Usefulness Of Tei Index In Patients With Heart Failure
A T.E., U D.I., O J.O.

Citation

Abstract
Background: Tei index is a Doppler derived myocardial performance index. It is a measure of combined systolic and diastolic myocardial performance of both the left and right ventricles. Incidence of heart failure (HF) is increasing globally. Systolic and diastolic dysfunctions frequently co-exist in HF hence a combined measure of left ventricular chamber performance may be more reflective of overall cardiac dysfunction than systolic or diastolic measures alone. Method: Ninety newly presenting patients with HF in New York Heart Association (NYHA) Class II to IV and ninety age and sex matched normal controls were recruited consecutively in the Cardiac Care Unit, Obafemi Awolowo University Teaching Hospitals Complex (OAUTHC), Ile-Ife, Nigeria. Using conventional 2–D and Doppler echo techniques, parameters assessed were; isovolumic relaxation time (IVRT), isovolumic contraction time (IVCT), ejection time (ET) and ejection fraction (EF). Tei index was obtained with the formula IVCT + IVRT/ET. Result: Mean Tei index (TI) of patients was significantly higher than that of controls (0.861 ± 0.501 vs. 0.36 ± 0.07; p = 0.0001). TI ranged 0.33 to 1.938 in patients and 0.29 to 0.43 in controls. There was an inverse relationship between TI and EF. As TI increased, EF decreased (r = −0.322, p = 0.002). There were significant differences between mean TI of patients in each of NYHA class II, III and IV and mean TI of controls (p = <0.0001 for all three comparisons). Comparison of mean Tei indices of patients in NYHA Classes II, III and IV by means of ANOVA showed statistically significant difference between all three groups (p=0.000). Conclusion: Tei index is a simple reproducible myocardial performance index which can reasonably separate normal controls (low and narrow TI) from patients with HF (high and wide TI). It shows significant difference with HF severity and an inverse relationship with EF.

INTRODUCTION
Tei index (TI) also referred to as myocardial performance index is defined as the sum of isovolumic ventricular contraction time (IVCT) and isovolumic ventricular relaxation time (IVRT) divided by ejection time (ET)\(^1\)\(^2\). It is a Doppler derived unit-less index and is a measure of combined systolic and diastolic myocardial performance\(^1\) of the left ventricle (LV) or right ventricle (RV)\(^3\). Heart failure (HF) is a final common pathway for diseases of diverse aetiologies\(^4\). In Africa, at least 3-7% of all hospital admissions are caused by HF\(^5\). The overall prevalence of HF is thought to be increasing in the developed world\(^6\). Little is known with respect to the prevalence or risk of developing HF in the developing world because of a paucity of population–based studies\(^7\). The two important cardiac functions are systolic and diastolic functions of which the leading non-invasive technique for evaluation is echocardiography\(^8\) and its findings are known to influence management decisions and outcomes\(^9\). There are many limitations to the use of classical echocardiographic indices for the estimation of systolic and diastolic left ventricular (LV) function\(^10\). The ejection fraction (EF), an index of systolic function, and LV volumes are subject to large errors when the ellipsoid shape of the heart becomes spherical\(^10\). Age, rhythm and conduction disturbances and changes in loading all affect the Doppler signal of transmural flow which is the most commonly used method\(^10\). The characteristics of the Tei index such as its feasibility, ease of use, less dependence on operator, geometry, heart rate, preload, afterload and excellent separation of clinical groups, as well as strong relation of outcome in patients in HF\(^5\)\(^11\)\(^12\) enhance its (Tei index) appeal for study in this part of the world with limited resources. This study aimed at determining the Tei index in patients with HF and matched normal controls. It also assessed if there was any significant difference in Tei index with severity of HF and if there was any relationship between Tei index and ejection fraction.

METHODOLOGY
Study Location: This study was conducted at the Cardiac Care Unit, Department of Medicine, Obafemi Awolowo University Teaching Hospitals Complex (OAUTHC), Ile-Ife, Nigeria.
University Teaching Hospitals Complex, (OAUTHC), Ile-Ife, Osun State. It serves as a tertiary care centre located in the Southwest geo-political zone of Nigeria.

Study Design: Case control study.

Study Population: Ninety consecutive patients, aged 22-88 years that fulfilled the Framingham criteria for diagnosing HF were recruited for the study. For the control group, ninety apparently healthy volunteers (without HF) matched for age and sex were also recruited consecutively from hospital staff, patients’ relatives and Obafemi Awolowo University staff. Inclusion criteria were adult Nigerians 18 years and above with symptomatic HF and who gave informed consent to participate in the study. Exclusion criteria included patients who refused to participate in the study, ages below 18 years, patients who did not partake or complete profile of investigations for the purpose of this study, patients with poor echo windows or poor quality echocardiogram, patients not in sinus rhythm, patients with bundle branch block, or with high-grade atrioventricular block and patients with severe mitral regurgitation.

Protocol I: Clinical Assessment

Diagnosis of HF was made using Framingham criteria for definitive HF. New York Heart Association (NYHA) classes were determined on admission. Anthropometric measurements included height, weight, waist circumference, body mass index. Peripheral arterial pulses were assessed and blood pressures were measured on admission.

Protocol II: Imaging Procedure

Chest radiograph (postero-anterior view) was done at the radiology department to assess the cardiac silhouettes, aorta and the lung fields.

A conventional resting 12-lead electrocardiography was performed with Cardiofax ECG – 9620 model machines. Lead II was recorded for a long rhythm strip. The recommendation of the American Heart Association (AHA) concerning standardization of leads and specification for instrument was followed.

Protocol III: Echocardiographic examination

Two-dimensional (2-D), motion mode (M-mode) and Doppler studies were performed with transthoracic echocardiography using Siemens Sonoline G60S ultrasound imaging system with P4–2 transducer. Measurements were in accordance with the recommendations of the American Society of Echocardiography with leading edge to leading edge recordings taken.

Calculations were made using the internal analysis software of the echocardiographic device. The 2-D views were used for real time morphological characteristics and also as a reference for the selection of the M–mode beam. The echo views utilized for the study included parasternal long axis view, short axis view, apical 4-chamber, and apical 5-chamber. Pulsed Doppler echocardiographic recordings of the mitral inflow were obtained from the apical 4-chamber view in order to assess LV filling dynamics.

The TI was calculated from the ratio of time intervals expressed by the formula a-b/b or IVCT + IVRT/ET¹º as shown in fig 1 below. Measurements were taken from three consecutive beats and averaged. The parameters for the formula were determined by first locating the sample volume at the tips of the mitral valve leaflets in the apical 4-chamber view which enabled the measurement of ‘a’ (the time interval between the end and the start of transmitral flow). The sample volume was then located in the LV out flow tract, just below the aortic valve (apical 5-chamber view) for the measurement of ‘b’ (LV ejection time). The interval ‘a’ included isovolumic contraction time (IVCT), the ejection time, (ET) and the isovolumic relaxation time.

**Figure 1**

DATA ANALYSIS

Data obtained were analyzed with a statistical computer software package (SPSS version 17.0). Continuous variables were expressed as means ± standard deviation, and categorical variables as percentages. The chi-square test was used to determine the statistical significance of associations between categorical variables while student t-test was used to determine the difference between two means. A p-value of less than or equal to 0.05 was considered significant.
RESULTS

The study population comprised 44 (48.9%) male patients with HF and 40 (44.4%) male control subjects. There were 46 (51.1%) females with HF and 50 (55.6%) female controls. There was no statistically significant difference between patients and controls (p = 0.531). The mean ages of the HF patients and control subjects were 56 ± 18.57 years and 57 ± 18.66 years respectively (p = 0.762). The ages ranged from 22 to 88 years for patients versus 23 to 88 years for control subjects. There was no statistically significant difference between patients and controls (p = 0.072). Seven disease conditions were identified as causes of HF in the patients studied. The commonest cause of HF was systemic hypertension accounting for over 60% of cases followed by dilated cardiomyopathy, rheumatic heart disease, renal failure, congenital heart disease, endomyocardial fibrosis, and ischaemic heart disease in decreasing order (table 1). As shown in table 2, majority of patients (51%) in heart failure recruited for this study presented in NYHA Class IV. The TI in HF patients was higher than that in control subjects and had a wider range (table 3) and there was statistically significant difference between mean Tei indices in patients with HF compared with control subjects. The mean value of EF in patients with HF (49 ± 14%) was lower than in control subjects (57 ± 9%). A comparison of the TI in patients in HF with EF >45% and those with EF ≤45% and controls, showed statistically significant difference between each HF subgroup and mean TI of the controls (see table 4). Also, the mean value of Tei index in patients with heart failure, subgrouped into two, showed that patients with EF >45% had a lower TI mean value than those with EF ≤45%. The difference in TI mean value between these two groups showed statistically significant difference (table 5). Figure 2 shows a statistically significant inverse relationship between TI and EF. As the TI increased, the EF decreased. (r = −0.322, p = 0.002). Table 6 compared the mean Tei indices of patients in all three NYHA classes at presentation, showing statistical significant difference between all three groups by means of analysis of variance (ANOVA). Using Post Hoc test (Turkey method), the group comparisons showing statistical significant differences were between NYHA II and IV (p = 0.0000), III and IV (p = 0.0000), but no statistically significant difference observed between II and III (p = 0.488). Also, when the patients in each NYHA class were compared with controls, the mean Tei indices of the patients were higher than that of controls in all three comparisons and all were statistically significant (table 7). Figs 3 & 4 respectively show Tei index values in a control subject and a patient with heart failure respectively.

TABLE 1: Aetiology of Heart Failure.

<table>
<thead>
<tr>
<th>Aetiology</th>
<th>Number of patients</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systemic hypertension</td>
<td>58</td>
<td>64.4</td>
</tr>
<tr>
<td>Dilated Cardiomyopathy</td>
<td>14</td>
<td>15.7</td>
</tr>
<tr>
<td>Rheumatic Heart Disease</td>
<td>13</td>
<td>14.4</td>
</tr>
<tr>
<td>Congenital Heart Disease</td>
<td>2</td>
<td>2.2</td>
</tr>
<tr>
<td>Endomyocardial Fibrosis</td>
<td>2</td>
<td>2.2</td>
</tr>
<tr>
<td>Ischaemic heart disease</td>
<td>1</td>
<td>1.1</td>
</tr>
</tbody>
</table>

TABLE 2: Percentage Distribution of New York Heart Association in Patients Presenting with Heart Failure.

<table>
<thead>
<tr>
<th>NYHA class</th>
<th>Number of patients</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>II</td>
<td>14</td>
<td>15.6</td>
</tr>
<tr>
<td>III</td>
<td>30</td>
<td>33.3</td>
</tr>
<tr>
<td>IV</td>
<td>46</td>
<td>51.1</td>
</tr>
<tr>
<td>Total</td>
<td>90</td>
<td>100</td>
</tr>
</tbody>
</table>

Figure 2
Figure 3
Figure 4
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**Figure 4**
TABLE 3: Tei Index in Heart Failure Patients and Controls.

<table>
<thead>
<tr>
<th>Tei index</th>
<th>Range</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean value</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart failure</td>
<td>0.861 ± 0.501</td>
<td>0.333 to 1.938</td>
</tr>
<tr>
<td>Control</td>
<td>0.36 ± 0.07</td>
<td>0.29 to 0.43</td>
</tr>
</tbody>
</table>

**Figure 5**
Table 4: A comparison of Tei Index in Subgroups of Patients with Heart Failure versus controls

<table>
<thead>
<tr>
<th>Patients EF</th>
<th>Mean TI of patients</th>
<th>Mean TI of controls</th>
<th>T</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>EF &gt;45%</td>
<td>0.779 ± 0.27</td>
<td>0.36 ± 0.07</td>
<td>10.09</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>EF ≤45%</td>
<td>0.97 ± 0.34</td>
<td>0.36 ± 0.07</td>
<td>10.73</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Number of patients in HF with EF >45% and EF ≤45% were 50 and 40 respectively.

**Figure 6**
Table 5: Tei Index and ejection fraction in Subgroups of Patients with Heart Failure

<table>
<thead>
<tr>
<th>EF &gt;45%</th>
<th>EF ≤45%</th>
<th>t</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean TI of patients</td>
<td>0.779 ± 0.27</td>
<td>0.97 ± 0.34</td>
<td>3.03</td>
</tr>
</tbody>
</table>

**Figure 7**
TABLE 6: Comparison of Mean Tei indices of Patients in NYHA Classes II, III and IV by Means of ANOVA

<table>
<thead>
<tr>
<th>NYHA</th>
<th>Tei index (mean values)</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>0.598 ± 0.122</td>
<td>31.04</td>
<td>0.000</td>
</tr>
<tr>
<td>III</td>
<td>0.688 ± 0.131</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>1.057 ± 0.312</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 8**
TABLE 7: Mean Tei indices of Heart failure patients compared with mean Tei index of controls.

<table>
<thead>
<tr>
<th></th>
<th>mean TI of patients</th>
<th>mean TI of controls</th>
<th>t</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NYHA II</td>
<td>0.598 ± 0.122</td>
<td>0.36 ± 0.07</td>
<td>6.34</td>
<td>&lt;0.000</td>
</tr>
<tr>
<td>NYHA III</td>
<td>0.688 ± 0.131</td>
<td>0.36 ± 0.07</td>
<td>10.94</td>
<td>&lt;0.000</td>
</tr>
<tr>
<td>NYHA IV</td>
<td>1.057 ± 0.312</td>
<td>0.36 ± 0.07</td>
<td>14.09</td>
<td>&lt;0.000</td>
</tr>
</tbody>
</table>

**Figure 9**
Figure 2: Scatter diagram showing correlation between Tei index and ejection fraction

$r = -0.322, p = 0.002$
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**Figure 10**

**FIG 3: TEI INDEX IN A NORMAL SUBJECT**

Pulsed Doppler recordings of mitral inflow (left side) and left ventricular outflow (right side) in a normal subject. The value of the Tei index is 0.32

**Figure 11**

**FIG 4: TEI INDEX IN HEART FAILURE**

Pulsed Doppler recordings of mitral inflow (left side) and left ventricular outflow (right side) in a heart failure subject. The value of the Tei index is 1.807

**DISCUSSION**

In virtually all regions of the world, heart failure is common and on the rise. Heart failure is a major and growing health problem resulting from cardiac damage caused by a variety of disease processes.

Two-dimensional and Doppler echocardiography facilitate the evaluation of different periods of the cardiac cycle, allowing the acquisition of a combined systolic and diastolic index of left ventricular performance (Tei Index) in a simple, reproducible and reliable manner. Study on this index is rather scarce in our environment. Our study revealed the usefulness of Tei index in patients with heart failure in Cardiac Care Unit at Obafemi Awolowo University Teaching Hospitals Complex, Ile – Ife, within the study period. The Tei indices obtained in the patients with heart failure were higher and with wider ranges when compared with age and sex matched normal controls. This higher values of the Tei indices in patients than in healthy individuals were due to prolongation of the isovolumic time intervals and a shortening of ejection time. This is because myocardial contractility and relaxation are energy dependent and significant myocardial dysfunction results in the prolongation of the isovolumic time intervals, and a shortening of the ejection period. Thus, the result of the formula (a – b)/b tends to increase. Similar findings were reported by Bruch et al and Dujardin et al, though the latter study group consisted only of dilated cardiomyopathy as the aetiology of the heart failure compared to our study where systemic hypertension, dilated cardiomyopathy and rheumatic heart disease were all involved in decreasing order, hypertension being the commonest cause (64.4%), a finding which agrees with previous local studies. Other causes of heart failure identified in the study include congenital heart disease (ventricular septal defect), endomyocardial fibrosis, and ischaemic heart disease showing the usefulness of the Tei index in various aetiologies of heart failure. This usefulness of Tei index in various aetiologies of heart failure also agrees with findings of authors such as Haque et al who reported that in symptomatic patients with severe aortic stenosis and compromised systolic function (EF < 45%), the isovolumic contraction time was prolonged and the ejection time shortened, resulting in significantly elevated Tei indices compared to healthy controls and that it was able to discriminate between those patients with severe aortic stenosis who had depressed systolic function and those whose systolic function were preserved. Furthermore, Eidem et al had also evaluated the usefulness of the index in Ebstein’s anomaly as a model of congenital heart disease. In their study, both the right ventricular and left ventricular Tei indices were significantly higher than in age and sex matched controls; the isovolumic time intervals were significantly prolonged and the ejection time significantly shorter in the patients. Nearchou et al had also demonstrated that in patients with acute myocardial infarction, the Tei index was found to be significantly increased compared to healthy controls secondary to prolongation of the isovolumic time intervals and reduction of ejection times. These aforementioned studies corroborate our findings on the usefulness of the Tei index with the
varied aetiologies of heart failure in patients.

In our study, the mean value of the index was significantly different between normal subjects and heart failure patients of varying severity as determined by the NYHA functional classification of heart failure, showing the index can reasonably differentiate heart failure patients and normal subjects. This finding is important as it shows Tei index can be used to identify patients in heart failure presenting with mild symptoms. This finding agrees with findings of the aforementioned Bruch et al study \(^{28}\) which had also compared the index in normal controls with patients in heart failure of mild to moderate severity.

Also in our study, the mean TI was higher with increased HF severity, and there was statistically significant difference between the mean Tei indices of patients in NYHA class II versus class IV, class III versus class IV, though not between class III and III. This finding agrees with several others including Tei et al \(^{1}\) who in their study, conducted in heart failure patients in NYHA Class II to IV with ejection fractions 30 to 50\%, showed statistically significant difference in the mean Tei indices between the functional groups of the patients. In addition, Ohno et al \(^{30}\) had also shown in their studies that patients with advanced NYHA classifications or patients with restrictive left ventricular filling patterns (which reflect higher pulmonary wedge pressure) and advanced congestive heart failure also exhibited increased myocardial performance index (Tei index) values.

Our study also revealed the trend of presentation of patients with heart failure in our environment, of which over 50\% were in NYHA Class IV. In most of these cases, the heart failure is structurally advanced with altered left ventricular geometric pattern, as the ellipsoid shape of the heart tends to become spherical and therefore leads to limitations in the use of most of the traditional parameters for assessing systolic and diastolic functions. This further buttresses the relevance of Tei index.

The comparison of two groups of patients with relatively normal ejection fraction (≥45\%) and low ejection fraction (≤45\%) to the corresponding Tei indices showed that the mean myocardial performance index was higher with decreased ejection fraction. There was an inverse relationship between TI and EF (as the TI increased, the EF decreased). Our finding agrees with that by Mohammed and colleagues \(^{25}\) who had reported in their study that Tei index was significantly higher in patients with left ventricular systolic dysfunction (EF < 45\%) and left ventricular end diastolic pressure > 15mmHg and also agrees with Tei et al \(^{1}\) and Dujardin et al \(^{11}\) regarding the correlation between the Tei index and other echocardiographic parameters of systolic LV function.

Myocardial performance index (Tei index) combining systolic and diastolic time intervals as an expression of global myocardial performance index correlates with cardiac function and seems to be a useful complimentary marker in assessing left ventricular function.

LIMITATIONS OF THE STUDY

The small sample size did not allow adequate stratification for the observation of significance or lack of it.

The effects of loading conditions and arrhythmias on this index remain to be elucidated.

CONCLUSION

The study indicates that Tei index is a useful myocardial performance index having a useful role in determining overall cardiac dysfunction and can be used to separate patients with and without heart failure. The index showed a significant difference with heart failure severity (functional class) and an inverse relationship with ejection fraction.

References

10. Lakoumentas JA, Panou FK, Kotseroglou VK, Aggeli
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Author Information

Ambakederemo T.E., MBBS, FWACP
University of Nigeria Teaching Hospital

Uchenna D.I., MBBS, FWACP, FMCP
University of Nigeria Teaching Hospital

Ogunmola J.O., MBBS, FWACP, FMCP
University of Nigeria Teaching Hospital