Review Article

# Myocardial Performance Index (Tei Index): Evaluating its Application to Myocardial Infarction

Emmanouil N. Karatzis, Anna T. Giannakopoulou, John E. Papadakis, Athanassios V. Karazachos, Nearchos S. Nearchou

*Department of Echocardiography, Hellenic Red Cross Hospital, Athens, Greece*

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*Address:*
Emmanouil N. Karatzis

*1 Isminis St.*
*14578 Ekali*
*Athens, Greece*
*e-mail:*
*manoskaratzis@yahoo.com*

Myocardial infarction (MI) induces impairment of left ventricular (LV) systolic and diastolic dysfunction to various degrees. These functions are energetically and tightly coupled: 1) at the cellular level, since adenosine triphosphate is a substance essential for both active contraction and relaxation;[1] 2) at the myocardial level, because regional wall motion asynchrony influences global LV diastolic function (contraction-relaxation axis);[2] and 3) at the hemodynamic level, because systolic function indirectly affects LV filling pressures.[3] Conventional echocardiographic indices that are routinely applied for the estimation of cardiac function face a number of limitations. The ejection fraction, the most reliable estimator of systolic function, is prone to significant inaccuracies when the elliptical cardiac chamber is transformed to a spherical one.[4] On the other hand, transmitral flow, which is the most frequent method for evaluation of diastolic function, is dependent on age,[5] heart rate,[6] as well as loading conditions.[7]

Taking into account all the above, we could hypothesize that measurement of a more complex parameter, capable of estimating combined systolic and diastolic performance and independent of the limitations mentioned previously, could be more advantageous than the isolated measurement of either systolic or diastolic parameters in the evaluation of the global LV function of MI patients. Quite recently, a method with these properties has been developed: the myocardial performance index, or Tei index, which was first applied in 1995[8,9] in patients with dilated cardiomyopathy[8] and with cardiac amyloidosis.[10]

## Tei index measurement

The index is a Doppler-derived time interval index that combines both systolic and diastolic cardiac performance. The Tei index is easily derived using conventional pulsed Doppler echocardiography, as previously described by Tei and colleagues (Figure 1).[8]

The mean normal value of the Tei index is 0.39 ± 0.05 for the LV,[8] while for the right ventricle (RV) it is 0.28 ± 0.04.[11] In adults, values of the LV index <0.40 and for the RV <0.30 are considered normal. Higher index values correspond to more pathological states with overall cardiac dysfunction.

## Advantages of the Tei index

The index is simple, noninvasive, easy to estimate and reproducible.[8-10] A number of studies have documented that the Tei index is independent of arterial pressure,[8-10,12-14] heart rate,[8-10,13-15] ventricular geometry, atrioventricular valve regurgitation,[8,11,16] af-

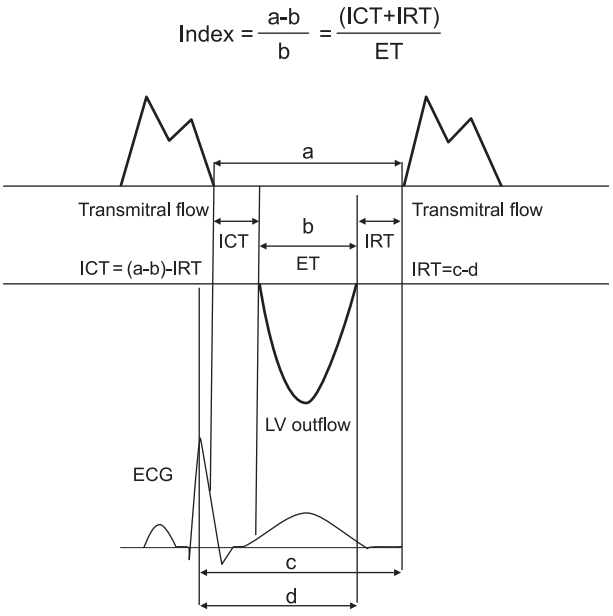


**Figure 1.** Depiction of measurement of Doppler intervals. The index is defined by the equation (a-b)/b, where a represents the interval between cessation and onset of mitral inflow and b represents the ejection time (ET) of the left ventricular outflow. Isovolumic relaxation time (IRT) is measured by subtracting d, the interval from the peak of the R wave on the ECG to the end of ejection time, from the interval c between the R wave and the onset of mitral inflow. Isovolumic contraction time (ICT) is obtained by subtracting IRT from a-b.

terload,[17] and preload in patients who are in a supine position.[18]

## Review of the index in various cardiac disorders

The Tei index appears to have close correlation with the widely accepted systolic and diastolic hemodynamic parameters[19,20] as well as potential for clinical application in the assessment of overall cardiac performance.[10,19-21] The index has been proposed as a useful method for the study of congestive heart failure syndrome,[8,10,22-24] congenital heart diseases,[25-27] in the evaluation of interventional therapies as regards global LV performance,[28,29] in cardiac rejection following transplantation,[30] and more recently in the study of valvular disease[31,32] and in stress echocardiography.[33-34] Furthermore, during its short lifespan from 1995 until today, the Tei index has been shown to have strong prognostic value in severe cardiac diseases, such as dilated cardiomyopathy,[21,22] cardiac amyloidosis,[10] pulmonary hypertension,[35,36] and recently in MI.

## Tei Index and myocardial infarction

### *Behavior and serial changes of the index through time*

In the hyper-acute phase of MI the index of both LV and RV is significantly higher than in control subjects, with a trend of significant reduction during the early and late phase of MI.[13] Improvement of the LV index continues for approximately 1 year after acute MI, but always remains pathologic, with significantly higher values than in normal individuals.[37] On the other hand, the RV index decreases at a faster rate compared to that of the LV[13] and normalizes rapidly, within the third month following acute MI.[13] The above alterations of the myocardial performance index show that biventricular overall function is significantly compromised during the hyper-acute phase of MI, with a trend to improvement during the acute and chronic phases. Improvement is faster for the RV, which has a complete recovery within the first months of MI, than for LV, which recovers significantly over time, but remains pathologic for at least 1 year. The different behavior of the index, confirms the higher resistance of the RV to ischemia,[38,39] mainly because of the lower afterload and lower oxygen demands.

The administration of renin-angiotensin inhibitors seems to play a crucial role in the previously mentioned recovery of the index value and in LV remodeling. These substances significantly reduce the values of the index among patients with MI, as a result of a beneficial effect on overall LV performance.[28,29,40]

Regarding the changes of Tei index value in relation with the location of the MI, the index for the LV of patients who have an anterior MI is significantly higher than that of those with an inferior MI,[12,29,37] a difference which is diminished a year post infarction.[37] On the other hand, the index of the RV is significantly higher in patients with an inferior MI, in comparison with patients with an anterior MI, whereas the index of those with echocardiographic findings of RV MI is significantly higher than that of those without infarction.[13]

### *Tei index as a surrogate of systolic function*

Because of the potent systolic parameters that contribute to the Tei index, such as isovolumic contraction time (ICT) and ejection time (ET), the index detects with reliability current alterations of LV systolic function.[10,19-21] Thus, the index maintains a strong inverse relation with ejection fraction:[20] the higher the value of the index, the lower the ejection fraction and *vice versa*.

It appears that in the early phase of MI the index is more sensitive in the detection of LV dysfunction and of the rate of heart failure development.[41] In the late post-infarct phase, the sensitivity of the index is higher than that of ejection fraction in patients with an adverse outcome.[37]

The superiority of the Tei index is attributed to its ability to reflect the combined systolic and diastolic performance (in contrast with the systolic ejection fraction), an advantage more evident in cases of isolated LV diastolic dysfunction. Furthermore, the index, as a Doppler-parameter, is independent of ventricular geometry, while ejection fraction is less reliable in cases of anatomic anomalies of LV,[4] such as those following MI.

### *Tei index as a surrogate of diastolic function*

LV systolic as well as diastolic dysfunction induces impaired relaxation (prolongation of isovolumic relaxation time, IRT). The fact that both phases of LV function are simultaneously reflected in the diastolic parameter of the index (IRT) renders the index sensitive in the identification of impaired relaxation. Thus, myocardial performance index has a close correlation with diastolic hemodynamic indices of relaxation (-dP/dt and tau)[19,20] and appears superior to conventional diastolic parameters in the detection of impaired relaxation. On the other hand, a debate exists regarding the ability of the index to reflect the severity of LV diastolic dysfunction in more advanced stages of diastolic dysfunction (pseudonormalization or restrictive physiology), especially in cases with preserved systolic function.[42] A number of research groups have shown that the Tei index reflects the severity of LV diastolic dysfunction in the hyper-acute[41] and chronic[13,37] phases of MI, while it pseudonormalizes during the acute phase of MI in patients with restrictive physiology,[42] as well as in patients with isolated diastolic heart failure.[24]

### *Interpretation of pseudonormalization*

Restrictive physiology shortens IRT because of the increase in left atrial pressures. This parameter (IRT), as a numerator of the index quotient (index=ICT+IRT/ET), is alone capable of reducing its value significantly. As a result, the final formation of the index value in patients with a restrictive filling pattern depends exclusively on the variations of the systolic quotient of the index (ICT/ET), and particularly on the current condition of LV systolic function. When severe systolic dysfunction exists, a significant increment (worsening) of the quotient ICT/ET (due to prolongation of ICT and shortening of ET) is induced, which not only counterbalances the short IRT, but also increases the index value. On the other hand, the combination of restrictive physiology with satisfactory LV systolic function reduces (improves) the quotient ICT/ET (due to shortening of ICT and prolongation of ET), and fails to counterbalance the shortened IRT and the significant reduction (pseudonormalization) of the index value.

In the hyper-acute phase of MI, acute ischemia and initiation of necrosis induce a predominance of severe LV systolic dysfunction, which also appears in the chronic phase, since dilatation and scar formation are consequences of left ventricular remodeling.[43,44] On the other hand, in the early phase of MI the already developed compensatory hypertrophy of the healthy myocardium,[43,44] which in this phase is beneficial and counterbalances lost myocardium, contributes to a significant improvement of LV systolic dysfunction. Thus, during the acute phase of MI, as well as in cases of isolated diastolic heart failure, the short IRT is not counterbalanced because of the satisfactory systolic function, resulting in a reduction of the index value. Taking into account that the pattern of restrictive syndrome accompanies advanced cardiac disease of various causes,[45,46] it becomes clear that this limitation reduces the value of the index as a method to estimate severe diastolic dysfunction with preserved LV systolic function.

### *Prognostic value of the index*

A number of studies have recently shown that the index has prognostic value in both the early and the late phase of MI.

#### *Early phase*

The Tei index has been documented as the most potent independent prognostic factor in the early phase of MI, in relation to the development of heart failure.[41] Furthermore, the index is significantly sensitive in distinguishing patients with a poor in-hospital outcome, and its value is an independent predictor of cardiac events during hospitalization[47,48] (cardiac death, cardiogenic shock, abdominal aneurysm, arrhythmias). In addition, the Tei index seems to be improved in patients treated with early reperfusion,[49,50] when the artery with the culprit lesion is revascularized,[51] as well as when metabolic control with insulin administration in type 2 diabetics is optimized.[52]

*Late phase*

In this phase of MI the index has shown prognostic value regarding death,[13,37,53-57] heart failure,[37,56,57] and new cardiac events.[50] The Tei index distinguishes patients with MI and cardiac death or heart failure from those without these adverse end-points,[37] even among patients treated with angioplasty.[56] The index of the RV, even independently of signs of MI, predicts future cardiac death or recurrent hospitalization due to worsening of heart failure.[13] Biventricular estimation of the index improves the prognostic accuracy of the LV Tei index significantly.[13] It seems that left ventricular disorders are transferred directly to the RV, and overall estimation of cardiac function appears more accurate in the identification of any problem than is the left ventricular assessment alone, because of the close relation of the two ventricles, as well as the sharing of interventricular septum and pericardium.

Most of the above studies documented that a value of the index $\geq 0.60$[14,37,47,53,55] (patients at increased risk) has the maximum sensitivity, specificity, and diagnostic accuracy in the identification of patients with adverse end points, superior to ejection fraction $\leq 40\%$ while being comparable with E wave deceleration time $\leq 140$ ms.

## Limitations of the Tei index

Like other methods, the Tei index has a number of limitations, as follows: 1) the previously mentioned "pseudonormalization" of the index, which should be considered as its main limitation but concerns a subgroup of patients with known poor outcome;[58,59] 2) the partial preload dependence,[18,20,60,61] although this limitation does not significantly affect patients with MI in a supine position[18] and is less dependent than other diastolic Doppler-parameters;[18] 3) the infeasibility or imprecision of the determination of the Tei index in patients with atrial fibrillation, frequent supraventricular and ventricular extrasystoles, atrioventricular and intraventricular conduction disturbances, ventricular pacing, significant atrial tachycardia with integration of the two transmitral flow waves. Finally, data from large scale epidemiological studies[62] regarding the application of echocardiographic parameters like the Tei index are lacking.

## Conclusions

The Tei index is a reliable Doppler parameter for the evaluation and prognostic assessment of patients with MI, and has marked advantages over established echocardiographic indices. Nevertheless, large-scale and long-term studies of this method are required before its exact clinical value can be clarified and final conclusions may justify the introduction of the Tei index into routine clinical practice.

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