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The prognostic value of tissue Doppler imaging in assessment of left ventricular function in patients with non-ST segment elevation myocardial infarction (NSTEMI) after successful revascularization

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Abstract
Background: The left ventricular ejection fraction (LVEF) is well recognized as a reliable indicator of cardiovascular prognosis in individuals with ischemic heart disease (IHD). This work aimed to assess the left ventricular (LV) performance following percutaneous coronary intervention (PCI) among individuals with non-ST segment elevation myocardial infarction (NSTEMI) following successful revascularization by pulsed wave (PW) - tissue Doppler Imaging (TDI) in comparison with two-dimensional (2 D) echocardiography.
Methods: This current work had been conducted on 40 individuals with NSTEMI, underwent conventional M-mode and 2 D echo-Doppler and TDI examinations. All patients were subjected to conventional echocardiography, TDI, coronary angiography and PCI.
Results: Troponin and creatine kinase MB (CKMB) were significantly greater following 1h contrasted to 0 h ($p<0.001$). A positive correlation existed among (LV end-systolic volume, LV end-diastolic volume (LVEDV) and LV stroke volume) and (female sex, DM, HTN, dyslipidemia, troponin and CKMB). LVEF, early/late ventricular filling velocities ratio peak early diastolic velocity (E′)/ Peak late diastolic velocity (A′) and peak systolic velocity can significantly diagnosis heart failure with preserved ejection fraction (HFpEF) individuals respectively at cut-off ≤48%, >1.27, >1.05 and ≤6.4 with 70.0%, 75.0%, 95.0% and 95.0% sensitivity, 75.0%, 60.0%, 85.0% and 90.0% specificity, 73.7%, 65.2% and 86.4%.
Conclusion: The left ventricular function after PCI showed enhancement following successful revascularization among individuals with NSTEMI. PW TDI can be used as valid imaging tool in comparison with 2 D Echocardiography.

Keywords: Prognosis, tissue Doppler, left ventricular function, non-ST segment elevation myocardial infarction, revascularization

Introduction

Acute coronary syndrome (ACS) can be categorized into subcategories including STEMI, non-STEMI (NSTEMI), and unstable angina [1]. NSTEMI and unstable angina exhibit numerous similarities, with the key distinguishing factor being the existence of positive cardiac biomarkers in NSTEMI [2-4].

The registry's data consistently showed that the occurrence of NSTEMI has risen and is more common than STEMI [5].

Two-dimensional (2 D) echocardiography is considered the optimal method for evaluating the overall and localized function of the ventricles. Nevertheless, the traditional evaluation of wall motion, which relies on visually interpreting the movement of the inner layer of the heart and the thickening of the myocardium, has certain drawbacks. It is a qualitative approach that is subjective and relies on the evaluator's expertise [6].

The LVEF is widely recognized as a reliable indicator of cardiovascular prognosis in individuals with ischemic heart disease (IHD) [7].

The precise time of PCI in those with NSTEMI who are stable in terms of their cardiovascular function is still a topic of discussion and disagreement. Prior randomized trials have shown that there is no significant disparity in the amount of tissue death or major negative outcomes between individuals who receive treatment during the initial two hours compared to those who receive treatment between 24 and 48 hours later [8].

TDI is an enhanced version of conventional Doppler-echocardiography that allows for direct assessment of tissue velocities by modifying the image acquisition procedure. The original utilization of TDI in assessing cardiac mechanical activities involved estimating the maximum systolic and diastolic tissue velocities of the specific segment. The outcomes have shown considerable promise thus far [9].

This work aimed to evaluate the LV function following PCI among individuals with NSTEMI after successful revascularization by pulsed wave (PW)-TDI in comparison with 2 D echocardiography.

Patients and Methods

This work had been performed on a sample of 40 participants diagnosed with NSTEMI, who underwent conventional M-mode and 2-D echo-Doppler and TDI examinations. PW-TDI was employed to evaluate the velocity profiles of the basal and mid sections of the septal, lateral, inferior, anterior, posterior, and anteroseptal left ventricular walls. The work had been performed following permission from the Ethics Committee Tanta University Hospitals, Tanta, Egypt. All subjects provided a written well-informed consent.

The criteria for exclusion included individuals who had ST segment elevation greater than 0.1 mV (0.2 mV in precordial leads V1-V3) in at least two adjacent leads on electrocardiogram (ECG), previous myocardial infarction (MI), atrial fibrillation, significant valvular cardiac disease, acute or recent history of chemotherapy, any systemic diseases, fever, and pregnancies.

Each participant had been exposed to taking of history, clinical examinations, laboratory tests [full blood picture (CBC), random blood sugar and if >200 mg/dl ask for fasting and post prandial blood sugar, total lipid profile (total cholesterol, LDL, HDL, triglyceride), renal function test (estimated glomerular filtration rate (eGFR), Blood Urea Nitrogen (BUN), and creatinine and cardiac enzymes (Troponin, creatine kinase MB (CKMB)] and radiological investigations.

Echocardiographic examinations were acquired using a Vivid E9 scanner.

Conventional Echocardiography

2-D echocardiography to assess the following: **[**LV functions, segmental wall motion abnormalities and valvular dysfunction]. The evaluation of LV functioning using M-mode or 2 D echocardiography may be conducted by positioning the calipers at a right angle to the long axis of the ventricle in the parasternal short- and long-axis views. The alteration in the cavity dimensions of LV throughout systole is capable of being utilized to compute EF and fractional shortening of LV. A significant drawback of this approach arises in individuals with localized LV dysfunction, as evaluating ventricular systolic performance in only two opposing basal segments is unlikely to accurately represent the entire LV performance. Geometric assumptions employed in the Quinones or Teichholz techniques to compute LV EF from linear ventricular dimensions might lead to inaccuracies. Furthermore, the positioning of the heart often leads to challenges in achieving a perpendicular alignment of the M-mode ultrasound beam with the long axis of the left ventricle.

Tissue Doppler Echocardiography

Assessment of the velocity profiles of the basal and mid sections of the septal, anterior, lateral, posterior, inferior, and anteroseptal walls of the left ventricle. The measured indicators include: late diastolic myocardial peak velocity (A´´), early diastolic myocardial peak velocity (E´), isovolumic relaxation period, peak systolic velocity (S´) and isovolumic contraction time (IVCT), E´/A´. The echocardiographic pictures were acquired utilizing a scanner (Ving med System 7; Vivid 9 Pro; Horton, Norway) equipped with a 2.5-3.5 MHz probe. Participant echocardiographic measures were obtained when they were positioned in the left lateral decubitus posture. The data were calculated as the mean of values acquired from 3 to 5 beats. An expert operator, who was unaware of the subject's clinical situation, conducted the echocardiographic examinations. The measurements of left atrial diameter (LA), LV end systolic diameter (LVESD), LV end diastolic diameter (LVEDD), end diastolic interventricular septum diameter (IVSD), and end diastolic posterior wall diameter (PWD) were acquired using M-mode echocardiographic tracing with the assistance of 2-D imaging. The LV EF was determined using Simpson's method, which involves calculating the difference between diastolic volume and systolic volume, and then dividing it by the diastolic volume. The transmittal diastolic velocity values were assessed in the apical four-chamber views utilising pulsed Doppler-echocardiography, with the sample volume positioned at the mitral leaflet tip. From an apical four-chamber views, measurements were taken for the velocity of mitral early diastolic velocity (E) and late diastolic velocity (A), as well as the E/A ratio, isovolumetric relaxation time (IVRT), and deceleration time (DT) [10].

Coronary angiography

Angiographic images were taken after injecting intracoronary nitrate (100 or 200 µg) utilizing a 6-F guiding catheter and a 5-F diagnostic catheter before and after PCI, correspondingly. To administer contrast, a contrast medium has been introduced into a coronary artery via a catheter. The injecting rates were 4 mL/s and 3 mL/s for the left and right coronary arteries, correspondingly. The injection process lasted roughly 2 seconds and was performed utilizing an automated injector from ACIST Medical Systems. The process of quantitative coronary angiography was conducted utilizing proven software (CAAS II, Pie Medical Imaging) in the most suitable projections. The degree of the coronary arteries atherosclerosis located on the epicardial area was evaluated utilizing the SYNTAX (Synergy between PCI with Taxus and Cardiac Surgery) score. Non-culprit vascular stenosis refers to the occurrence of a ≥50% narrowing in diameter in no less than one major artery that is not directly related to the MI.

Percutaneous coronary intervention: A PCI intervention was conducted on each individual with culprit lesions. Coronary angiograms were digitally recorded for the purpose of quantitative analysis. Upon admission, the patient is given only one administration of chewable aspirin (300 mg), as well as a loading do dosage se of either

Ticagrelor (180) mg or clopidogrel (600 mg). Before the intervention, a standard dosage of heparin at 70 U/kg was also administrated. Experienced interventional cardiologists performed all PCI interventions through the femoral artery. Lesions are passed using guidewires with a diameter of .014 inches. Individuals were subjected to conventional stenting, direct stenting, or balloon dilation depending on their anatomy of coronary and characteristics of the lesions. Following the intervention, 75 mg/day clopidogrel or Ticagrelor 90 mg BID and aspirin 75-150 mg/day were administered. Syntax score recorded after PCI, then patients categorized according to their score into high syntax score group (≥ 22) and low syntax score group (< 22).

Statistical analysis: Statistical analysis had been conducted employing SPSS v26 (IBM Inc., Chicago, IL, USA). The Shapiro-Wilks test and histograms had been utilised to assess the normality of the data distribution. Quantitative parametric variables had been presentedas mean and standard deviation (SD) and contrasted among both groups employing unpaired Student's t-test. Quantitative non-parametric data had been displayed as median and interquartile range (IQR) and had been analysed by Mann Whitney-test. Qualitative parameters had been displayed as frequencies and percentages (%) and had been analysed employing the Chi-square test. A two tailed P value < 0.05 was considered statistically significant.

Results

Demographic data, medical history, vital signs and laboratory parameters were enumerated in this table. Table 1.

Table 1: Demographic data, medical history, vital signs and laboratory parameters of the studied patients

		N=40
Age (years)		63.9±15.45
Sex	Male	27 (67.5%)
	Female	13 (32.5%)
Weight (Kg)		74.1±11.92
Height (m)		1.7±0.07
BMI (Kg/m^2)		26.4±5.3
Medical history	DM	18 (45%)
	HTN	29 (72.5%)
	Dyslipidemia	23 (57.5%)
	Smoking	19 (47.5%)
Vital signs	HR (beats/min)	85.9±16.06
	SBP (mmHg)	134.5±16.55
	DBP (mmHg)	83.4±10.75
Laboratory parameters	Hb (g/dl)	12.7±1.43
	Platelets (10^9/L)	269.6±97.02
	TLC (cells /mm^3)	6878.7±2752.09
	Serum creatinine (mg/dl)	0.9±0.29
	Fasting glucose (mg/dl)	96.2±10.55
	TC (mg/dl)	203.3±38.29
	Triglyceride (mg/dl)	191.9±107.51
	HDL (mg/dl)	49.7±12.54
	LDL (mg/dl)	130.9±57.77

Data are presented as mean ± SD or frequency (%). BMI: Body mass index, DM: Diabetes mellitus, HR: heart rate, HTN: Hypertension, DBP: diastolic blood pressure, SBP: Systolic blood pressure, Hb: Hemoglobin, TLC: Total lymphocyte count, TC: Total cholesterol, LDL: Low-density lipoprotein, HDL: High-density lipoprotein.

Troponin and CKMB were significantly greater following 1h contrasted to 0 h (*p*<0.001). Table 2.

Table 2: Cardiac enzymes of the studied patients

	0 h	3h	P
Troponin (ng/mL)	6.3±1.79	9.2±1.91	<0.001*
CKMB (U/L)	44.1±8.54	51.3±8.61	<0.001*

Data are presented as mean ± SD. * significant p value <0.05. CKMB: Creatine kinase MB

Conventional echocardiography, tissue Doppler echocardiography and vessel affected in coronary angiography were enumerated in this table. Table 3.

Table 3: Conventional echocardiography, tissue doppler echocardiography and vessel affected in coronary angiography of the studied patients

		N=40
Conventional Echocardiography		
LVEDV (ml)		93.3±8.22
LVESV (ml)		47.8±7.09
LVSV (ml)		44.6±10.14
LVEF (%)		50.2±7.21
E velocity		66.3±26.41
A velocity		83.9±44.47
E/A ratio		1.3±0.36
Diastolic dysfunction	Grade I	10 (25%)
	Grade II	14 (35%)
	Grade III	16 (40%)
Tissue doppler Echocardiography		
E′ (cm/s)		6.8±3.02
A′ (m/s)		7.6±5.53
E′ / A′ratio (m/s)		1.1±0.34
E'/A ratio		0.1±0.07
S′ (cm/s)		6.8±2.2
Lateral S' (cm/s)		9.7±2.59
IVRT (m/s)		87.6±11.03
Coronary angiography		
Vessel affected	LAD	18 (45%)
	LCX	13 (32.5%)
	RCA	9 (22.5%)

Data are presented as mean ± SD or frequency (%).LVESV: Left ventricular end-systolic volume, LVEDV :Left ventricular end-diastolic volume, LVEF: Left ventricular ejection fraction, LVSV: Left ventricular stroke volume, E′: Peak early diastolic velocity, A′: Peak late diastolic velocity, S′: Peak systolic velocity, IVRT: Isovolumetric relaxation time, E/A ratio: ratio of the early (E) to late (A) ventricular filling velocities, PCI: Percutaneous coronary intervention, LAD: Left anterior descending artery, LCX: circumflex artery, RCA: Right coronary artery.

A negative correlation was existed among age and [LVEF (%), E/A ratio, E′, E′ / A′ ratio, peak systolic velocity and Lateral S']. Table 4.

Table 4: Correlation between age and LVEF, E/A ratio and peak systolic velocity of the studied patients

	Age (years)	
	r	P value
LVEF (%)	-0.442	0.004*
E/A ratio	-0.401	0.010*
E′ (cm/s)	-0.356	0.024*
E′ / A′ ratio (m/s)	-0.350	0.026*
Peak systolic velocity (cm/s)	-0.321	0.042*
Lateral S' (cm/s)	-0.374	0.017*

r: Pearson coefficient, *significant as P value ≤0.05, LVEF: Left ventricular ejection fraction

A positive correlation was existed among (LVEDV, LVESV and LVSV) and (female sex, DM, HTN, dyslipidemia, troponin and CKMB). There was a negative correlation between LVEF and (female sex, DM, Hypertension, Dyslipidemia, Troponin and CKMB) (p<0.05). Table 5.

Table 5: Correlation between Conventional Echocardiography parameters and other variables

	LVEDV (ml)		LVESV (ml)		LVSV (ml)		LVEF (%)	
	r	P	r	P	r	P	r	P
Sex (female)	0.416	0.011*	0.367	0.012*	0.547	0.001*	-0.354	< 0.001*
DM	0.406	0.047*	0.441	0.006*	0.483	0.006*	-0.429	0.005*
HTN	0.417	0.006*	0.459	0.002*	0.328	0.025*	-0.440	0.006*
Dyslipidemia	0.392	0.018*	0.380	0.026*	0.475	0.002*	-0.369	0.019*
Troponin (ng/mL)	0.454	0.003*	0.388	0.013*	0.373	0.017*	-0.357	0.025*
CKMB (U/L)	0.338	0.032*	0.412	0.008*	0.341	0.030*	-0.423	0.007*

r: Pearson coefficient, *significant as P value ≤0.05, LVESV: Left ventricular end-systolic volume, LVSV: Left ventricular stroke volume, LVEF: Left ventricular ejection fraction, DM: Diabetes mellitus, HTN: Hypertension, LVEDV: Left ventricular end-diastolic volume, CKMB: Creatine kinase MB

LVEF, E/A ratio, E′/A′ ratio and S′ can significantly diagnosis HFpEF individuals respectively (AUC = 0.805, 0.801, 0.921 and 0.950) at cut-off ≤48%, >1.27, >1.05 and ≤6.4 with 70.0%, 75.0%, 95.0% and 95.0% sensitivity, 75.0%, 60.0%, 85.0% and 90.0% specificity, 73.7%, 65.2%, 86.4% and 90.5% PPV and 71.4%, 70.6%, 94.4% and 94.7% NPV. Figure 1.

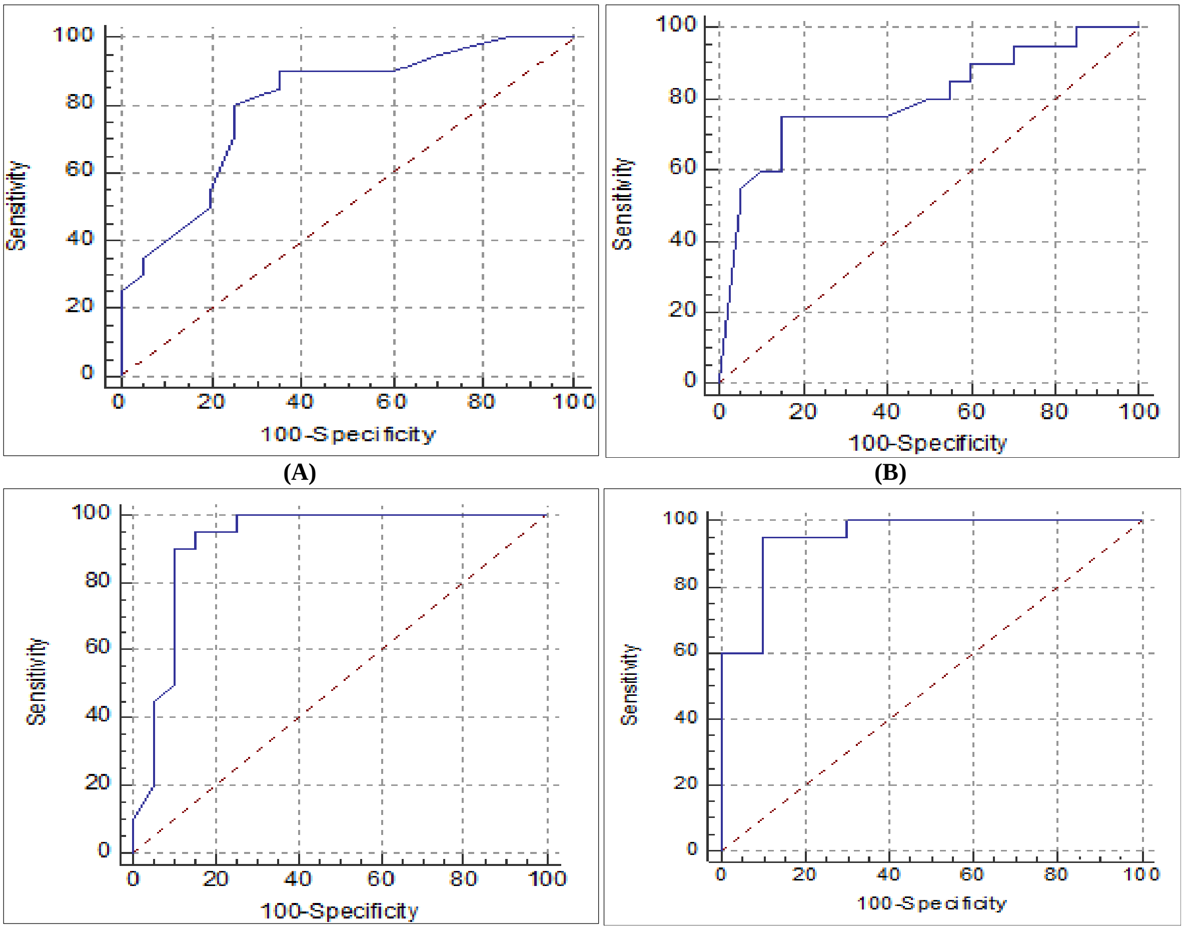

Fig 1: ROC curve of (A) LVEF, (B) E/A ratio, (C) E′ / A′ ratio and (D) S′ for diagnosis of HF-PEF patients

Discussion

ACS is defined by reduced blood flow to the cardiac muscle, which encompasses both MI and unstable angina. The primary pathogenic characteristic of ACS is the occurrence of unstable plaque rupture or erosion, which results in either full or partial occlusive thrombosis. ACS comprises three primary subtypes: unstable angina pectoris, STEMI, and NSTEMI [11].

In agreement with our results about conventional echocardiography analysis, Lang *et al.* [12] recommended that it is recommended to regularly evaluate the size of the LV utilizing 2DE by computing volumes utilizing the biplane technique for disks summation approach. It is advisable to do 3D measurements as well as reporting of LV volumes at laboratories that have expertise in 3DE, when possible and based on the quality of the images. The preferred approach for reporting LV linear dimensions is to use 2D-guided measures. LV volume and size measures ought to be given in relation to BSA. Nevertheless, Chowdhury *et al.* [13] showed that after successful PCI, neither group's LVEF, number of segments with LVIDD, WMA, or LVIDs showed any early improvement in NSTEMI diabetic or non-diabetic patients.

In agreement with our results about tissue doppler echocardiography, Chahal *et al.* [14] The myocardial S' velocity, evaluated at the septal mitral annulus, didn't reveal a significant association with age. The velocity of E' determined at both the lateral and septal mitral annular segments, as well as their averages, reduced significantly with aging. This led to a corresponding and significant raise in the E/E' ratio when determined at either annular site or when averaged between both. Our findings align with the study conducted by Nabati *et al.*, which revealed that individuals admitted to the hospital with NSTE-ACS and an E/(e′s′) ratio ≥ 1.63 had poorer echocardiographic, demographic, and laboratory characteristics, as well as an increased occurrence of a SYNTAX score ≥ 22 compared to individuals with a reduced ratio [15].

Also, in this study, Cardiac enzymes were measured. the troponin of the studied patients ranged from 3.3 to 9.3 ng/mL with a mean value (± SD) of 6.33 (±1.79) ng/mL and CKMB ranged from 23.5 to 62.3 U/L with a mean value (± SD) of 42.9 (±11.84) U/L. Troponin and CKMB were significantly higher after 3h compared to 0 h. Our study is in the same line with Neumann *et al.* found that the results did not show any significant statistical differences. However, using the 1-hour strategy might enable quicker diagnosis or discharge. A lower threshold value yielded significantly superior results compared to using the 99th percentile as the cutoff point when considering death during the follow-up period [16]. Aydin *et al.* [17] demonstrated that CK-MB remains diagnostically useful in both cardiac and non-cardiac situations. CK-MB is present in the blood 4 hours following damage to the heart muscle, reaches its highest level within 24 hours, and returns to normal within 48 to 72 hours. CK-MB is a valuable biomarker for identifying acute

MI due to its unique affinity for cardiac tissue. However, it can also increase in non-cardiac diseases like skeletal muscle injuries, chronic kidney failure, hypothyroidism, and intense exercise. A CK-MB2 to CK-MB1 ratio of 1.5 or higher, together with a CK-MB relative index (CK-MB/total CK x 100) of 2.5 or higher, increases the accuracy in identifying cardiac tissue and indicates the presence of acute MI.

Regarding Vessel affected in coronary angiography of the studied patients18 (45%) patients affected in LAD. 13 (32.5%) patients affected in LCX. 9 (22.5%) patients affected in RCA. Coronary angiography occurred in 17 (42.5%) patients. This results was in agreement with Muneeb *et al.* [18] revealed that the coronary artery size influences the effective outcome of therapeutic measures like PCI, and diagnosis of coronary artery diseases. Patients' age, gender, BMI, anatomical variations, and increased LV size all have an effect on coronary artery parameters.

In the present study, conventional echocardiography and TDI have been utilized to diagnose heart function. LVEF can significantly diagnose HF-PEF patients with 70.00% sensitivity, 75.00% specificity, 73.7% PPV and 71.4% NPV. E/A ratio can significantly diagnose HF-PEF patients with 75.00% sensitivity, 60.00% specificity, 65.2% PPV and 70.6% NPV. E′ / A ‘ratio can significantly diagnose HF-PEF patients with 95.00% sensitivity, 85.00% specificity, 86.4% PPV and 94.4% NPV. S′ can significantly diagnose HF-PEF patients with 95.00% sensitivity, 90.00% specificity, 90.5% PPV and 94.7% NPV. That means that TDI is more accurate and sensitive procedure than Conventional echocardiography. Similar findings were obtained by Noori *et al.* [19] compared TDI with conventional echocardiography to diagnose cardiac dysfunctions in DMT1 patients. Also, Kurapati *et al.* [20] concluded that TDI is a non-invasive method used to assess both diastolic and systolic dysfunctions of the LV. The use of TDI could be advantageous as a prognostic and diagnostic tool in individuals with heart failure. A cohort of 100 individuals (72 male and 28 female) who underwent echocardiography were involved in the work. The LV performance was evaluated using TDI.

Limitations of the work involved relatively small sample size. The duration of patient follow-up was rather brief. LV volume and size measures ought to be provided with the BSA taken into account. This study did not evaluate the specific timing of PCI in patients with hemodynamically stable NSTEMI.

Conclusion
The LV function after PCI showed enhancement after successful revascularization in patients with NSTEMI. PW - TDI can be used as valid imaging tool in comparison with 2 D Echocardiography.

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Conflict of Interest: Nil.

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