Results

Measurements for ICT, ET and IRT were obtained for all 69 cases. MPI and Mod-MPI were calculated by the equation ICT+IRT/ET (Figure 5).

Evaluation of MPI lead to: 41±12 ms average of ICT, 169 ± 14ms average of ET, 46± 12 ms average of IRT (Table 1). Average cardiac frequency was 140±11 bpm and MPI was 0.51±12 for 18-31 weeks of gestation.

Evaluation of Mod-MPI resulted in: 32±5 ms average of ICT, 170±6 ms average of ET and 36±5 ms average of IRT. Average cardiac frequency was of 140±11bpm. Average modified myocardial index (Mod-MPI) was 0.40±4 for 18-31 weeks of gestation (Table 2).

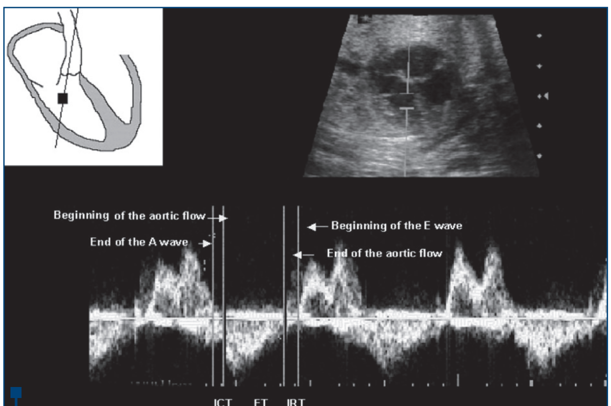

Figure 2. ***Measurement of time intervals to determine MPI***

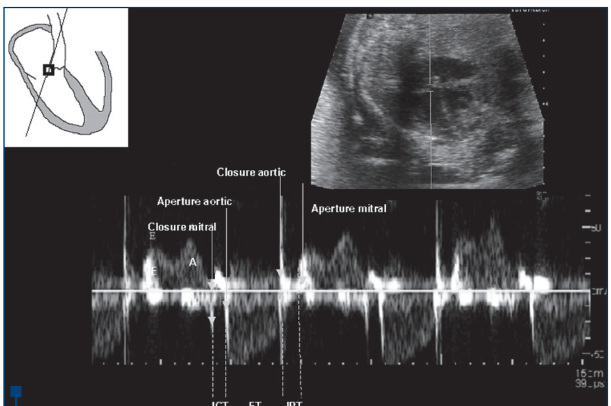

Figure 3. ***The measurement of time intervals to determine Mod-MPI***

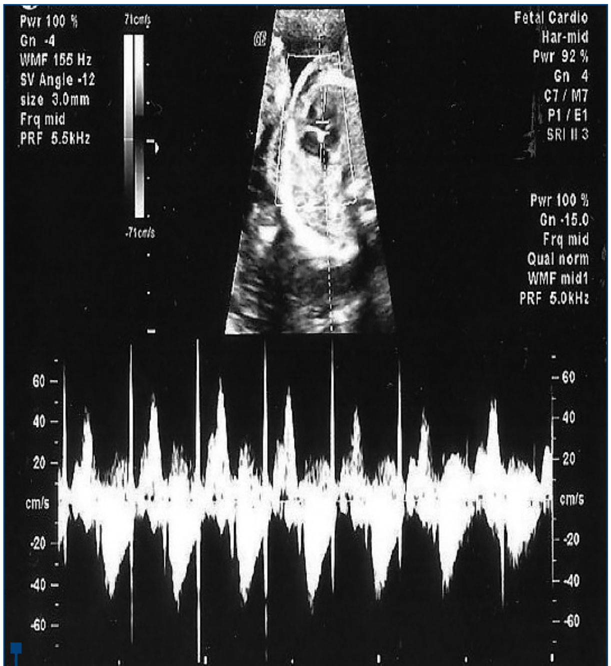

Figure 4. Doppler echocardiogram signals of aperture and closure of semilunar aortic valves when measuring Mod-MPI

No significant correlation was registered between the value of the myocardial index and gestational age or fetal cardiac frequency (p>0.05). ICT, IRT, ET intervals did not vary with gestational age. ICT and IRT were inversely proportional to cardiac frequency, the more advanced the gestational age was significant (p<0.05). ET registered a variation tendency that was inversely proportional to cardiac frequency (p<0.07).

Discussion

The ejection volume for the left ventricle can be very accurately estimated through the mitral or aortic valve, and for the right ventricle, through the tricuspid and pulmonary valve. This volume is slightly higher if measured through atrioventricular valves rather than through the semilunar ones, which can lead to errors in result interpretation. Due to its position close to the aortic ejection cone and the mitral valve, positioning the sample volume caliper (gate) in the left ventricle can simultaneously measure both flows[4]. This allows the simultaneous measurement of isovolumic relaxation time, isovolumic contraction time, and ejection time.

This MPI, which reflects the systolic function, has recently been standardized as a measurement protocol and is more precise and easier to do than the conventional measurement of the ejection fraction, to which it correlates anyway (like in the case of adult cardiology). In addition, this index does not depend on gestational age and does not present intra- and inter-observational variations[5].

Considering the high risk of perinatal mortality and morbidity, the identification of fetal cardiac dysfunction can be relevant for the clinical monitoring of such cases. One of the situations in which this can be applied is intrauterine growth restriction (IUGR), which is associated with numerous modifications at the level of the fetal heart, involving cardiac preload, afterload, ventricular compliance and myocardial contractility. Increased afterload, sensed at the level of the right ventricle, is the consequence of increased placental vascular impedance. A decrease of left ventricle afterload is the consequence of a decrease of cerebral impedance, associated to the phenomenon of blood redistribution. These modifications, in afterload, lead to the redistribution of ejection volume from the right to the left ventricle. Hypovolemia, associated to IUGR, decreases the preload and is reflected in the decrease of E/A ratio at the level of the mitral and tricuspid valve. The right ventricle is generally more affected by compliance decrease than the left one. Another consequence of the reduction of right ventricle afterload is a reduction of the peak-systolic velocity at the level of the semilunar valves, the increase of the time to peak velocity through the aorta and its decrease through the pulmonary artery. Severe IUGR also presents a decrease of myocardial contractility, exemplified on Doppler by MPI, as an index of ventricular systolic function which is independent of pre- and afterload and decreased at the level of the right and left ventricles, when the fetus is severely compromised[6].

Fetuses with IUGR, presenting a modified MPI have an alarming cardiotocographic profile and have a low pH at birth. There is a significant correlation between the severity of fetal acidosis and IPM values, which confirms the strong association between this index and the degree of severity of fetal compromise[6].

In hypoxia and placental insufficiency, the fetal heart plays a central role in adaptive mechanisms. Normal hemodynamic evolution of a fetus with IUGR indicates the Doppler-detectable values, on the umbilical and middle cerebral artery, as being the first to deteriorate. These modified Doppler-detectable arterial values are followed by the deterioration of diastolic indices of the right heart, followed by the systolic indices of the right heart, and, finally, by the deterioration of the diastolic and systolic function of the whole heart. Maintaining at least the left ventricular systolic function, as the last factor to deteriorate, ensures a left ejection fraction sufficient for fetal cerebral and coronary circulation. MPI can be a potential method to monitor fetal cardiac adaptive changes in delayed growth[7].

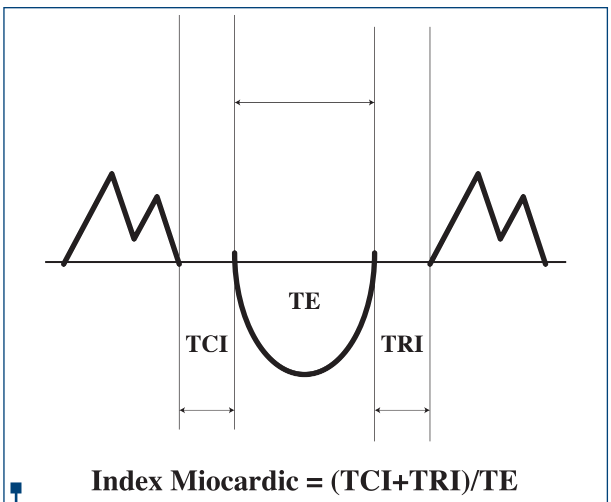

Figure 5. Equation for myocardial index (MPI and Mod-MPI), where TCI=ICT, TE=ET, TRI=IRT

Table 1 Average values and time intervals for MPI, measured by pulsed Doppler

Measured Parameters	Average values +/- standard deviation
ICT	41 ± 12 ms
ET	169 ± 14 ms
IRT	46 ± 12 ms
MPI	0.51 ±12

Table 2 Average values and time intervals for Mod- MPI, measured by pulsed Doppler

Measured Parameters	Average values +/- standard deviation
ICT	32±5 ms
ET	170±6 ms
IRT	36±5 ms
Mod-MPI	0.40±4

The data obtained within the present study correspond to the data quoted by the literature evaluating fetal systolic and diastolic parameters(8). There is still great variability among the values obtained by different studies, most probably due to the different measurement methods for the time intervals as well as to the technical parameters used for the calibration of the pulsed Doppler(9). In the present study we used the methods advanced by Friedman (MPI) and Hernandez – Andrade (Mod-MPI) respectively, and we calculated the values of the myocardial index in both variants.

The results obtained for the modified myocardial performance index (Mod-MPI) are more precise and register smaller intra-and inter-observational variations. Mod-MPI value is similar to the value quoted in the literature (0.43) as being of reference for the performance of the left ventricle for a healthy fetus population(9,10). The average Mod-MPI value is more reduced, as the positioning of the caliper to determine the time intervals is different when measuring MPI. Measuring ICT from the end of mitral valve closure to the onset of the click of aortic valve aperture and IRT from the end of the click of aortic closure to the onset of the click of mitral aperture we did not include the time for the movement of the valves. These intervals not included lead to a longer ET and shorter IRT and ICT intervals, resulting in a shorter Mod-MPI compared to the MPI, in which the delimitation of the time intervals measured is not as precise. We demonstrated that MPI does not vary with cardiac frequency and it is independent of ventricular form, its determination not depending on the obtaining of an extremely precise anatomical image. Furthermore, we established that MPI was independent of gestational age in the group we evaluated.

The limits of the present study derive from the fact that we evaluated only the left ventricle function, and only for the second and the beginning of the third trimester of pregnancy.

Conclusions

The results of this study demonstrate that it is possible to obtain reproducible measurements of an important clinical value. The potential applications of the myocardial performance index are in the delayed intrauterine growth, fetuses from mothers with diabetes, fetofetal (twin-to-twin) transfusion syndrome, as well as Rh isoimmunisation. Although past studies suggested that cardiac parameters change only in the case of severely compromised fetuses, more recent studies highlight the possible presence of subclinical cardiac dysfunction in the early stages of fetal deterioration. Adding the measurement of the Mod-MPI values can improve the monitoring of high risk pregnancies. Further research will offer a prospective evaluation of its clinical utility. ■

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