Original Article

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Relationship between Myocardial Performance Index (Tei Index) and angiographic severity of coronary artery disease in patients with Acute ST Elevation Myocardial Infarction

Sutap Yadav[1], Ratna Mani Gajurel[2], Chandra Mani Poudel[2], Rajaram Khanal[2], Nischal Shah[3], Roshan Ghimire[4], Lisha Yadav[5]

[1] Department of Cardiology, Karnali Province Hospital, Birendranagar-4, Surkhet, Nepal.
[2] Department of Cardiology, Manmohan Cardiothoracic and Vascular Transplant Centre, Tribhuvan University, Institute of Medicine, Kathmandu
[3] Department of Cardiology, Madhesh Provincial Hospital, Janakpur
[4] Department of Cardiology, Lumbini Provincial Hospital, Butwal
[5] Department of Pediatrics, Kanti Children's Hospital, Maharajgunj, Kathmandu

Corresponding Author:
Sutap Yadav,
Department of Cardiology,
Karnali Province Hospital,
Birendranagar-4, Surkhet, Nepal.
Contact: 9860274607
Email address: sutapyadav@gmail.com
ORCHID ID No: 0000-0003-0526-9415

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Abstract

Background: Tei index is a Doppler-derived measure of combined systolic and diastolic myocardial function and a better predictor of global LV function and outcome in patients with acute STEMI. The objective of this study was to determine the relationship between the myocardial performance index of LV (Tei index) and angiographic severity of coronary artery disease as assessed by SYNTAX score in patients with acute STEMI.

Methods: This was a prospective, observational single, centered study conducted from March 2022 to November 2022 at Manmohan Cardiothoracic Vascular and Transplant Centre, Institute of Medicine. (MCVTC, IOM). One hundred and sixty patients with acute STEMI were enrolled. LV Tei index was calculated with the help of 2D and Tissue Doppler imaging, and the lesion severity was categorized with the help of the SYNTAX score after the patients underwent coronary angiography.

Results: The mean age was 61.23±12.33 years, with a male preponderance. 107 (67%) were male with male to female ratio of 2:1. Tei index was significantly higher among the hypertensive (0.74±0.17) and diabetic (0.78±0.18) patients. 64 (40%), 51(31.9%), and 45(28.1%) had Single vessel disease (SVD), Double vessel disease (DVD), and Triple vessel disease (TVD), respectively, with the Mean Tei index values of 0.57 ± 0.10, 0.76 ± 0.11, and 0.88±0.11 ($p<0.05$). The Tei index increased when patients were divided into low, mid, and high SYNTAX score groups as 0.58±0.11, 0.61±0.73, 0.88±0.13 respectively, p-value < 0.05). Moreover, the study showed a positive correlation between the Tei index and SYNTAX score with increasing severity of coronary artery stenosis. ($r=0.654$, p-value<0.001). Proximal LAD, LCx, and RCA lesions had a greater Tei index than the distal lesions.

Conclusion: As assessed with the SYNTAX score, more proximally located LAD, LCx, and RCA lesions had higher values of the Tei index.

Keywords: Angiographic severity of coronary artery disease, Double vessel disease, location of infarct territory STEMI, Myocardial performance index or Tei Index, Single vessel disease, SYNTAX score, Triple vessel disease

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Introduction

Acute myocardial infarction (AMI) remains a leading cause of morbidity and mortality worldwide that induces variable degrees of impairment in left ventricular (LV) systolic as well as diastolic function. In Nepal, CVDs accounted for 12.8 % of all DALYs and 26.9 % of the total deaths in 2017. With total deaths of 16.4 % and total DALY of 7.5%, ischemic heart disease was the most common CVD.[1] The prevalence of coronary artery disease was reported to be 5% in a study conducted in six hospitals in Kathmandu in 2003 and 5.6% in another population-based study in eastern Nepal in 2009.[2,3]

The SYNTAX score (SS) is a lesion-based angiographic scoring system originally devised to grade the complexity of coronary artery disease to aid in revascularization decisions and predict mortality and morbidity in patients with CAD. In acute MI, there is a decline in LVEF and, elongation of the pre-ejection phase, and shortening of the ejection phase.[4] The Tei index, first introduced in 1995 by Chuwa Tei, is a simple tool to obtain measurements from Doppler echocardiography that assesses the ratio of systolic and diastolic time intervals.[5] It reflects combined systolic and diastolic function and can be defined as the sum of the isovolumic contraction time and isovolumic relaxation time, divided by the ejection time, with a reported normal mean ± standard deviation (SD) value for the left ventricle of 0.39 ± 0.05[4] while for the right ventricle (RV) it is 0.28 ± 0.04.[6] The higher values denote overall cardiac dysfunction.

Methods

The study was a single-centered, observational, prospective study conducted over 12 months, starting from March 2022 to November 2022, in Manmohan Cardiothoracic Vascular and Transplant Center, Maharajgunj, Kathmandu, Nepal. Ethical approval for conducting the study was taken from the Institutional Review Committee (IRC) of the Institute of Medicine (IOM). Informed written consent after proper counseling regarding the nature and purpose of the study was taken. All the STEMI patients who met the inclusion criteria were enrolled.

Sample size (n) = 160

Inclusion criteria

1. Those who provide written consent for the study
2. Patients with acute STEMI were included.
   - ☐ The diagnosis of myocardial infarction was based on the presence of Detection of rise and/or fall of cTn with at least one value above the 99th percentile upper reference limit (URL) and at least 1 of the following:[7]
   - ☐ Typical precordial pain
   - ☐ ECG changes suggestive of MI (ST-segment elevation of >0.1 mv in limb leads or > 0.2 mv in precordial leads)
   - ☐ Development of pathological Q waves;
   - ☐ Imaging evidence of new loss of viable myocardium or new regional wall motion abnormality in a pattern consistent with an ischemic etiology

Exclusion criteria

1. Significant valvular heart disease
2. Cardiomyopathies
3. Unstable angina, NSTEMI
4. Significant tachyarrhythmia or bradyarrhythmia, AV blocks, and atrial fibrillation
5. Unwilling to give written consent

Procedure:

The variables recorded were classified under socio-demographic factors, in addition to other study variables like age, gender, conventional risk factors (smoking, family history of coronary artery disease, history of diabetes, hypertension, and dyslipidemia), type of MI (anterior, extensive anterior, anteroseptal, inferior, lateral, posterior, inferior wall with right ventricular extension), time delay in presentation. All the patients were subjected to 12 lead electrocardiography to detect signs of ischemia and location of MI and to rule out other STEMI equivalents.

Transthoracic Echocardiography (TTE) with standard Doppler echocardiograms and pulse TDI were conducted utilizing a Canon Aplio i900 model and Philips Affinity 50G. 2D-guided, M-mode LV analyses and Doppler recording of the LV trans mitral diastolic inflow velocity were done. Determination of the presence of regional wall motion abnormality was done as per 17 wall segments. LVEF was evaluated by eyeball estimation or by Simpson's method (LVEDV-LVESV/LVEDV x 100%).

Pulse wave Doppler and Tissue Doppler imaging:

In the apical 4 C view, the Doppler sample volume was placed in the middle of the LV inflow tract 1 cm below the plane of the mitral annulus between the mitral leaflet tips 1 cm below the plane of the mitral annulus between the mitral leaflet tips. The peak velocities of the early (E), late (A) filling velocities, E/A, and the E wave deceleration time (DT) were obtained from the mitral inflow velocity curve. To measure the IVRT, the sweep speed was increased to 100mm/sec. Isovolumic relaxation time (IVRT) was measured from the time the aortic valve closure to the time the mitral valve opening.

Isovolumic contraction time (IVCT) is measured from the closing of the mitral valve to the opening of the aortic valve. Ejection Times were measured from the opening of the aortic valve to its closure on the LV outflow velocity profile.

Finally, MPI or the Tei index was calculated as: a (IVCT + IVRT + ET) −b (ET)/b (ET).

MPI calculation from Tissue Doppler Imaging:

Sample volume was placed at medial mitral annulus in apical 4-chamber view.

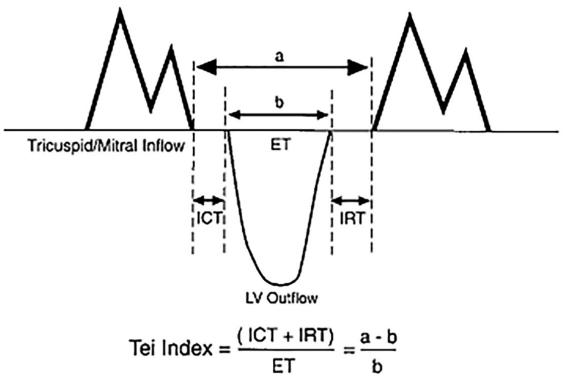

Figure 3. 1: Calculation of MPI.[8] (IVCT = Isovolumic contraction time; IVRT = Isovolumic relaxation time, ET = Ejection Time)

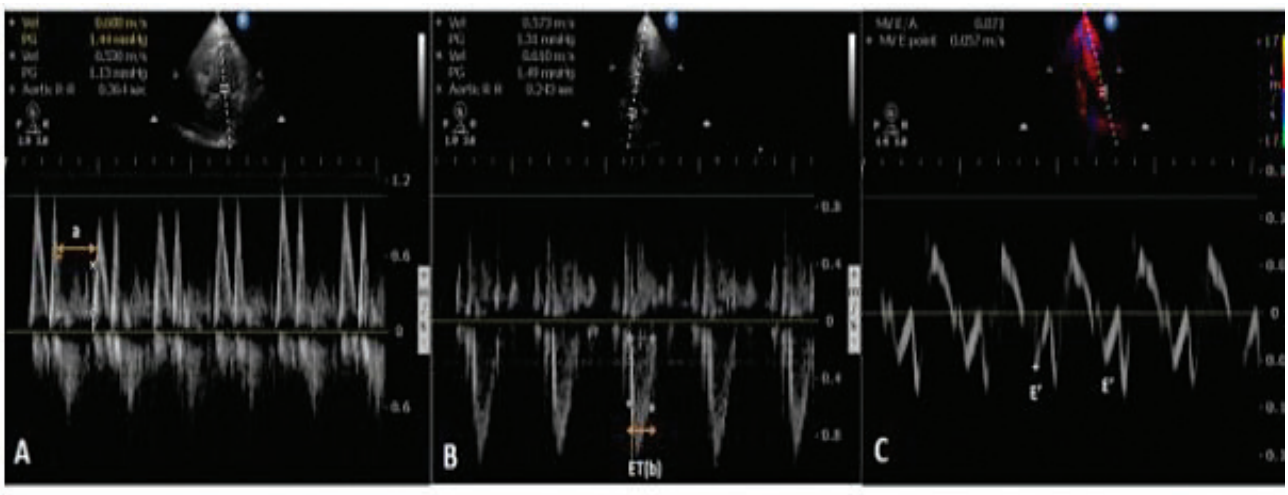

Fig: Measurement of MPI - (A and B); calculated (a-b)/b. (C) tissue Doppler-derived e'

Angiography and assessment of the severity of coronary artery stenosis:

The patients underwent coronary angiography via a radial or femoral route with the Judkins technique using the Siemens Angioscop X-ray Siemens Artis zee machine or Philips allura xper FD10 angiography machine performed by interventional cardiologist supported by scrub nurse and radiographer. Relevant angiographic views were taken, and origin, dominance, anomaly, presence of stenosis and its site/extent/severity, and presence of collaterals were ascertained. An estimated diameter stenosis severity of ≥70% for non–left main disease and ≥50% for left main disease was used to define significant stenosis.[9] An angiographically intermediate coronary stenosis is defined as a diameter stenosis severity of 40% to 69% according to the 2021 ACC/AHA/SCAI coronary revascularization guidelines.[9] Angiographic multivessel CAD was defined as stenosis ≥50% in at least 2 of the 3 major epicardial coronary arteries (angiographic 2- or 3-vessel disease) requiring stenting. The lesion categorization was done according to visual angiographic stenosis severity into 50% to 70%, 71% to 90%, and 91% to 100% diameter stenosis.[10]

Minor CAD: <50 % stenosis in the coronary artery.

Left main disease: the presence of ≥50% stenosis in the left main coronary artery.

Single-vessel disease (SVD), double-vessel disease (DVD), and triple-vessel disease (TVD) were defined as the presence of ≥50% stenosis in one, two, and all three major epicardial coronary arteries or their major branches, respectively.

Determination of SYNTAX score:[11,12]

SYNTAX scores were calculated from baseline angiograms to all coronary lesions with diameters narrower than 50% of vessels and larger than 1.5 mm.

The score was calculated for all patients using dedicated software (available at http://www.syntaxscore.com/calc/start.htm). Finally, the score was divided as:

Low (≤16), intermediate (16-22), and high (>23).

Statistical Analysis

Data was compiled, edited, and entered in Microsoft Excel (Ver. 2013) by the treating physicians involved. For statistical analysis, SPSS 21 (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.) was used. Descriptive analysis was done to identify the distribution of socio-demographic characteristics of patients, and the association was measured using a parametric and non-parametric test (depending upon the distribution of data). A p-value <0.05 for the two-tailed test was considered statistically significant.

Results

A total of 160 STEMI patients were enrolled in the study. 107 (67%) were male, and 53 (33%) were female, with male to female ratio of 2:1. The mean age was 61.23±12.33 years (in males: 65.15+/-11.6 years and in females: 59.40+/-12.2 years).

Table 1. Baseline characteristics of the study population (n=160)

Baseline characteristics		Frequency (No. %)	Tei Inde (Mean±SD)	p-value
Age	20-35	3(1.8%)	0.53±0.07	0.04
	36-50	30(18.7%)	0.67±0.12	
	51-65	69(43.1%)	0.73±0.17	
	66-80	49(30.6%)	0.73±0.18	
	81-95	9(5.6%)	0.81±0.16	
Gender	Male	107(66.8%)	0.7131	0.147
	Female	53(33.1%)	0.7458	
Smoking		106(66.3%)	0.72±0.16	0.62
Hypertension		91(56.9%)	0.74±0.17	0.037
Diabetes		52(32.5%)	0.79±0.18	0.000
Dyslipidemia		61(38.1%)	0.71±0.15	0.57
Family history of premature CAD		21(13.1%)	0.77±0.22	0.23
Hypothyroidism		26(16.3%)	0.70±0.15	0.49

** statistically significant- p-value (<0.05)*

In our study, elderly patients had a significantly higher Tei index, a statistically significant association. However, there was no relation between Gender and the Tei index.

Tei index was found to be statistically significant in hypertensives and diabetics with Tei index of 0.74±0.17 (p<0.05) and 0.79±0.18 (p<0.05), respectively.

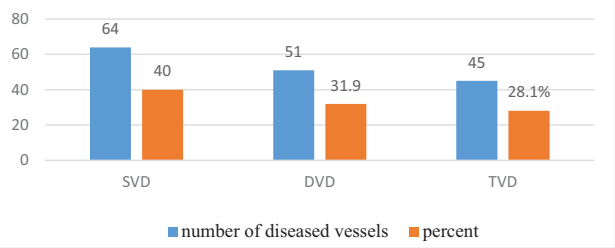

Figure 1.2: Bar Chart showing the distribution of patients according to the severity of coronary artery stenosis based on the no. of diseased vessels

Among the 160 patients studied, most of them 64 (40%) had single vessel disease, followed by 51(31.9%) and 45 (28.1%) with double vessel disease and triple vessel disease, and Mean Tei index values 0.57±0.10, 0.76±0.11 and 0.88 ± 0.11 respectively. As the number of hemodynamically significant stenoses increased, the value of MPI also increased significantly (p-value <0.05).

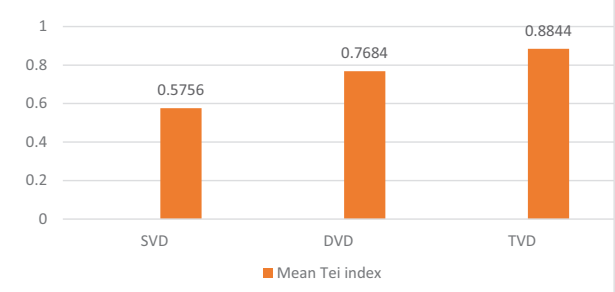

Figure 1.3: Bar Diagram showing the mean Tei index and angiographic severity of coronary artery stenosis according to vessels involved

Table 2. Tei index and location of the lesion severity in LAD, RCA, and LCx

LAD lesion (n= 111)	N (%)	Mean Tei ±SD	P-value
Ostioproximal LAD	27(24.3)	0.90±.14	0.000*
Proximal LAD	36(32.4)	0.74±0.14	
Mid LAD	36(32.4)	0.70±0.15	
Distal LAD	12(10.8)	0.66±0.13	
Severity of LAD lesion			0.001*
40-69% stenosis	38(34.2%)	0.73±0.13	
70-90% stenosis	55(49.5%)	0.74±0.16	
>90% stenosis	18(16.2%)	0.91±0.16	
RCA lesion (Total: 100)			0.01*
Proximal RCA	42(42.0)	0.82±0.16	
Distal RCA	19(19)	0.66±15	
Mid RCA	39(39)	0.71±15	
LCx lesion (Total: 87)			0.08
Ostioproximal	10(11.5)	0.86±0.10	
Proximal	50(57.5)	0.84±0.14	
Distal	27(31)	0.71±0.11	

**statistically significant- p-value (<0.05)*

In our study, we found that the Tei index values of the more proximal lesions were greater than those of the distal lesions for LAD, LCx, and RCA, as tabulated in Table 2.

Table 3. SYNTAX score with Tei index and mortality (n=160)

SYNTAX score (SS)	No. (%)	Mean Tei Index	p-value (SS with Mean Tei)	mortality	p-value (SS with mortality)
<=15-low	54(33.8)	0.58±0.11	0.00*	1(1.88%)	
16-22 Intermediate	61(38.1)	0.73±0.11		3(4.83%)	0.02*
>=23-High	45(28.1)	0.88±0.13		7 15.6%)	

**statistically significant –p-value (<0.05)*

The mean SYNTAX score in our study was 18.9±5.11. Most of the patients fall in the intermediate group, followed by low and high SYNTAX groups, respectively. It was evident that the mean Tei index increased considerably from low to high scores when patients were divided into groups with low, mid, and high SYNTAX scores (low 0.58±0.11, intermediate 0.73±0.11, high 0.88±0.13 (p-value < 0.05) which was statistically significant.

Table 4. SYNTAX score with Tei index (n=160)

		SYNTAX	Tei Index
SYNTAX score with Tei index	Pearson Correlation	1	0.654*
	Sig. (2-tailed)		0.000
	N	160	160

**Correlation is significant at the 0.01 level (2-tailed)*

Our study indicates a positive correlation between the Tei Index and the SYNTAX score, r=0.654 (p-value<0.05). In our study, mortality occurred in 1(1.88%), 3(4.83%), and 7(15.6%) of the patients in the low, intermediate, and high SYNTAX groups, which was statistically significant (p-value – 0.02 <0.05). The Tei index was significantly higher in patients who died than those who survived (0.83 ± 0.12 and 0.71 ± 0.17; p-value-0.02).

Table 5. LV systolic function (LVEF) and Tei index (n=160)

LVEF	No.(%)	Tei Index ±SD	p-value
>=50%	16(8.1)	0.58±0.16	0.00*
41-49%	81(49.5)	0.70±0.15	
30-40%	46(29.9)	0.75±0.14	
less than 30%	17(12.5)	0.85±0.19	

** statistically significant- p-value (<0.05)*

As the severity of systolic dysfunction increases, the Tei index value is expected to increase, reflecting the decline in left ventricular function. This study shows a significant association between LVEF and Tei index (p<0.05)

Discussion

Among 160 STEMI patients studied, the mean age of the patient was 61.23±12.33 years, with male preponderance. There was no statistically significant difference while comparing the value of Tei with Gender and risk factors (smoking, hyperlipidemia, hypothyroidism, and history of premature coronary artery disease, p-value > 0.05), however, increasing age groups had significantly higher Tei index as it is evident from the study by Ascione et al. in 2003 that elderly patients are more prone to coronary artery disease and in-hospital cardiac complications.[13] The presence of potential confounders that are not adjusted for, like older age, hypertension, and diabetes, that are likely to affect the Tei index values are acknowledged.

The increase in IVRT (impaired relaxation) explains both the LV diastolic and systolic dysfunction seen in diabetes.[14,15] When there is severe systolic dysfunction, there is a considerable increase in the ICT/ET quotient, which not only balances the short IVRT but also raises the index value. The results were similar to the study done by Goroshi et al., implying that the Tei index positively correlated with diastolic dysfunction in patients with diabetes.[16] Concentric hypertrophy has been attributed to an increase in cardiovascular events linked to systolic and diastolic dysfunction, as has been described by Adamu et al.[17] In our study, the Tei index was found to be significantly higher in hypertensive subjects-0.74±0.17 than in non-hypertensive, with 0.69±0.16, a finding well supported by a study by AA Akintunde.[18]

The study demonstrated a significant increase in the Tei index with an increasing number of stenosis severity in patients undergoing CAG. The Tei index values were 0.57±0.10, 0.76±0.11, and 0.88±0.11 for SVD, DVD, and TVD, respectively (P value < 0.001). These findings are consistent with previous studies conducted by Akanda et al. and Tewari et al., who also observed similar results.[19,20]

We found that the Tei index of the more proximal lesions was greater than that of the distal lesions. The ostio-proximal lesion, proximal lesion mid LAD, and distal LAD lesion had Tei indices: 0.90±0.14, 0.74±0.14, 0.70±0.15, 0.66±0.13 (p-<0.05) respectively. The result was statistically significant, a finding in line with a study conducted by Kuwahara et al., which concluded that the Tei index tended to be smaller for distal coronary lesions than the proximal ones.[25] Though, the exact reasoning behind the higher values in proximal coronary artery lesions compared to distal lesions is not established in the literature. However, it has been suggested that the proximal lesions involve larger coronary territories and may lead to more severe myocardial ischemia, which in turn results in greater impairment of LV function. Also, we found that the MPI value was significantly higher in hemodynamically severe and very severe stenosis than in intermediate stenosis.

In our study, the Tei index of patients with an anterior wall STEMI was significantly higher (0.76±0.17) than that of patients with an inferior wall STEMI (0.66±0.15), attributed to a greater amount of myocardial damage even with small infarction and greater occurrence of concomitant LV myocardial dysfunction.[8,21,22] In yet another study by Uzunhasan et al., it has been observed that patients with anterior infarction had a higher Tei index>0.60 (63.4%) than patients with inferior infarctions (29.7%), a finding consistent with the results of our study.[23] In contrast, according to a study conducted by Kennedy et al., inferior/posterior myocardial infarctions are generally believed to result in a relatively smaller loss of viable myocardium.[24]

Our study revealed that the Tei index values of the more proximal RCA lesions were higher than those of the distal lesions. Proximal, mid, and distal lesions had Tei indices of 0.82±0.15, 0.71±0.15 and 0.66±0.16(p-<0.05). 10(6.3%) had IWSTEMI with RV involvement with Tei index 0.77+/-0.17, which was significantly higher than the other IWMI groups. Our findings were in accordance with the study done by Ghosh et al., which showed that a higher Tei index value statistically predicted the lesion being in the proximal segment of RCA as a culprit vessel, but increasing RV diastolic dimension indicated a distal RCA lesion.[26] Among patients with IWSTEMI with RV and posterior extension, since a significant area is affected by the infarct, increased risk of complications, such as left ventricular dysfunction and death, have been observed in studies by EL Sebaie et al., Matetzky et al., and Oraii et al.[26–28] Similarly, our study revealed that the Tei values of the more proximal LCx lesions were higher than those of the distal lesions. Ostioproximal, proximal, and distal lesion had Tei indices 0.86±0.10, 0.84±0.14, 0.77±0.11. The result was per study done by Ghosh et al. and Baykan et al., which showed a higher Tei index with proximal LCx lesion.[26, 29]

SYNTAX score is the most recent quantitative and qualitative method to define coronary vasculature, guide revascularization decisions, and predict mortality and morbidity in patients with CAD. This semi-quantitative score was particularly developed by an expert consensus from the various pre-existing classifications to prospectively characterize angiographies of participants enrolled in the SYNTAX trial.[19] It takes into account the number, location, complexity, and functional significance of angiographically obstructive lesions.[20] In the current study, it was evident that the mean Tei increased considerably from low to high scores when patients were divided into groups with low, mid, and high SYNTAX scores as per the complexity of lesion - (low 0.58±0.11, mid 0.73±0.11, high 0.88±0.13; p-value < 0.05) as depicted in studies by Sahin et al. and Ammar et al.[21,22] The results of the present study indicate a positive correlation between MPI and the SYNTAX score (r=0.654, p-value <0.05).

The studies by Lacorte et al. and Karatzis et al. showed that the Tei index retains a strong inverse relationship with ejection fraction and has a substantial negative association between LVEF and Tei index using conventional Doppler.[14, 23] Our study, too, showed a significant association between the Tei index and EF. According to Yuasa et al., Tei index≥ 0.59 demonstrated 79% sensitivity and 73% specificity with an overall accuracy of 76%, while EF less than 45% demonstrated 66% sensitivity and 76% specificity with an overall accuracy of 71% for the prediction of complications in an acute MI, which is also consistent with our findings.[24] According to Poulsen et al., a cut-off point of EF less than 50% had 50% sensitivity and 33% specificity, while a cut-off point of Tei index > 0.45 had 100% sensitivity and 41% specificity.[25] Systolic measures like IVCT and ET enable it to reliably identify the changes in LV systolic function. The negative relation with the ejection fraction is comparable to the studies conducted by Moller et al., Zabalgoitia et al., and Poirier et al.[26–28]

Limitations

Our study is a single-center observational study with a small sample size. The index may be altered by changes in preload, and further studies are needed to clarify this issue. Certain comorbidities, age, hypertension, and diabetes mellitus already present might have influenced the Tei index value. However, the separate relationship between comorbidities and syntax score was not ascertained. The assessment of angiographic findings of coronary artery stenosis

was limited to visual interpretation, with inter- and intra-observer variability. The findings and conclusions drawn are limited to the small group of the population and, therefore, cannot be generalized.

Conclusion:

The Tei index is a reliable and valuable Doppler parameter for the evaluation and prognostic assessment of patients with MI, the measurement of which can be effective in assessing the severity of CAD patients. Since it is unaffected by the LV geometry, it is therefore probable that the index represents the systolic and diastolic function more accurately, as literature has convincingly illustrated. Despite all these advantages, to determine the precise therapeutic utility of this approach and to draw conclusions that would support integrating the Tei index into standard clinical practice, extensive and prolonged research on this strategy is pivotal.

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