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Fetal cardiac function assessed by Doppler myocardial performance index (Tei Index)

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KEYWORDS: fetal echocardiography; fetal myocardial function; Tei Index

ABSTRACT

Objectives *The Tei Index (TI) is a useful, non-invasive, Doppler-derived myocardial performance tool which can be used to assess aspects of systolic and diastolic function. The aim of this study was to determine normal values of fetal left ventricular (LV) TI in second- and third-trimester fetuses and to compare these to other values reported in the literature.*

Methods *Doppler waveforms of the LV outflow tracts were obtained in 74 second- and early third-trimester fetuses. The LV isovolumic contraction time (ICT), isovolumic relaxation time (IRT) and ejection time (ET) were measured and the TI calculated using the formula (ICT + IRT)/ET. The literature on LV myocardial function in the fetus was also reviewed.*

Results *The normal TI in second- and early third-trimester fetuses (18–31 weeks' gestation) was 0.53 ± 0.13. The ICT was 43 ± 14 ms, the ET was 173 ± 16 ms and the IRT was 48 ± 13 ms.*

Conclusion *The TI can be easily obtained in the fetus without the need for precise anatomic imaging. The TI may be a useful tool to explore fetal myocardial function in different clinical situations. Copyright © 2003 ISUOG. Published by John Wiley & Sons, Ltd.*

INTRODUCTION

Fetal echocardiography has developed over the past 20 years as the primary non-invasive modality to evaluate fetal cardiac anatomy, function and hemodynamics. Specifically, M-mode, two-dimensional imaging and pulsed Doppler techniques have been used in both animal models[1] and in fetuses[2–7] to evaluate cardiac function, both systolic and diastolic, throughout gestation.

Recently, an easily measured Doppler-derived index of left (LV) or right ventricular (RV) myocardial performance combining systolic and diastolic time intervals was described in the literature by Tei *et al.*[8]. The Tei Index (TI) has been reported to be a useful, non-invasive, Doppler-derived myocardial performance index that serves as a combined index of global myocardial function. By incorporating only time intervals, the index is less dependent on anatomy or precise imaging. Furthermore, the TI is independent of both heart rate and ventricular geometry[8,9]. The TI is defined as the sum of isovolumic contraction time (ICT) and isovolumic relaxation time (IRT) divided by ejection time (ET).

The TI has been reported in the literature in the assessment of myocardial performance in a variety of clinical conditions in adults including myocardial infarction[10], dilated cardiomyopathy[8] and amyloidosis[9] to predict clinical outcome. In addition, the TI has also been used in pediatric populations to evaluate myocardial function in patients undergoing anthracycline therapy[11], in those with congenital heart disease (CHD) with single ventricle physiology[12] and also in pediatric patients who have undergone a cardiac transplant[13]. Published normal values for the TI in children (aged 3–18 years) range between 0.32 and 0.33[11,13] and in adults (aged 18–51 years) between 0.28 and 0.39[10,14].

We hypothesized that the TI would be technically feasible to obtain in the fetus using the pulsed Doppler technique. By simultaneously obtaining the mitral valve inflow waveforms and the aortic outflow waveforms from the LV outflow tract, the time intervals needed for the calculation of the TI, namely the ICT, IRT and the ET, could be measured. The LV TI has been demonstrated in several studies in adult, pediatric and fetal populations to be independent of ventricular geometry and precise anatomic location[8–14]. We wanted to use the TI as

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a means of assessing physiological changes in global ventricular function during advancing pregnancy and, in particular, attempt to try to distinguish systolic and diastolic function during the second and early third trimesters. We also reviewed the literature on normal values of fetal LV myocardial function.

METHODS

Patient selection

Seventy-four healthy pregnant women were recruited after normal fetal echocardiograms had been obtained. These women had been referred to a pediatric cardiologist for a fetal echocardiogram because of a family history of CHD or suspicious findings on routine level two ultrasound. The mean gestational age (GA) was 24 ± 3.4 (range, 18–31) weeks. A full fetal echocardiographic examination was performed and findings documented, and multiple pulsed Doppler tracings of the mitral valve inflow and aortic valve outflow tract were obtained from the LV only.

Echocardiographic evaluation

Two-dimensional fetal echocardiography was performed with commercially available equipment (Acuson Sequoia, Mountain View, CA, USA). All images were recorded on videotape and measurements were obtained using the machine's software package on the Acuson Sequoia. A gated pulsed Doppler sample volume was placed in the LV at the junction of the anterior leaflet of the mitral valve and the LV outflow tract in an apical five-chamber view and normal LV filling and emptying was noted (Figure 1). The following time intervals were measured: from the end of the A-wave to the onset of the aortic pulsed Doppler tracing (ICT), from the onset to the end of the aortic pulsed Doppler tracing (ET) and from the end of the ejection time to the onset of the E-wave (IRT) (Figure 2). Three successive measurements including all of the above intervals were obtained and averaged. The fetal heart rate was also measured from the three successive aortic pulsed Doppler tracings and averaged. The TI was calculated from an average of the three successive measurements of each of the intervals measured. The TI was calculated in

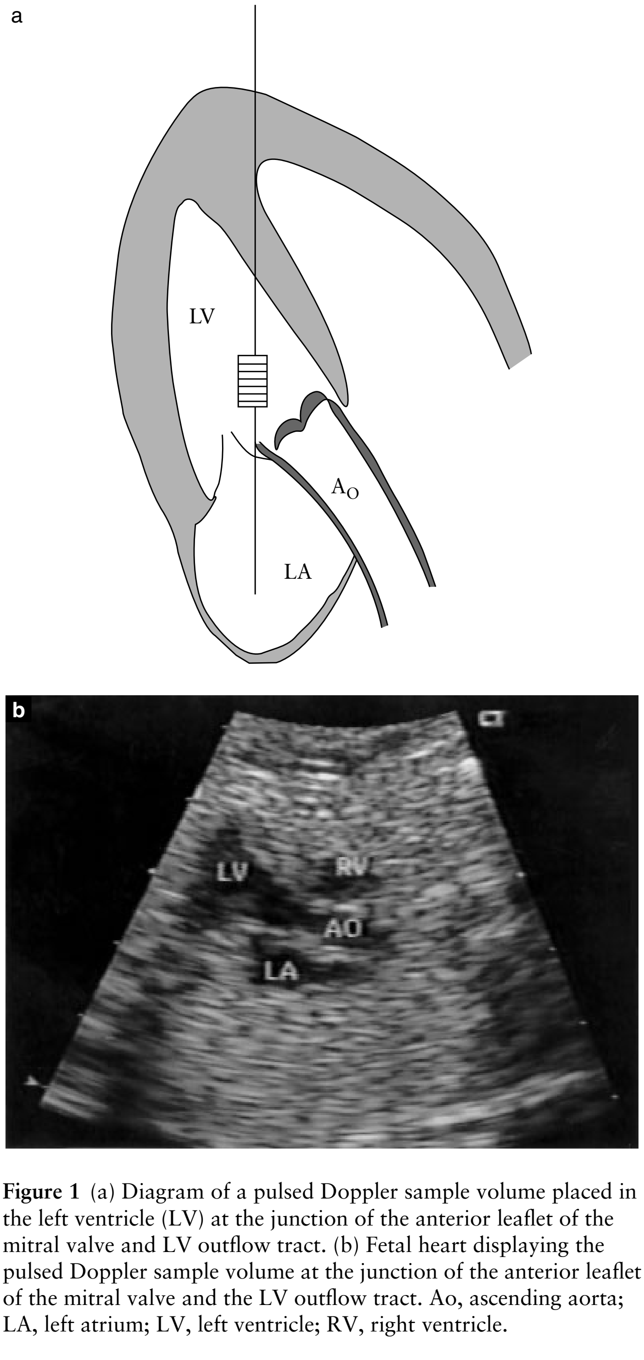

Figure 1 (a) Diagram of a pulsed Doppler sample volume placed in the left ventricle (LV) at the junction of the anterior leaflet of the mitral valve and LV outflow tract. (b) Fetal heart displaying the pulsed Doppler sample volume at the junction of the anterior leaflet of the mitral valve and the LV outflow tract. Ao, ascending aorta; LA, left atrium; LV, left ventricle; RV, right ventricle.

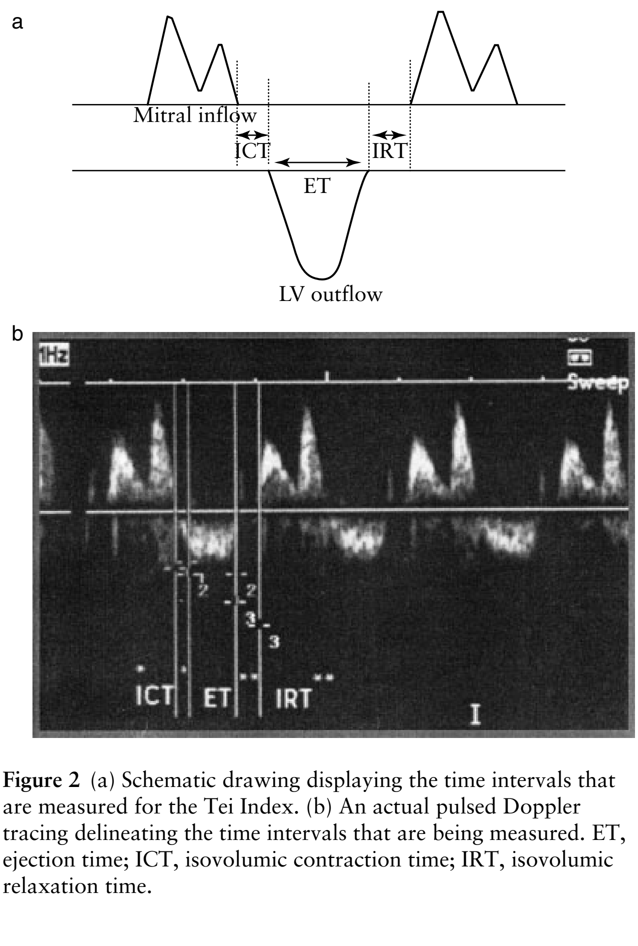

Figure 2 (a) Schematic drawing displaying the time intervals that are measured for the Tei Index. (b) An actual pulsed Doppler tracing delineating the time intervals that are being measured. ET, ejection time; ICT, isovolumic contraction time; IRT, isovolumic relaxation time.

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this manner so that the separate intervals of ICT, ET and IRT could be assessed.

Statistical analysis

Data are expressed as mean ± standard deviation (SD) for the TI as well as for the ICT, IRT, ET and heart rate. Linear regression analysis was used to evaluate the relationship of the TI and the other measured time intervals, ICT, IRT and ET, to GA and heart rate.

RESULTS

Pulsed Doppler-derived time interval data

The fetal ICT, IRT and ET were easily obtained in all 74 cases. The TI was calculated from the above measured data (TI = ICT + IRT/ET). The mean ICT (systolic time interval) was 43 ± 14 ms. The mean ET (systolic time interval) was 173 ± 16 ms. The mean IRT (diastolic time interval) was 48 ± 13 ms. The mean heart rate was 145 ± 11 bpm. The mean TI was 0.53 ± 0.13 for 18–31 weeks of gestation (Table 1).

The heart rate decreased with advancing GA ($P < 0.02$). The TI, however, appeared to be independent of GA and of heart rate ($P > 0.05$). The ICT, IRT and ET were independent of GA ($P > 0.05$). The ICT and IRT were inversely proportional to heart rate ($P < 0.05$) during advancing GA. The ET tended to be inversely proportional to heart rate ($P = 0.07$).

DISCUSSION

The correct assessment of fetal myocardial function is of critical importance when evaluating high-risk fetuses. Early recognition of subtle changes in myocardial performance may be potentially lifesaving for the fetus. It is well known that impairment of ventricular function may lead first to diastolic and then to systolic dysfunction in children and adults with heart disease.

The data in the literature evaluating specific systolic and diastolic parameters in the fetus are varied. Much of the variation is attributable to the different methods researchers have used to evaluate systolic and diastolic function in fetal hearts.

Table 1 Pulsed Doppler-derived time interval data obtained from 74 normal fetuses at 18–31 weeks' gestational age

Parameter	*Time interval data (mean ± SD)*
ICT	43 ± 14 ms
ET	173 ± 16 ms
IRT	48 ± 13 ms
TI	0.53 ± 0.13

ET, ejection time; ICT, isovolumic contraction time; IRT, isovolumic relaxation time; SD, standard deviation; TI, Tei Index (ICT + IRT/ET).

Tulzer *et al.* evaluated diastolic function in the fetus during the second and third trimesters of pregnancy. In their study, they used the pulsed Doppler tracing of the mitral valve and calculated the area under the pulsed Doppler E/A tracing. They found no evidence to support change in diastolic function during the second and third trimesters in human fetuses[6]. van Splunder *et al.* evaluated cardiac functional changes in the human fetus in the late first and early second trimesters. They used a combination of pulsed Doppler techniques integrating both the mitral and aortic valve Doppler tracings to assess systolic and diastolic function in their fetal population. They found that there is an increased filling phase and reduced isovolumic relaxation and ventricular ejection phases of the cardiac cycle during the first and early second trimesters[2].

Tsyvian *et al.* assessed the IRT in third-trimester fetuses (30–39 weeks' gestation). The measured IRT in their 17 normally grown fetuses was 51 ± 8 m[5], quite similar to our value of 48 ± 13 ms (mean GA 24 ± 3.4 weeks). The study of Tsyvian *et al.* did not, however, address systolic function, or global myocardial function.

Kleinman *et al.* using M-mode techniques assessed cardiac function in human fetuses. They primarily evaluated systolic time intervals in the human fetal heart by using M-mode echocardiographic recordings of fetal semilunar valves and simultaneously inscribed fetal electrocardiographic signals that were obtained utilizing electrodes placed on the maternal abdominal wall[3]. Their methodology only evaluated systolic function in the fetus. Data collection was lengthy, 30–40 min per study, and the data were difficult to obtain clearly[3]. St John Sutton *et al.*[15] and Rizzo *et al.*[16] assessed RV and LV systolic function in fetuses by cross-sectional Doppler echocardiography and calculated the force developed by myocardial shortening. This index of ventricular performance is, like the TI, independent of ventricular geometry and heart rate. However, unlike the TI, it requires excellent two-dimensional visualization in order to measure accurately the great vessel wall diameters in the human fetus. Sutton *et al.* determined that the development of the RV and LV force in the human fetus is similar during gestation in spite of the greater volume handled by the RV[15]. This method only looked at systolic function however.

Tsutsumi *et al.* were the first to report using the TI to assess fetal global myocardial function. Our data are very similar to those of Tsutsumi *et al.* in a similar fetal model. Their LV TI was 0.62 ± 0.07 (18–26 weeks). After 34 weeks' gestation, they found that the LV TI fell to 0.43 ± 0.03[7]. They suggested that the maturational changes in the LV properties in human fetuses accelerate after late gestation and that the global changes in ventricular function may relate to developmental changes of the fetal myocardium in late gestation[7]. However, in this study, the systolic (ICT and ET) and diastolic function (IRT) components which comprise the TI were not independently reported.

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Other data in the literature regarding the fetal TI do not support maturational changes in the LV TI. Mori *et al*. reported normal RV and LV TI of 0.35 ± 0.07, and 0.35 ± 0.03, respectively. Mori and his colleagues did not find any difference in the TI throughout gestation[17]. Similarly, Eidem *et al*. demonstrated the fetal LV TI to be 0.35 ± 0.03 with no change during gestation[18].

In our preliminary study, we demonstrated that the measurements of the ICT, IRT and ET are easily obtained in the fetus during the gestational time period we evaluated and so we were able to easily calculate a TI in these fetuses.

Normal values for these specific time intervals, as well as for the calculated fetal TI, were established in our study. Our data are similar to those of other groups who have assessed LV myocardial performance. We demonstrated that the fetal TI does not vary with heart rate and appears to be independent of ventricular geometry[8–14] and it is not necessary to perform precise anatomic imaging to obtain the fetal TI. In addition, we found that the TI appeared to be independent of GA within the gestational age group we evaluated.

The most significant limitation of our study was the obvious lack of an invasive gold standard to compare with our non-invasive measurements in assessing global myocardial function in the fetus. In addition, our study group was cross-sectional and limited to the second and early third trimesters of gestation. Furthermore, we only assessed LV myocardial function in our study and cannot comment upon RV myocardial performance.

CONCLUSION

We report the use of an easily obtainable Doppler-derived index that combines elements of systolic and diastolic function in the fetus independent of heart rate, ventricular geometry and precise anatomical imaging. The data presented here also evaluate the individual indices (ICT, ET, IRT) comprising the LV TI. The TI may be a useful additional tool to explore perturbations of fetal myocardial function in a variety of clinical conditions. Potential applications of the TI would be in the investigation of growth-restricted fetuses, fetuses of diabetic mothers, fetuses with heart failure including hydropic fetuses, and fetuses with Rh sensitization. The TI of LV myocardial performance should be considered part of a routine fetal well-being assessment.

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