Int Cardiovasc Res J.2011;5(4):134-138. DOI: 10.5812/icrj.3957

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International Cardiovascular Research Journal
www.ircrj.com

Evaluation of Pulsed Doppler-Versus Tissue Doppler-Derived Tei Index of Right and Left Ventricle in Fetuses

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ARTICLE INFO

Article type:
Original Article

Article history:
Recevied: 23 Feb 2011
Revised: 13 Apr 2011
Accepted: 22 Apr 2011

Keywords:
Heart Function Tests
Polarography
Elasticity Imaging Techniques

ABSTRACT

Background: The myocardial performance index (MPI), also known as the Tei index, was introduced by Tei et al. to evaluate cardiac function in adults with dilated cardiomyopathy. This index is defined as the sum of isovolumic contraction time (ICT) and isovolumic relaxation time (IRT), divided by ejection time (ET).

Objectives: To determine the correlation between pulsed Doppler (PD)- and tissue Doppler imaging (TDI)-derived Tei indices in fetuses.

Patients and Methods: Right and left ventricle PD and TDI echocardiographic data were obtained from 59 fetuses (11 pregnant women who were positive for anti-SSA-Ro or anti-SSB-La antibodies, 18 women who were referred due to dysrhythmia, and 30 women who had normal clinical findings).

Results: Mean fetal gestational age was 27 ± 6.4 weeks. Mean PD Tei index of the mitral and tricuspid valve was 0.58 ± 0.05 and 0.53 ± 0.08, respectively. Mean TDI indices for the mitral and tricuspid valve were 0.56 ± 0.09 and 0.55 ± 0.08, respectively. There were no significant differences between mitral and tricuspid PD- and TDI-derived Tei indices (P = 0.87, P= 0.21), but the Bland-Altman diagrams showed no fine agreement between the indices (the mean difference ± 1 standard deviation of the right ventricular PD- and TDI-derived Tei indices was 0.24 ± 0.02 and 0.29 ± 0.04 for the left ventricle). There were no significant differences in PD- and TDI-derived Tei indexes between groups of evaluated fetuses (Mitral valve: PD-Tei P=0.69, TDI-Tei P=0.49; Tricuspid valve: PD-Tei P=0.41, TDI-Tei P=0.36).

Conclusions: Although the mean values of the two indices did not differ significantly, the TDI-derived and PD-derived Tei indices did not have fine agreement.

▸ *Implication for health policy/practice/research/medical education:*
The result may be implicated in echocardiographic evaluation of neonates by prenatologist and pediatric cardiologist.

▸ *Please cite this paper as:*
Amoozgar H, Soltani M, Borzoee M, Ajami G, Cheriki S. Evaluation of Pulsed Doppler-Versus Tissue Doppler-Derived Tei Index of Right and Left Ventricle in Fetuses. *Int Cardiovasc Res J*.2011;5(4):134-8. DOI: 10.5812/icrj.3957

1. Background

The myocardial performance index (MPI), also known as the Tei index, was introduced by Tei *et al.* to evaluate cardiac function in adults with dilated cardiomyopathy (1). This index is defined as the sum of isovolumic contraction time (ICT) and isovolumic relaxation time (IRT), divided by ejection time (ET). Recently, pulsed Doppler (PD) and tissue Doppler imaging (TDI) methods to measure the Tei index have become easy means of evaluating global systolic and diastolic heart function in healthy and diseased neonates and fetuses. However, there are contradictory results regarding the correlation between Tei indices by PD and TDI in fetuses (2,3).

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DOI: 10.5812/icrj.3957

2. Objectives

In this study, we compared PD- and TDI-derived Tei indices for the right and left ventricles to identify a possible correlation between these methods in fetuses with normal heart structures in 2-dimensional echocardiography and various maternal diseases.

3. Patients and Methods

The study population consisted of 59 pregnant women who were referred consecutively for fetal echocardiography and prenatal evaluation. Gestational age was determined according to the sonographic findings and last menstrual period. The study was performed at a clinic that was affiliated with Shiraz University of Medical Sciences, Shiraz, Iran. The parents were informed, and written consent was obtained. The study was approved by the university's ethics committee.

3.1. Echocardiographic Data

To minimize errors, all echocardiographic examinations were performed by the same pediatric cardiologist. Two-dimensional and PD echocardiography were performed using a General Electric Vivid 3 (General Electric, Vingmed, Horten, Norway) with a 3-MHz probe and pulsed tissue Doppler software. First, the mitral and tricuspid inflow velocities were recorded with the PD sample volume positioned at the tips of the mitral and tricuspid leaflets in 4-chamber views. We tried to record inflow and outflow velocities simultaneously in the same strip, but in patients for whom this was not feasible, right and left ventricular inflow and outflow velocities were recorded separately. Tissue Doppler studies of the mitral and tricuspid lateral walls were done in 4-chamber views with no angle correction (*Figure 1*). All recorded strips were saved and evaluated offline to determine IRT, ICT, and ET. The Tei index was calculated as (ICT + IRT)/ET. At least 3 consecutive heartbeats were obtained.

3.2. Statistics

Independent sample t-test was used to compare continuous variables, and a *P* value < 0.05 was considered significant. Pearson's correlation coefficient was used to evaluate the relationship between Tei indices by PD and TDI and gestational age. The data were expressed as mean ± standard deviation. The agreement between PD and TDI measurements was analyzed per Bland and Altman (4). SPSS version 15 was used for all statistical analyses.

4. Results

A total of 59 fetuses with a gestational age between 16 and 38 weeks (mean 27 ± 6.4) were evaluated. Eleven pregnant women were positive for anti-SSA-Ro or anti-SSB-La; their mean age was 26 ± 3.4 years, and the mean gestational age of their fetuses was 25.1 ± 5.6 weeks. Eighteen women were referred due to dysrhythmia (all of them had premature atrial contraction without evidence of heart dysfunction); their mean age was 26.8 ± 4.7 years and the mean gestational age was 29.7 ± 6.9 weeks. The remaining 30 women had normal clinical findings but were referred for imaging studies due to a positive medical history of congential heart disease in their siblings.

The mean PD-derived Tei index was lower for the tricuspid annulus and higher for the mitral annulus than the corresponding tissue Doppler-derived Tei indices (*P* = 0.87, *P* = 0.21) (mean PD-derived time intervals in the mitral and tricuspid valves are shown in *Table 1*). There was no correlation between fetal gestational age and PD-derived Tei indices for the mitral (r = 0.002, *P* = 0.14) or tricuspid valve (r = 0.145, *P* = 0.59). Gestational age did

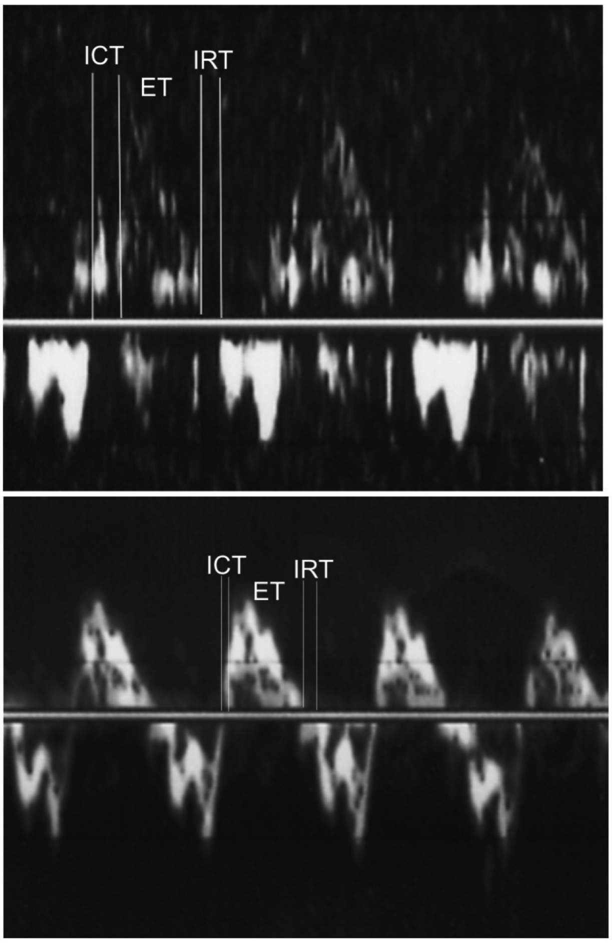
Table 1. Mean Pulsed Doppler-Derived Time Intervals in Mitral and Tricuspid Valves

	Ejection Time, ms, mean ± SD	Isovolumic Contraction Time, ms, mean ± SD	Isovolumic Relaxation Time	Tei Index, mean ± SD,ms, mean ± SD
Mitral valve				
Pulsed Doppler	150.1 ± 26.4	34.2 ± 8.5	49.1 ± 5.7	0.58 ± 0.05
Tissue Doppler Imaging	151.3 ± 29.2	36.1 ± 5.0	46.3 ± 7.4	0.56 ± 0.09
P value	0.85	0.13	0.01	0.87
Tricuspid valve				
Pulsed Doppler	148.3 ± 22.7	34 .3± 4.1	43.2 ± 6.5	0.53 ± 0.08
Tissue Doppler Imaging	152.4 ± 26.6	36.1 ± 5.2	46.2 ± 6.3	0.55 ± 0.08
P value	0.40	0.02	0.01	0.21

Table 2. Pulsed - and Tissue Doppler Imaging- Derived Tei Indices or the Mitral and Tricuspid Valves of Three Groups

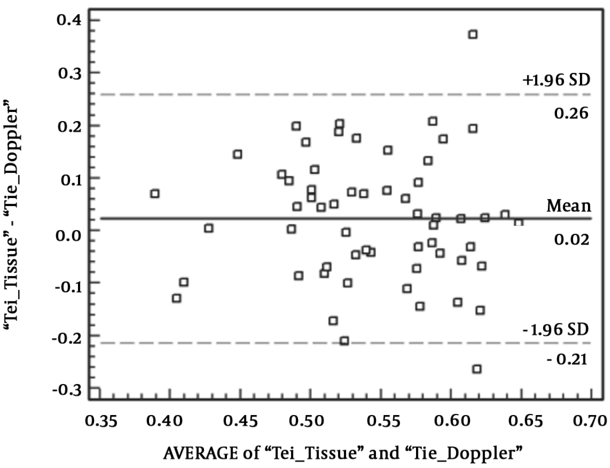
Measured Variables	Fetus With Dysrhthmia, mean ± SD	Positive Maternal Antibodies, mean ± SD	Normal Fetuses	*P* value
Mitral Pulsed Doppler	0.53 ± 0.1	0.51 ± 0.11	0.52 ± 0.13	0.69
Tricuspid Pulsed Doppler	0.54 ± 0.07	0.53 ± 0.12	0.52 ± 0.08	0.41
Mitral Tissue Doppler Imaging	0.56 ± 0.1	0.58 ± 0.05	0.55 ±.09	0.49
Tricuspid Tissue Doppler Imaging	0.56 ± 0.6	0.56 ± 0.05	0.54 ± 0.1	0.36

Figure 1. Pulsed (Top Panel) and Tissue Doppler Images (Bottom Panel) in the Four-Chamber View



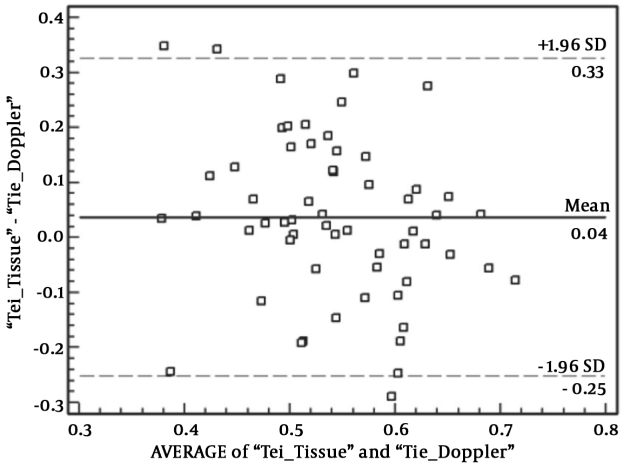
ICT, Isovolumic contraction time; ET, Ejection time; IRT, Isovolumic relaxation time

Figure 2. Bland–Altman Plot of the Differences Against the Mean for the Right Ventricular



Tei index measured with tissue doppler imaging (tdi) and pulsed-wave doppler (pd) methods. The lines represent the mean and 95% limits of agreement.

Figure 3. Bland–Altman plot of the Differences Against the Mean for the Left Ventricular



Tei index measured with tissue Doppler imaging (TDI) and pulsed-wave Doppler (PD) methods. The lines represent the mean and 95% limits of agreement.

not correlate significantly with TDI-derived Tei indices (mitral: r = – 0.033, P = 0.33; tricuspid: r = – 0.132, P = 0.49).

Bland-Altman diagrams were used to plot the agreement between the indices by the two methods (*Figure 2* and *Figure 3*). There was no significant difference in Tei indices between the 3 groups (mean PD- and TDI-derived time intervals for the mitral and tricuspid valves in the 3 groups are shown in *Table 2*).

5. Discussion

Our findings show that in normal fetuses with maternal antinuclear antibodies or dysrhythmia, PD- and TDI-derived Tei indices in the right or left ventricles do not differ significantly, but there is a wide difference in mean PD- and TDI-derived Tei indices of the right and left ventricle. An earlier study found that Tei indices, calculated from PD and TDI measurements, correlated well with invasive measurements of global cardiac performance (5), and in pediatric patients, there was a close correlation between left ventricular Tei indices, as calculated from both sets of measurements (6). Despite changes in load and heart rate, the Tei index is a good indicator of global myocardial heart function in healthy and diseased newborns and fetuses. However, loading conditions may affect the agreement between PD- and TDI-derived Tei indices (7-18). Su et al. found that the TDI-derived Tei index is relatively less affected by changes in loading conditions and may be more sensitive to acidosis or infection (4). Another study has demonstrated that the PD-Tei index is a useful tool in evaluating fetal heart function in twin-to-twin transfusion syndrome, fetuses of diabetic mothers, and fetuses with hydrops fetalis. This group also found a significantly higher Tei index in these fetuses versus the control group (14). Comas *et al.* reported that TDI was a more sensitive index than conventional echocardiography in evaluating fetal heart dysfunction in patients with intrauterine growth retardation (19).

In practice, it is easier to measure the TDI-derived Tei index than its PD-derived counterpart, because the former makes it possible to measure systolic and diastolic velocities simultaneously. However, a study by Raboisson *et al.* demonstrated good correlation between the Tei index that was obtained from simultaneous left ventricular inflow and outflow Doppler recordings and that using separate aortic and mitral Doppler waveforms (15). We found no significant difference in mean Tei indices between the right and left ventricles in fetuses. Right ventricular TDI-Tei index was larger than the PD-Tei index (mean difference = 0.02 ± 0.12), and left ventricular TDI-Tei index was smaller than the PD-Tei index (mean difference = –0.02 ± 0.48), which is not consistent with findings in adults and some studies in fetuses, in which the TDI-derived Tei index was significantly larger than the PD index for both ventricles (2,3,20).

Our study found no changes in Tei indices with gestational age, which is consistent with a study by Friedman *et al.,* who calculated left ventricular PD-Tei index in 74 normal fetuses with a mean gestational age of 24 ± 3.4 weeks (range 18-31 weeks gestation) and found that Tei index was independent of gestational age [21]. In addition, Mori et al. reported that PD-Tei indices in the right and left ventricles did not change with increasing gestational age (22). Another study by Van Mieghem *et al.* determined Tei index in 117 healthy fetuses with gestational ages of 20-36 weeks and noted that Tei index was not dependent on gestational age (23). In contrast, Tsutsumi et al. calculated right- and left-side PD Tei indices in normal fetuses and observed that these indices declined with increasing gestational age, especially in the left ventricle (17).

Our analysis did not detect a fine agreement between TDI- and PD-derived Tei indices in the right and left ventricles. Cui et al., who studied the left ventricle, and Harada *et al.*, who analyzed the right ventricle, noted good correlation between PD- and TDI-Tei indices (6,24). Acharya *et al.* calculated PD- and TDI-Tei indices in normal fetuses and those with various congenital heart diseases, observing that the mean TDI-Tei index was significantly higher than the PD-Tei index for both ventricles ($P < 0.0001$) and that there was weak correlation between PD- and TDI-derived Tei indices. This group also reported a significant difference between indices by the 2 methods, concluding that one measurement can not be substituted by the other (2). Duan *et al.* compared right ventricular PD- and TDI-Tei indices in 29 normal fetuses with gestational age 24-39 weeks (mean: 29.9 ± 4.0 weeks) and found a good correlation between Tei indices, calculated from both TDI and PD findings (3).

It was not always feasible to simultaneously record inflow and outflow of the left or right ventricle, which may have affected the accuracy of some of our data. In addition, various maternal diseases might have affected pulse and tissue Doppler differently.

In our study, we compared right and left ventricular PD-and TDI-derived Tei indices in fetuses whose mothers were positive for anti-SSA-Ro or SSB-La, fetuses with arrhythmia, and normal fetuses and found no significant difference in Tei indices between groups. Tei index values in fetuses whose mothers were positive for anti-SSA-Ro or SSB-La were similar to the indices reported earlier for normal fetuses (12). We conclude that the PD or TDI Tei index in the right or left side of the heart are not good indicators of early cardiac involvement in fetuses without evidence of carditis and are unable to differentiate normal fetuses from those whose mothers had anti-SSA-Ro or SSB-La.

In conclusion, our analysis does not support the existence of any significant correlation between gestational age and PD- or TDI-Tei index. Although the mean PD- and TDI-derived Tei indices were similar, no fine agreement was observed between them for the right or left ventricle. Therefore, these indices should not be used interchangeably to assess fetal cardiac function in different disease states.

Acknowledgments

This work was supported by the Vice Chancellory of Research, Shiraz University of Medical Science. We thank K. Shashok (AuthorAID in the Eastern Mediterranean) for improving the use of English in the manuscript, and M. Gholami at the Center for Development of Clinical Research of Nemazee Hospital for research assistance.

Financial Disclosure

Echocardiography finance was supported by the Vice Chancellory of Research, Shiraz, Iran.

Funding/Support

Neonatology research center, Shiraz University Medical Sciences, Shiraz, Iran. Cardiac Research Center, Shiraz University Medical Sciences, Shiraz, Iran.

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