

Intraoperative transesophageal echocardiographic assessment of left ventricular Tei index in congenital heart disease

Shanthi Sivanandam, Andrew Wey¹, James St. Louis²

Departments of Pediatrics, ¹Biostatistics and ²Surgery, University of Minnesota, Minneapolis, Minnesota, USA

ABSTRACT

Background: Use of the Tei index has not been described to assess myocardial function before or after surgery in pediatric patients. This study was designed to evaluate the left ventricular (LV) function using the Tei index pre- and post-cardiopulmonary bypass in patients with lesion that result in a volume loaded right ventricle (RV). **Methods:** Retrospective data on 55 patients who underwent repair of a cardiac defect were analyzed. Patients with volume overload RV ($n = 15$) were compared to patients without volume overload but with other cardiac defects ($n = 40$). We reviewed pre- and post-operative LV myocardial performance index (Tei index). Tei index was obtained from transesophageal Doppler echocardiogram. **Results:** Patients with right heart volume overload, the mean preoperative Tei index was 0.6, with a postoperative mean decrease of 0.207 ($P = 0.014$). Patients without right heart volume overload, the mean preoperative Tei was 0.48 with no significant postoperative change ($P = 0.82$). **Conclusion:** Pre- and post-operative transesophageal echocardiogram assessment provides an easy and quick way of evaluating LV function intra-operatively using LV Tei index. Preoperative LV Tei index was greater in the RV volume overload defects indicating diminished LV global function. This normalized in the immediate postoperative period, implying an immediate improvement in LV function. In patients without right heart volume load, consist of other cardiac defects, demonstrated no changes in the pre- and post-operative LV Tei. This implies that LV function was similar after the surgery.

Key words: Congenital heart defect; Transesophageal echocardiogram; Tei index

Received: 04-09-14

Accepted: 10-03-15

INTRODUCTION

The Tei index, which measures global ventricular function, can be measured from the transesophageal echocardiogram (TEE) during cardiac surgery. TEE has become the method of choice for assessing of the quality of operative repair and the ventricular function in congenital heart disease. Quantifying ventricular function intra-operatively is not a routine and measurements of Tei index has not been described during cardiac surgery in pediatric patients. Myocardial performance index (also denoted Tei-Doppler index) reflects both left ventricular (LV) systolic and diastolic function. It is the summation of the

isovolumetric contraction time and isovolumetric relaxation time divided by the ejection time (ET).^[1-3] Tei index is relatively independent of heart rate and ventricular geometry.^[1-3] Assessment of cardiac function before and after cardio-pulmonary bypass in children with a cardiac anomaly is important, and Tei can easily be measured and reliably obtained. Our study examines the change in the LV function utilizing Tei index obtained by TEE before and immediately after cardiopulmonary bypass surgery in children with cardiac anomaly. Our study interest was focused on right ventricular (RV) volume overload defects because of the unique contour of the interventricular septum and its effect on the left ventricle.

Access this article online
Website: www.annals.in
DOI: 10.4103/0971-9784.154474
Quick Response Code:


Address for correspondence: Dr. Shanthi Sivanandam, University of Minnesota, 2450 Riverside Ave., MN 55454, USA. E-mail: silv0099@umn.edu

METHODS

We retrospectively analyzed 55 patients who underwent cardiac surgery from 2010 to 2012 for spectrum of congenital heart defects [Table 1]. The Institutional Review Board at the University of Minnesota approved the study. The cardiac surgery included: Atrial septal defect (ASD) closure; seven had moderate to large secundum ASD, quantified by transthoracic echocardiography (TTE) with right heart enlargement and Qp: Qs was above 1.7:1; pulmonary valve replacement for pulmonary regurgitation in eight patients, seven patients previously had Tetralogy of Fallot repair and has wide open pulmonary regurgitation with RV volume measured by cardiac magnetic resonance imaging (MRI) above 160 cc/m² underwent pulmonary valve replacement, one had dysplastic pulmonary valve with wide open pulmonary insufficiency and RV volume by cardiac MRI was 165 cc/m² (volume overload heart defects) were compared to other cardiac defect without volume overload: Complete Tetralogy of Fallot repair, atrioventricular canal repair, Rastelli procedure, aortic root replacement, truncus arteriosus repair, mitral valve repair, tricuspid valve repair, aortic valve repair, arterial switch operation. There was no evidence of any significant right to left shunt in these patients. Patients who underwent pulmonary valve replacement had RV volume above 160 cc/m² or they had exercise intolerance along with RV volume load. Medical records were reviewed for age, gender, and the cardiac diagnosis. Patients with pulmonary hypertension and patients who did not undergo TEE in the operating room were excluded. We were able to obtain Tei index in all the patients enrolled in the study. None of them were excluded following enrollment. Standard pediatric anesthesia protocol was followed. None of the patients had any significant hemodynamic instability during induction or during cardiac surgery. We reviewed the pre- and post-operative Tei index that was obtained

Table 1: Study groups for pediatric patients with congenital heart disease undergoing cardiac surgery

Study groups	N (%)
Volume overload CHD	15 (27.3)
Atrial septal defects, pulmonary regurgitation lesions	
Without volume overload with significant CHD	40 (72.7)
TOF, AVC, Tricuspid valve dysplasia, aortic valve stenosis, cleft mitral valve, TGA, Truncus arteriosus, Aortic root dilatation, TGA, VSD, PS	

TGA: Transposition of great arteries, VSD: Ventricular septal defect, PS: Pulmonary stenosis, TOF: Tetralogy of fallot, AVC: Atrioventricular canal defect, CHD: Congenital heart disease

from a transesophageal Doppler echocardiogram. The studies were performed using standard pediatric TEE probe (above 2.7 kg), Philips iE33 equipment. All patients underwent complete TEE that includes two-dimensional, Doppler examination. Pulse wave Doppler tracings were stored digitally and analyzed offline. Doppler intervals were measured as shown in Figures 1 and 2. The Doppler measurements were obtained 15–20 min prior to cardio-pulmonary bypass and 5–10 min post bypass. Tei index was measured as follow: ET was determined from the five-chamber view using pulsed wave Doppler interrogation of the LV outflow tract with a sample volume positioned just below the leaflets of the aortic valve. The time from the end of the onset of left ventricle inflow was determined from pulsed wave Doppler with the sample volume placed at the tips of the mitral valve leaflets in diastole from the apical view.

A paired *t*-test compared the pre- and the post-operative change in the Tei Index for both groups. Statistical significance was defined as a *P* < 0.05. All analyses were carried out using SAS version 9.3.0 (The SAS Institute, Cary, NC, USA).

RESULTS

A total of 15 patients were identified to have increased volume overload right heart defect (15/55 27.3%) and 40 patients with other cardiac defects as described (40/55 72.7%). The age range was 6 days to 22 years. The weight range from 2.7 kg to 49 kg. Increased volume overload (10 females 67%), other cardiac defects (13 females 33%). The *P* value for the difference in gender between the groups is *P* = 0.0476. Patients with volume overload right heart defects had a preoperative mean LV Tei of 0.6 with a significant decrease to

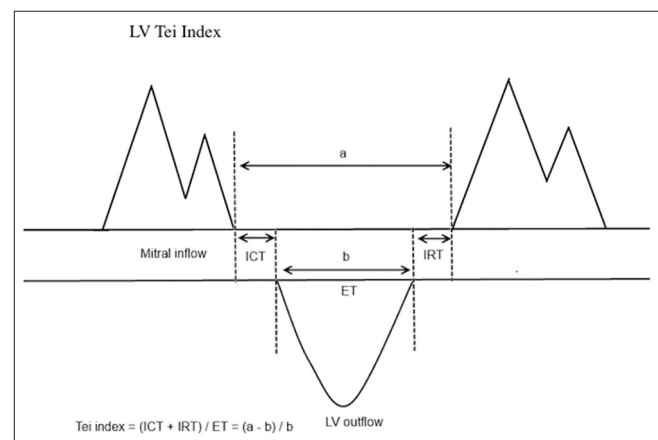


Figure 1: Tei index measured

0.207 (SD) postoperative Tei ($P = 0.0137$). Postoperative Tei values normalized after the increased RV volume has been eliminated. In patients without volume overload, with other cardiac defects preoperative mean LV Tei was 0.48 with no significant change of 0.01 postoperative Tei ($P = 0.82$). Patients without increase in right heart volume had no significant postoperative change in the LV Tei index [Table 2].

DISCUSSION

Currently, there exists a paucity of information relating to the use of the Tei index in pediatric cardiac surgery. The lack of literature on the use of the Tei index in children during cardiac surgery within is intriguing, given its routine use, and was the impetus for our study. In our study, two groups were selected because our interest was focused on RV volume overload defects, the unique contour of the interventricular septum in this population and its effect on the left ventricle. We evaluated if there will be any immediate changes in the interventricular septum after the volume load has been eliminated. We compared the LV Tei changes in two groups because all these patients undergo cardio-pulmonary bypass, myocardial protection, alterations in hemodynamic changes and also alter the physiological state, but have a difference in volume overloaded states.

Transesophageal echocardiogram is routinely used during cardiac surgery in children to assess ventricular function, and allows assessing the immediate results

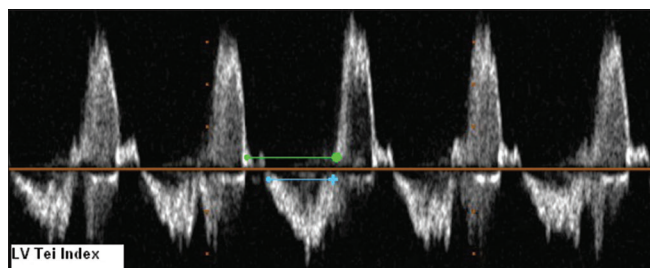


Figure 2: Tei index measured by transesophageal echocardiogram

Table 2: Change in LV function for two groups

	Mean change	95% confidence interval for mean change	P
Volume overloaded cardiac defect	-0.207	(-0.364, -0.049)	0.0137
Other cardiac defects	-0.01	(-0.098, 0.078)	0.8201

A paired *t*-test was used to compare the groups. LV: Left ventricular

of surgical reconstruction or valve replacement. Global ventricular function, however, is not routinely quantified pre- or post-cardiopulmonary bypass. The use of a single index (Tei) to quantify global LV function is easy, reliable and has an important role during the postoperative course. It is a valuable tool for intra- and post-operative management strategies for possible goal-directed therapy most importantly the need for pharmacological agents (inotropes, vasodilators, vasopressors) and mechanical support devices can potentially improve the outcome. This single dimensionless parameter permits serial assessment of ventricular function both before and following immediate cardiac surgery in children.

While there are other indices to measure cardiac performance, the Tei index is ideal because it is relatively independent of heart rate and ventricular geometry. In adults, the LV Tei index was found to correlate with invasive measurement of LV systolic and diastolic function in patients with dilated cardiomyopathy and with ischemic heart disease.^[4] A recent study comparing the transthoracic Tei index versus Doppler derived index. The systolic to diastolic ratio to detect LV dysfunction, a Doppler derived mitral insufficiency time interval ratio of systolic duration to diastolic duration (S/D), found the Tei index to be slightly more accurate and sensitive, with a greater predictive value and likelihood ratio, than the systolic to diastolic ratio in detecting LV dysfunction in a group of children with various congenital heart defect diagnoses.^[5] Another recent study of assessing cardiac function with TTE after cardiac transplant in children, utilized the Tei index to evaluate the acceptance versus rejection of the transplant. It showed that LV Tei was greater at the time of biopsy-proven acute cellular rejection than on the echocardiogram performed in the absence of acute cellular rejection.^[6] A previous study in adults has also documented the prognostic value of the Tei index, in patients with idiopathic-dilated cardiomyopathy. This study identified that the Tei index to reflect both disease severity and suggested an additional prognostic value in these patients.^[7,8]

The systemic left ventricle is a prolate ellipsoid with circular geometry in the transverse equatorial plane. This configuration minimizes wall tension and functionally commits the interventricular septum to the left ventricle. This explains how the left ventricle generates a normal stroke volume against the systemic after load with the least wall tension. With increased RV

volume, the interventricular septal motion is abnormal, it moves anteriorly toward the sternum during systole. Therefore, the LV geometry becomes altered with a characteristic flattening of septal contour, and this influences changes in the LV function.^[9,10] The contour of the interventricular septum normalizes when the volume overload is eliminated. Since LV configuration is abnormal in patients with increased RV volume, Tei index can quantify the abnormal LV function. Our study demonstrates LV Tei index in the increased RV volume in the preoperative was greater indicating diminished LV global function. Postoperative Tei values normalize after the increased RV volume had been eliminated. Tei index for the left ventricle pre- and post-cardiac surgery can be measured reliably in children.

Within the intra-operative period, a recent pilot study measuring the technical performance in cardiac surgery of various congenital heart defects created a technical scoring tool for various procedures. This scored procedures as optimal, adequate, or inadequate, based on echocardiographic parameters, measured both pre- and post-operatively. While this study did not specifically use the Tei index, it provides a model on analyzing cardiac surgery in children with echocardiography.^[11] Tei could be utilized as an adjunctive quantifying tool of the ventricular performance and could guide during the postoperative management if there is LV dysfunction.

CONCLUSIONS

Pre- and post-operative TEE assessment provides an easy and quick way of evaluating global LV function intra-operatively using Tei index. Tei index has been shown in TTE, studies to be a reliable indicator of ventricular performance. The effects of increased RV volume overload on the ventricular septal motion and the differential effect on the LV function remains controversial and has not been well-described in children. Our data demonstrates LV Tei index in patients with increased RV volume the preoperative value was higher indicating diminished LV global function. Postoperative value Tei index was normal. LV function recovered immediately after the placement of a pulmonary valve or closure of an ASD. In patients without volume overload, demonstrated no changes in the pre- and post-operative LV Tei.

REFERENCES

1. Tei C. New non-invasive index for combined systolic and diastolic ventricular function. *J Cardiol* 1995;26:135-6.
2. Lakoumentas JA, Panou FK, Kotseroglou VK, Aggeli KI, Harbis PK. The Tei index of myocardial performance: Applications in cardiology. *Hellenic J Cardiol* 2005;46:52-8.
3. Kerut KE. The Tei index: Methodology and disease state values. *Echocardiogr J Cardiovasc Ultrasound Allied Technol* 2004;21:669-72.
4. Tei C, Nishimura RA, Seward JB, Tajik AJ. Noninvasive Doppler-derived myocardial performance index: Correlation with simultaneous measurements of cardiac catheterization measurements. *J Am Soc Echocardiogr* 1997;10:169-78.
5. Patel DR, Cui W, Gambetta K, Roberson DA. A comparison of Tei index versus systolic to diastolic ratio to detect left ventricular dysfunction in pediatric patients. *J Am Soc Echocardiogr* 2009;22:152-8.
6. Flanagan R, Cain N, Tatum GH, Debrunner MG, Drant S, Feingold B. Left ventricular myocardial performance index change for detection of acute cellular rejection in pediatric heart transplantation. *Pediatr Transplant* 2013;17:782-6.
7. Dujardin KS, Tei C, Yeo TC, Hodge DO, Rossi A, Seward JB. Prognostic value of a Doppler index combining systolic and diastolic performance in idiopathic-dilated cardiomyopathy. *Am J Cardiol* 1998;82:1071-6.
8. Tei C, Ling LH, Hodge DO, Bailey KR, Oh JK, Rodeheffer RJ, *et al.* New index of combined systolic and diastolic myocardial performance: A simple and reproducible measure of cardiac function – A study in normals and dilated cardiomyopathy. *J Cardiol* 1995;26:357-66.
9. McCullagh WH, Covell JW, Ross J Jr. Left ventricular dilatation and diastolic compliance changes during chronic volume overloading. *Circulation* 1972;45:943-51.
10. Kerber RE, Dippel WF, Abboud FM. Abnormal motion of the interventricular septum in right ventricular volume overload. Experimental and clinical echocardiographic studies. *Circulation* 1973;48:86-96.
11. Larrazabal LA, del Nido PJ, Jenkins KJ, Gauvreau K, Lacro R, Colan SD, *et al.* Measurement of technical performance in congenital heart surgery: A pilot study. *Ann Thorac Surg* 2007;83:179-84.

Cite this article as: Sivanandam S, Wey A, St. Louis J. Intraoperative transesophageal echocardiographic assessment of left ventricular Tei index in congenital heart disease. *Ann Card Anaesth* 2015;18:198-201.

Source of Support: Andrew Wey was supported by grant UL1TR000114 of the National Center for Advancing Translational Sciences, **Conflict of Interest:** None declared.