Original Article

Doppler-Derived Myocardial Performance Index in Healthy Children in Shiraz

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Abstract

Background: Assessment of myocardial function is essential in heart disease, but in regard to systolic and diastolic functions such evaluation has limitation. Ejection fraction is difficult to assess in abnormally-shaped ventricles, and diastolic inflow velocity pattern may be fused because of tachycardia.

Objective: A myocardial performance index (MPI) or Tei index has been developed for adults and children. It is a Doppler derived non-geometric measure of ventricular function and is independent of heart rate. This index measures the ratio of isovolumic contraction time plus isovolumic relaxation time to ventricular ejection time.

Methods: We studied 108 healthy children from 3 days to18 years of age, in whom ejection fraction was measured using M-mode (73±8%) and 2-dimensional echocardiogram biplane Simpson's method (62±7%).

Results: Right and left ventricular myocardial performance indices were 0.25 ±0.09 and 0.36 ±0.11 respectively. No correlation was found between Echo Doppler index and age, heart rate and left ventricular dimensions.

Conclusion: Thus, MPI is a simple and accurate tool for quantitative assessment of right and left ventricular functions and because of easy application and reproducibility; it could be regarded as an important measurement in a comprehensive hemodynamic study, especially in those with abnormal ventricular geometry.

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Key Words: Myocardial performance • ejection fraction • Doppler echocardiography • Child • Tei-index

Introduction

Cardiac function depends on the contraction of the sarcomeres, organization and configuration of the ventricular chambers, valvular functions and loading conditions. Thus cardiac function can be evaluated at several levels of integration such as myocardial function, chambers pumping performance and integrated cardiac output. It is important to recognize at which level of integration cardiac function is being evaluated. The myocardial function is determined by preload, afterload, contractility, heart rate and rhythm. Many indices have been suggested for measuring left ventricular contractile function. These can be divided into pre-ejection phase indices of contractility, ejection phase indices and measures derived

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Table 1: Echocardiographic measurements		
Measurement	**Mean±SD**	**No of subjects**
LV ejection time (ms)	238±32	108
RV ejection time (ms)	250±39	107
ICT + IRT of LV	87±29	108
ICT + IRT of RV	66±25	107
LVIDD (cm)	3.3±0.8	67
LVIDS (cm)	2.1±0.5	66
SFM (%)	37.5±7	106
EFM (%)	73±8	107
EF-Sim (%)	62±7	62
RVTei-index	0.25±0.09	107
LV Tei-index	0.36±0.11	108

LVIDD = Left ventricular internal diameter in diastole
LVIDS= Left ventricular internal diameter in systole
SFM= Shortening fraction obtained by M-mode
EFM= Ejection fraction by M-mode
EF-Sim= Ejection fraction by Simpson's formula U/a

from ventricular pressure volume relations [1]. These indices of myocardial function may be evaluated by several methods including contrast ventriculography, radionuclide angiography with technetium 99m[2], ultra-fast CT scan[2], magnetic resonance imaging[3-4-5] and echocardiography. The development of 2 dimensional (2-D) echocardiography has raised new expectations and hopes for improving the accuracy of echocardiography in quantitating left ventricular (LV) function. Because of the capacity for visualizing 2-D echocardiography the left ventricle in multiple tomographic planes versus the single ice pick view of the motion-mode (M-mode) echocardiography should theoretically lead to improved assessment of LV function, particularly in the presence of regional dyssynergia.[6]

Many clinical studies have demonstrated a consistent underestimation of end-diastolic and end-systolic volumes by 2-D echocardiography as compared with angiography.[3,5-7] The principal limitation of 2-D echocardiography in the clinical quantification of ventricular function seems to be related to restricted acoustic window and assessment of unusual geometry of the ventricle.[7] This is especially true for both ventricular volumes in univentricular heart.[7]

Doppler derived index of myocardial performance is correlated with invasive measurements of ventricular systolic and diastolic functions.[7] It is promising, non-invasive measurement of overall cardiac function. Tei-index is independent of chamber geometry, heart rate or technical interference with chamber's volume assessment.

Some studies concluded that the performance of myocardial index (PMI or Tei-index) is not affected by age.[8-10] The exception is that during 18-33 weeks of gestation, Tei-index of left ventricle increases and then decreases line-arly, whereas, the index of the right ventricle decreases slightly and linearly during 18-41 weeks of gestation. In neonates the Tei- index of right and left ventricles increases immediately after birth followed by a decrease and stability after 24 hrs.[4]

Patients and Methods

The details of this study are approved by the Ethical Committee of Shiraz Medical Sciences University and conformed to the Helsinki Declaration.

Selection of Subjects
One hundred and eight healthy subjects ((64 females and 44 males) from 3 days to 18 years of age (mean = 7.8 ± 4.8 yrs) were selected from amongst healthy volunteered individuals, under care of Motahari Polyclinic of Namazee hospital affiliated to Shiraz University of Medical Sciences. They had no structural cardiovascular diseases and had normal physical examination, 2-D, pulsed and color Doppler echocardiography. All subjects were in sinus rhythm during the recording of echocardiogram. Complete 2-D, pulsed wave and color Doppler echocardiographic examination were performed with ultrasound instruments (Vingmed and Hewlett Packard Sonos 1000).

Echocardiograms of 20 subjects were recorded on a video tape for subsequent off-line analysis. All data analysis was performed by one clinician on online measurement system. As for ejection fraction by 2-D mode, LV end-diastolic and systolic volumes were calculated by area-length and modified by Simpson's rule.[11] These were achieved by measuring areas and lengths which were traced from apical four chamber and also areas from parasternal short axis at the level of mitral valve and then papillary muscle. LV dimensions were also measured from M-mode at or just below the tips of mitral leaflets. Fractional shortening and ejection fraction were also measured by this mode. The tricuspid and mitral inflow velocities were recorded from the apical four chamber view with Doppler sample volume placed at the tip of leaflets during diastole. The LV outflow velocity pattern was recorded from apical five chamber view of echocardiography with the sample volume just below the aortic valve. RV outflow velocity pattern was also recorded from the parasternal short axis view with the Doppler sample volume positioned just distal to the pulmonary valve. Care was taken to perform these studies with the transducer beam as close as possible to the Doppler beam at $\leq 20^0$ in selected planes.

Five consecutive Doppler signals were meas-

ured and the values averaged. The following Doppler time intervals were measured. The interval-a (a), from the cessation to the onset of mitral or tricuspid inflow was equal to the sum of the isovolumetric contraction time (ICT), ejection time (ET), and isovolumetric relaxation time (IRT). The interval-b (b) was measured as the duration of ventricular ejection flow from the onset to the end of ejection. Thus the sum of the ICT and the IRT was obtained by subtracting interval-b from interval-a. The Doppler- derived Tei-index, combining systolic and diastolic functions, was then calculated using (a-b)/b formula.

Statistical analysis

Data entry and analysis were performed with SPSS software version 10. Pearson correlation coefficient was determined for RV and LV Tei-indices and taken as the dependent variable separately. Other variables, such as heart rate and age were regarded as independent entities. A $p<0.05$ was considered significant. The Tei-indices were standardized and their standard distribution was obtained, by using Kolmogroroy Smirnov Z-test. The differences between the standard distributions of ejection fraction (EF) and shortening fraction (SF) and LV Tei-index were compared.

Results

In our study the normal value of LV and RV Tei-indices were 0.36±0.11 and 0.25±0.09 with mean confidence intervals of 0.34-0.38 and 0.24-0.26 respectively. Demographic data (age and heart rate) were correlated with LV and RV Tei-indices by using Pearson's correlation coefficient. Echocardiograhic data are summarized in Table 1. LV and RV Tei-indices were independent of heart rate. However, there was an inverse relationship between heart rate and ejection time and also sum of isovolumic contrition time (ICT) + isovolumic relaxation time (IRT). There was also no correlation between Echo-Doppler index and age (Fig.1).It was concluded that in normal subjects there were no meaningful differences between LV Tei-index, EF (obtained by M-mode or 2-D echocardiography), SF and the resultant indices. Similarly, the traditional index of systolic function (SF and EF) follows a normal distribution in our population and could be easily used as an independent index for assessing ventricular function. The comparison of our data with those of other studies is demonstrated in Table 2.

Discussion

The MPI is a simple, quantitative, non geometric index of ventricular function and is readily applicable to studying the functions of right ventricle which has a complex geometry, as well as the assessment of the distorted ventricular morphologies that are present in congenital heart disease. It is especially appealing because it is the Doppler derived index and independent of heart rate which is easily reproducible in children and adults by measuring relatively large time intervals.

EF and SF are sensitive to changes in preload, contractility and afterload and accordingly to heart rate. An invasive assessment of diastolic function could be made in catheterization laboratory or by radionuclide angiography and several empiric echocardiographic Doppler indices.[12] There is difficulty in assessing EF in abnormally-shaped ventricles alone.[13,14] Also using echo Doppler indices of mitral inflow velocity pattern for assessing diastolic function is limited due to the fact that they are affected by heart rate and loading conditions. Since the results obtained from Tei-index correspond to those of invasive methods it would be preferable to the available invasive techniques.[14-15]

We determined the range of normal values for RV and LV Tei-indices as presented in Table 1. These values are consistent with those of other studies, Table 2. Tie-indices of this study were independent of age and heart rate as noted in others studies.[8-10] Although, LV Tei-index is not correlated with LV end diastolic diameter, it may be indicative of preload.

Other studies which evaluated ventricular function after, anthracycline therapy, showed an increase in MPI despite normal LV ejection fraction in children who developed LV dysfunction during follow up and concluded that MPI was a more sensitive technique for detecting suclinical LV dysfunction than current echocardiographic measurements.[21,22] This implies that there may not be an exact inverse relationship between MPI and EF and SF. How-

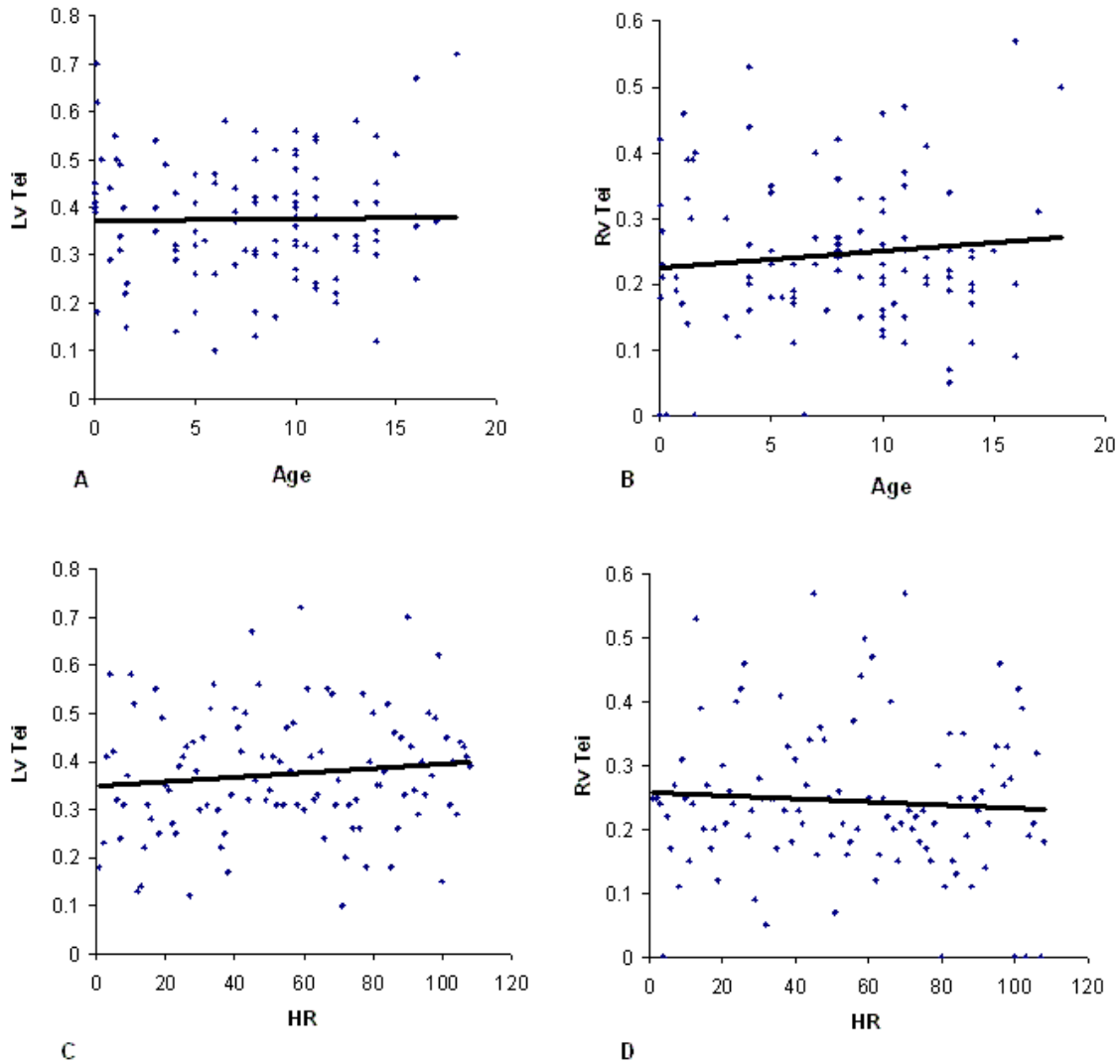| Table 2: MPI in different studies on echocardiographic patients			
Study	No of patients	LV MPI	RV MPI
Kim[15]	26	0.38±0.04	-
Eidem[16]	152	0.35±0.03	-
Dujardin[17]	75	0.37±0.05	-
Williams[18]	30	0.32±0.1	-
Bruch[14]	38	0.39±0.31	-
Ishii[19]	150	-	0.24± 0.04
Tei[20]	37	-	0.28±0.04
This study	108	0.36±0.11	0.25±0.09

Fig 1: Correlation between Doppler indices of LV and RV functions with age (A,B) and HR (C,D) in healthy children
RV= right ventricle LV= left ventricle HR=heart rate

ever, in an overt LV dysfunction there is a relationship between EF, SF and Tei-index.

Our study presented LV and RV Tei-indices in normal children. The validity of using Tei-index as an independent entity in myocardial performance was shown after it was standardized and compared with standard EF and SF. As expected, the Tei-index obtained, followed a normal distribution, used for healthy children.

The Tei-index is a simple, sensitive and accurate tool for quantitative assessment of functions of RV and LV. Because its use is easy and highly reproducible, it could be considered as a valuable technique in a comprehensive hemodynamic workup, especially when other indices of myocardial performance are within normal range. It could be used for the follow-up of patients with cardiac dysfunction to predict the results. It is more useful than other indices for evaluation of abnormal cardiac chambers, different geometrics, various positions of the heart and congenital malformations.

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