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Role of Tissue Doppler Tei Index in Evaluating Myocardial Performance after Coronary Revascularization

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Abstract

Background: Tei index expresses the overall systolic and diastolic myocardial function in a single number. The use of tissue Doppler instead of conventional pulsed wave Doppler enables us to measure Tei index in a single scan. It also has many advantages for the assessment of myocardial function with coronary revascularization in IHD patients.

Methods: We included 47 chronic ischemic heart disease patients with LV dysfunction (EF<50%) who were subjected to coronary revascularization with either CABG or PCI. They were divided into 2 groups according to the improvement of EF after revascularization. Group I: Included 35 patients who had an increase ≥ 5% in LV EF at follow up. Group II: Included 12 patients who had an increase <5% increase in LV EF at follow up. Echocardiography including tissue Doppler Tei index (tdTei) was done twice; just before and at least 4 months after coronary revascularization.

Results: Following revascularization; improvement of ejection fraction correlated well with tdTei improvement (r=0.67, p<0.001) and was associated with improvement of wall motion score index (p<0.001) and diastolic function parameters including E`/A` (p<0.05) and E/E` (p<0.001). Using ROC curve, we found that the tdTei index at cut-off point 72.9; can predict patients who are expected to have ejection fraction improvement from coronary revascularization with high sensitivity (83.3%) and specifity (80%). It also correlated well to TIMI score (p<0.05).

Conclusion: Tissue Doppler Tei index is a promising technique allowing accurate quantitative description of the effect of ischemia on myocardium including both diastolic and systolic dysfunction in a single number. Baseline tdTei index can predict patients who are expected to have improvement of myocardial function (both diastolic and systolic) after coronary revascularization.

Keywords: Tei index; Myocardial performance index; Tissue Doppler; Ischemic heart disease

Introduction

Tei index is a simple, reproducible and inexpensive method for the assessment of overall cardiac function. Its value was validated in many cardiac diseases as heart failure, pulmonary hypertension, pulmonary embolism and cardiotoxicity from chemotherapy. It is also used as an early predictor of rejection of heart transplantation and in cardiac amyloidosis [1]. Tei index assesses both systolic and diastolic function by assessing the time intervals of three of the cardiac cycle phases; the isovolumetric contraction time (IVCT), ejection time (ET), and isovolumetric relaxation time (IVRT) using the formula Tei index=(IVCT+IVRT)/ET [2]. Unfortunately, there are some other limitations using the conventional pulsed-wave Doppler Tei index (pwTei index) that can affect its accuracy. One of these limitations is that the time intervals used for calculating pwTei index should be measured in two separate cardiac cycles (one for systolic time intervals from pulsed wave Doppler analysis over the LV outflow and the other for the diastolic time intervals over the mitral inflow) and not on a single echocardiographic scan. Consequently, the accuracy of the results may be compromised by heart rate fluctuations and beat-to-beat variation, and the results are probably less reliable in the presence of even physiologic heart rate changes during echocardiographic examination [3]. Tekten et al. have suggested measuring the Tei index using tissue Doppler (tdTei index) in substitution for the classical pulsed-wave Doppler approach (pwTei index). It enables us to simultaneously measure all cardiac cycle intervals from a single heart beat and that it correlates well with conventional Tei index in normal and diseased heart [3]. Also, it was found that there is a high correlation between the pwTei index and peak dp/dt, suggesting a relationship between the pwTei index and the preload state of the heart. So, mild changes in ventricular preload can significantly affect pwTei values [4]. Tissue-Doppler imaging, conversely, is relatively preload-independent in evaluating diastolic function i.e. less dependent on the volume loading condition [5]. Besides, we can evaluate the subclinical long axis cardiac abnormality with tissue Doppler which cannot be evaluated by conventional pulsed wave Doppler [6]. It is also more sensitive than pwTei index in assessing LV function in the ischemic myocardium with RWMA (regional wall motion abnormality) [3]. Many studies have shown that revascularization of dyssynergic myocardium in ischemic heart disease patients results in improvement of LV function (both systolic and diastolic functions) and this can be assessed using Tei index [6]. So, tissue-Doppler Tei index is suggested to be a good indicator for detecting reversal of left ventricular systolic and diastolic dysfunction following coronary revascularization.

The aim of work is to investigate the value of tissue Doppler Tei index as an indicator of the improvement of myocardial function after elective coronary revascularization therapy in chronic ischemic heart disease patients with left ventricular dysfunction who were subjected to full revascularization with either coronary artery bypass graft (CABG) or percutaneous coronary intervention (PCI).

Patients and Methods

Our study included 47 chronic ischemic heart disease patients with LV dysfunction (EF<50%) who were subjected to coronary revascularization with either CABG or PCI. All of them had echocardiographic assessment of the heart twice including tdTei index. The first time was before revascularization, and the second time was at least 4 months after coronary revascularization. These 47 patients were divided into 2 groups according to echocardiographic response to the revascularization. Group I included 35 patients who had ≥ 5% increase in LV EF at follow up (Good improvement group). Group II included 12 patients who had <5% increase in LV EF at follow up (Little improvement group). The study was performed prospectively in the period from July 2014 to October 2016 in the critical care and cardiology departments, Fayoum University.

All patients were subjected to all of the following

Full history taking, complete clinical examination, routine labs especially renal function tests before coronary angiography and standard 12-lead resting ECG before and after coronary angiography and before the follow up echocardiographic assessment.

Baseline echocardiography using Philips HD-11XE machine equipped with TDI technology with 2.5 MHz transducer, to asses LV end diastolic volume and diameter, (LVEDV,LVEDD), LV end systolic volume and diameter (LVESV, LVESD), ejection fraction using the biplane Simpson's method from outlining the endocardial border in the apical 4- and 2-chamber views, E/A ratio, EDT (E wave deceleration time), tissue Doppler E`/A`, E/E` and tdTei-index. The examination will be performed at base line under resting conditions. Echocardiographic follow-up evaluation, performed at least 4 months later after coronary revascularization, was done and compared with the baseline echocardiographic findings including repeated assessment of tdTei index.

To calculate the tdTei index, we use the tissue Doppler in the apical four-chamber view, the tissue Doppler cursor is placed at the septal side of the mitral annulus in such a way that the mitral annulus at the septum moves along the sample volume line. Two negative diastolic velocities were recorded when the mitral annulus moves away from the apex (one during the early phase of diastole (E') and another in the late phase of diastole (A') with atrial contraction). The Tei index was calculated as (IVCT+IVRT)/ET [2]. All interval measurements by tissue Doppler can be performed within one cardiac cycle [4] as shown (Figure 1). We measured tdTei index in three successive cardiac cycles and then were averaged.

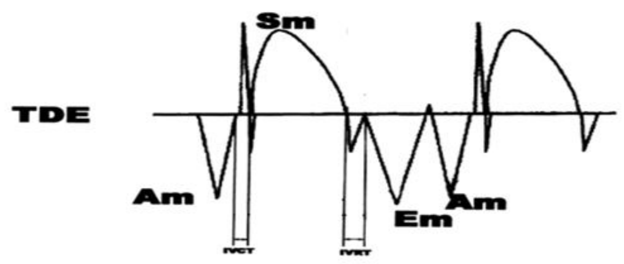

Figure 1: Tissue Doppler examination for calculating tdTei index; TDE: Tissue Doppler Examination; Am: diastolic late filling phase (A`) at mitral annulus; Em: diastolic early filling phase (E`) at mitral annulus; Sm: systolic ejection phase (S`) at mitral annulus; IVCT: Isovolumetric Contraction Time; IVRT: Isovolumetric Relaxation Time.

Regional wall motion was assessed using the 16-segment model of LV. Wall motion score index (WMSI) was calculated as the sum of the score of each segment, divided by the number of segments scored; using a 4-point scale: 1-normal or hyperkinesia, 2-hypokinesia, 3-akinesia and 4-dyskinesia.

After diagnostic coronary angiography using Judkins technique with Siemens Hicor system, patients either had stent inserted in the diseased vessels or referred to undergo CABG. TIMI flow score (Thrombolysis In Myocardial Infarction) was used for the determination of the patency of the coronary arteries.

Exclusion criteria

Excluded from this study patients with any of the following: Significant left main coronary artery stenosis, severe valvular lesions, serious atrial or ventricular arrhythmias, atrial fibrillation or atrial flutter, non ischaemic cardiomyopathy (hypertrophic, restrictive or dilated cardiomyopathies), intraventricular or atrioventricular conduction delays, pacemaker insertion, previous CABG or PCI, suspected or known aortic dissection, acute pulmonary embolism, acute myocarditis, endocarditis or ventricular aneurysm. We also excluded patients who had acute coronary syndrome during the period of the follow up.

Statistical methods

SPSS (Statistical Package for Social Sciences) version 25 was used for data analysis. We used mean and standard deviation (SD) for quantitative data. One way ANOVA test and independent t-test were used to test the difference about mean values of measured parameters among study groups. Pearson and Spearman correlations were used for calculating correlations between variables. We defined the cutoff point that differentiates between both study groups with the maximum possible sensitivity and specificity of tdTei index by using ROC curve. For interpretation of results of tests of significance, significance was adopted at $P \leq 0.05$.

Results

In our study, we found no significant differences between both study groups regarding age, sex, the affected vessels in coronary angiography, or the risk factors for coronary artery disease.

After coronary revascularization, patients in group I had statistically significant lower value of tdTei index compared to its baseline value (60.73 ± 4.45 before *vs.* 51.30 ± 4.30 after revascularization, p<0.001), while patients in group II had no statistically significant different results compared to baseline value of the tdTei index (82.44 ± 5.30 before and 80.56 ± 6.27 after revascularization, p>0.05).

We also found lower values of diastolic echocardiographic parameters E`/A` (p<0.05) and E/E` (p<0.001) in group I before and after revascularization. In group II, there were no statistically significant differences regarding E`/A` and E/E` after revascularization (p>0.05 for both).

Regarding cardiac cycle phases of the tdTei index after revascularization, we found a decrease in both tdIVCT and tdIVRT and an increase tdET, P<0.05 for each) in group I. Also, parameters assessing LV volumes decreased (LVESV and LVEDV; P<0.05 for each); while in group II, there were no statistically significant differences in all cardiac cycle phases and LV volumes.

Also the decrease of the tdTei index in group I was associated with less myocardial regional wall motion assessed by WMSI (1.77 ± 0.29 before, 1.26 ± 0.31 after revascularization with p<0.05).However, in group II there were no statistically significant differences (p>0.05) (Table 1).

Variable	Group II			Group I			P value (of both groups before revasc.)	P value (of both groups after revasc.)
	Before	After	P value	Before	After	P value		
	Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD			
tdIVCT msec	50.87 ± 6.21	49.84 ± 7.35	N.S.	49.36 ± 7.88	45.00 ± 5.34	<0.05	N.S.	<0.05
tdET msec	273.87 ± 26.16	280.41 ± 29.97	N.S.	283.48 ± 31.52	302.13 ± 34.96	<0.05	N.S.	<0.00
tdIVRT msec	121.47 ± 10.38	118.03 ± 12.55	N.S.	116.42 ± 13.29	102.98 ± 12.09	<0.05	N.S.	<0.05*
td-Tei index	82.44 ± 5.30	80.56 ±6.27	N.S.	60.73 ± 4.45	51.30 ± 4.30	<0.001	0.001*	<0.001
EF %	43.48 ± 4.85	43.91 ± 5.10	N.S.	46.83 ± 6.54	52.56 ± 5.30	<0.001	N.S.	<0.001
E`/A`	1.52 ± 0.62	1.38 ± 0.56	N.S.	1.61 ± 0.53	1.09 ± 0.66	<0.05	N.S.	<0.00
EDT msec	188.73 ± 34.92	192.98 ± 25.50	N.S.	184.03 ± 31.29	175.53 ± 32.18	N.S.	N.S.	N.S.
E/A	1.54 ± 0.72	1.59 ± 0.61	N.S.	1.61 ± 0.56	1.55 ± 0.49	N.S.	N.S.	N.S.
E/E`	13.10 ± 8.94	12.59 ± 7.24	N.S.	12.36 ± 6.44	7.40 ± 4.79	<0.001	0.05	<0.001
LVEDV ml	166.93 ± 14.66	165.43 ± 13.45	N.S.	164.72 ± 13.02	137.96 ± 14.34	<0.05	N.S.	<0.05
LVESV ml	90.20 ± 15.18	89.91 ± 15.11	N.S.	89.78 ± 15.32	68.23 ± 11.51	<0.05	N.S.	<0.05
WMSI	1.83 ± 0.34	1.69± 0.44	N.S.	1.77 ± 0.29	1.26 ± 0.31	<0.05	N.S.	<0.001

Table 1: Comparison of echocardiographic parameters in both study groups; Td: Tissue Doppler; revasc: Revascularization; IVCT: Isovolumetric Contraction Time; ET: Ejection Time; IVRT: Isovolumetric Relaxation Time; EF: Ejection Fraction; EDT: E wave Deceleration Time; LVEDV: Left Ventricular End Diastolic Volume; LVESV: Left Ventricular End Systolic volume; WMSI: Wall Motion Score Index; N.S.: Non-significant

In our study, we found a strong correlation between the delta EF % (the relative change in EF value before and after revascularization) and delta tdTei index % (the relative change in tdTei index value before and after revascularization). The higher the increase in the EF after revascularization, the more the decrease in tdTei index (r=0.67, p<0.001) (Figure 2).

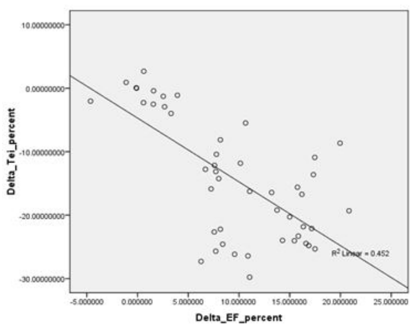

Figure 2: Correlation between Delta EF % and Delta Tei index % in our study population; R=-0.67.

By means of ROC curve as shown in Figure 3, we found that the tdTei index value before revascularization i.e. baseline tdTei index, can differentiate between patients in group I and group II at cut-off point of Tei index= 72.9; with high sensitivity (83.3%) and specifity (80%) as shown (Table 2).

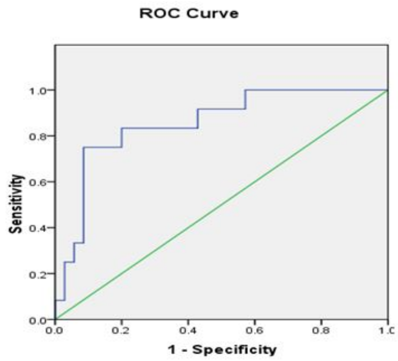

Figure 3: ROC curve of tdTei-index before coronary revascularization to differentiate little improvement group from good improvement group (group I from group II).

Sensitivity	Specificity	Overall accuracy
83.30%	80%	85.70%
P-value <0.001; at cut of point of tdTei index=72.9		

Table 2: Sensitivity and specificity of baseline tdTei index as a predictor of good improvement after coronary revascularization and to differentiate between group I and group II at cut of point of tdTei index=72.9.

Intended for further validation of this result, we compared the echocardiographic parameters before and after revascularization in patients with tdTei index >72.9 and also in those with tdTei index <72.9, and found that it also predicts the change in other echocardiographic parameters such as E`/A`, E/E`, LVESV, LVEDV and WMSI (Tables 3 and 4).

Variable	Before	After	P-value
(group II)	Mean ± SD		
tdIVCT msec	50.8 ± 7.46	48.27 ± 8.12	N.S.
tdET msec	275.78 ± 30.2	282.50 ± 32.48	N.S.
tdIVRT msec	122.11 ± 13.17	120.18 ± 13.74	N.S.
td-Tei index	82.74 ± 9.71	80.14 ± 7.48	N.S.
EF	43.14 ± 3.02	44.21 ± 4.19	N.S.
E`/A`	1.56 ± 0.41	1.46 ± 0.32	N.S
EDT msec	192.49 ± 28.72	198.22 ± 32.26	N.S.
E/A	1.48 ± 0.63	1.61 ± 0.61	N.S.
E/E`	12.81 ± 9.74	10.56 ± 8.29	N.S.
LVEDV ml	172.26 ± 19.79	166.64 ± 17.22	N.S.
LVESV ml	93.02 ± 17.66	91.27 ± 13.41	N.S.
WMSI	1.91 ± 0.41	1.81± 0.38	N.S.

Table 3: Differences in echocardiographic parameters before and after revascularization in patients with high pre-revascularization Tei index (>72.9)

Variable	Before	After	P-value
(Group I)	Mean ± SD		
tdIVCT msec	50.05 ± 6.54	46.17 ± 4.45	<0.05
tdET msec	279.51 ± 29.18	307.74 ± 29.45	<0.001
tdIVRT msec	119.25 ± 9.27	113.92 ± 11.20	N.S.
td-Tei index	62.48 ± 10.18	49.24 ± 12.78	<0.001
EF	45.86 ± 4.32	52.17 ± 6.21	<0.001
E`/A`	1.58 ± 0.42	1.11 ± 0.046	<0.05
EDT msec	183.01 ± 28.79	174.23 ± 27.94	N.S.
E/A	1.57 ± 0.43	1.23± 0.11	<0.05
E/E`	12.96 ±3.31	7.45 ± 3.54	<0.001
LVEDV ml	167.16 ± 17.27	133 ± 13.78	<0.05
LVESV ml	86.8 ± 11.30	70.04 ± 9.47	<0.05
WMSI	1.82 ± 0.18	1.24 ± 0.21	<0.001

Table 4: Differences in echocardiographic parameters before and after revascularization in patients with low pre-revascularization Tei index (<72.9)

We also found a significant correlation between baseline tdTei index and TIMI flow before revascularization in patients with single vessel disease. The higher the baseline tdTei index, the lower the TIMI flow seen in pre-revascularization angiography. (Rho=-0.61, p<0.05 for LAD; Rho=-0.45, p<0.05 for RCA; Rho=-0.51, p<0.05 for LCx; Rho=-0.53, p<0.05 in allover coronary vessels) (Figure 4 and Table 5).

TIMI grade	Tei index with (LAD)	Tei index with (RCA)	Tei index with (LCx)	Average Tei
TIMI 0	76.23 ± 5.17	70.14 ± 4.51	68.15 ± 5.14	71.20 ± 5.12
TIMI I	70.25 ± 6.29	69.75 ± 5.24	66.24 ± 7.12	68.33 ± 6.11
TIMI II	61.14 ± 7.24	61.21 ± 7.25	61.24 ± 8.49	61.13 ± 7.41
TIMI III	49.91 ± 6.21	54.51 ± 8.19	59.12 ± 4.20	55.21 ± 6.18
P value	<0.05	<0.05	<0.05	<0.05
Rho	-0.61	-0.45	-0.51	-0.53

Table 5: Correlation of tdTei index to TIMI flow in each of the affected vessels

In our study, the patients who had PCI were 32 patients (68%) (25 patients of group I and 7 patients of group II). Patients who had CABG were 15 patients (32%) (10 patients in group I and 5 patients in group II). There were no statistically significant differences in EF or tdTei-index improvement at follow-up between patients who were treated with PCI and those who underwent CABG in both groups.

Discussion

The following were observed in our study:

Effect of revascularization on tdTei index: We compared the value of the tdTei index in each group before and after coronary revascularization, and found that patients in group I (Good improvement group) had statistically significant better (lower) tdTei index after coronary revascularization compared to its baseline value. However, patients in group II (Little improvement group) had no statistically significant different tdTei index value compared to its baseline value. This shows that tdTei index is a good indicator of the improvement of myocardial function after coronary revascularization therapy. This high value of Tei index with myocardial ischemia agrees with Halyna et al. who in 2013 investigated 135 patients with acute myocardial infarction and ST segment elevation. High values of Tei index were noticed at the beginning of the disease pointing to deterioration of myocardial functions of the left ventricle with ongoing ischemia [7].

Relation between tdTei index and diastolic parameters: We found that tdTei index is a good indicator of the improvement of myocardial diastolic function after coronary revascularization therapy with statistically significant better values of diastolic echocardiographic parameters E`/A` and E/E` in group I; while in group II there were no statistically significant differences of E`/A` and E/E` before and after revascularization. There were no statistically significant differences regarding EDT and E/A ratio in both groups after coronary revascularization. This agrees with Gertie May et al. that in 2009 investigated the prognostic implications of pulsed wave Tei index among patients with acute coronary syndrome, and found that EDT and E/A ratio were not predictors of any cardiac event or between cases and control [8]. This insignificant difference regarding EDT before and after coronary revascularization can be due to the pseudonormalization of EDT with increasing severity of LV diastolic dysfunction making it difficult to differentiate normal from pseudonormal pattern [9]. The similar U-shaped relation with increasing grades of LV diastolic dysfunction is found with E/A ratio [10].

Relation between tdTei index and cardiac time intervals and left ventricular volumes: the parameters of improvement of the myocardial function in group I included improvement of cardiac cycle phases of the tdTei index after revascularization (tdIVCT, tdET, tdIVRT; $P<0.05$ for each). Also parameters assessing LV volumes were improved (LVESV and LVEDV; $P<0.05$ for each).However, there were no statistically significant differences in group II after revascularization regarding these parameters. These agree with Erberto et al. who found improvement in all these mentioned values after coronary revascularization as IVCT, ET, LVEDV and LVESV [11]. However, they had a disagreement with our study as IVRT in their study had no significant improvement after revascularization (102 ± 27 to 105 ± 19 in the responder group; 99 ± 27 to 99 ± 36 in the non-responder group, $p>0.05$), while in our study there is significant improvement of the IVRT before and after revascularization in group I (116.42 ± 13.29 to 102.98 ± 12.09, $p<0.05$, respectively).This can be attributed to the different population of study, as we had wide range of EF as the mean baseline EF of our study population is EF 40.2 ± 9.6; while in Erberto et al. study was 32 ± 6 which are expected to have severe degree of diastolic dysfunction [11]. As mentioned in the ASE/EACVI guidelines in 2016 for the evaluation of left ventricular diastolic function by echocardiography [10], the IVRT value increases gradually with increasing the degree of the diastolic dysfunction, but returns to decrease in the severe degrees of diastolic dysfunction with increasing left atrial pressure which was the case with most of their cardiomyopathic patients with low EF (32 ± 6), which are expected to have severe degree of diastolic dysfunction [11]. This can be also attributed to the different modalities used to assess the IVRT in both studies (tissue Doppler *vs.* conventional pulsed wave Doppler), as tissue Doppler is less dependent on the volume loading condition [5] which is found clearly in the cardiomyopathic patients in their study.

Relation between tdTei index and wall motion score index (WMSI): We found that the improvement of the tdTei index in group I after revascularization was associated with better WMSI. In group II, they showed non-significant improvement in the WMSI after revascularization. This shows that the improvement of the tdTei index after revascularization is well related to the improvement in myocardial segmental wall motion and myocardial function. This agrees with Erberto et al., who found improvement in WMSI after coronary revascularization [11].

In our study, we found a strong correlation between the delta EF % and delta tdTei index % with coronary revascularization. The more the improvement in the EF after revascularization, the more the improvement in tdTei index ($r=0.67$, $p<0.001$).This agrees with Lacorte et al., who found that Tei index maintains a strong inverse relation with ejection fraction; the higher the value of the index, the lower the ejection fraction and vice versa [12]. Also, as we found in our study, Halyna et al. found inverse correlation between pwTei index and left ventricular ejection fraction in patients with acute myocardial infarction [7]. This strengthens our finding that tdTei index is a good indicator of myocardial function improvement after revascularization.

Baseline tdTei index as a predictor of myocardial improvement after coronary revascularization: In the line of research in our study, using ROC curve, we found that the tdTei index value before revascularization i.e. baseline tdTei index can predict patients who are expected to have ejection fraction improvement from coronary revascularization at cut-off point of Tei index=72.9; with high sensitivity (83.3%) and specifity (80%). For further validation of this cut-off point, we have compared patients with tdTei index >72.9 and those with <72.9, and found that it not only predicts recovery of ejection fraction, but also predicts improvement in other echocardiographic parameters such as diastolic parameters (E`/A`, E/E`), LV volumes (LVESV, LVEDV). It can also predict those who will have better improvement of WMSI (Tables 3 and 4). Up to our knowledge, this is the first research that specifies such a cut-off point that can predict myocardial function improvement before doing coronary revascularization.

We also found that the higher the baseline tdTei index, the worse the TIMI flow seen in pre-revascularization coronary angiography; as seen in patients with single vessel disease .The baseline tdTei-index was higher in patients with less TIMI flow, increasing gradually from TIMI III to TIMI 0 ($p<0.05$), and vice versa (Figure 4). Our results are in agreement with Yuasa et al. who studied 85 patients with first acute anteroseptal myocardial infarction. They measured pwTei index just after admission, and the TIMI grade was evaluated. The Tei index was significantly better in patients who had TIMI score of 3 compared to those with a TIMI of less than 3 [13]. This shows the value of tdTei index in clarifying the relation between the severity of the anatomical lesion of the coronary vessel (with TIMI flow) and the functional state of the myocardium (tdTei index).

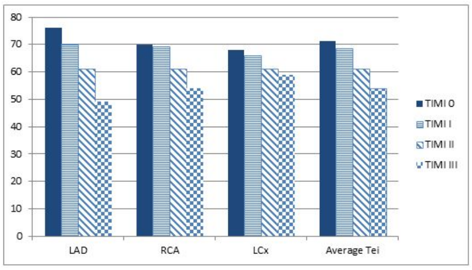

Figure 4: Relation between tdTei index and TIMI flow in each of the affected vessels.

Conclusion

Tissue Doppler Tei index (tdTei) is a promising technique allowing good quantitative description of the effect of ischemia on myocardium including both diastolic and systolic dysfunction in a single number in a single cardiac cycle.

Baseline tdTei index can predict patients who are expected to have improvement of myocardial function (both diastolic and systolic) after coronary revascularization with either PCI or CABG.

Baseline tdTei index correlates well with the severity of the coronary vessels lesion and TIMI flow.

Limitations

The limited number of patients could limit the strength of the findings obtained from the study.

We need more follow up period to evaluate if there are significant differences in the results between CABG and PCI and also the echocardiographic parameters in each group.

We excluded patients with significant left main coronary artery stenosis, severe valvular lesions, serious atrial or ventricular arrhythmias, atrial fibrillation or atrial flutter, non-ischemic cardiomyopathy. So, our results may not be applicable to them.

Angiographic follow-up was not performed routinely. So, graft occlusion or stent thrombosis may have had occurred in some patients preventing adequate recovery of function during follow-up study. However, patients who experienced new symptoms of angina or had hospital readmission because of acute coronary syndromes during the follow-up period before the second echocardiographic evaluation were excluded from our study.

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