The Egyptian Journal of Hospital Medicine (January 2023) Vol. 90 (2), Page 2353-2358

Evaluation of Myocardial Tissue Doppler Echocardiography as a Predictor for Recovery of Left Ventricular Function after Percutaneous Coronary Revascularization for Patients with Coronary Artery Disease

Ahmed M. Fareed*, Ahmed S. Youssef, Mohamed A. Oraby, Ahmed S. Salem
Department of Cardiology, Faculty of Medicine, Suez Canal University, Egypt
***Corresponding author:** Ahmed M. Fareed, **Mobile:** (+20)1282637291, **E-mail:** ahmed_ali1@med.suez.edu.eg

ABSTRACT

Background: The experiments show that pre-ejection velocity analysis is particularly sensitive to blood flow. After reduced regional perfusion, tissue velocities drop, but they rise with reperfusion. Thus, following revascularization, cardiac function recovery may be predicted using tissue doppler imaging (TDI).

Objective: The aim of the current work was to determine the effectiveness of tissue Doppler imaging echocardiography in predicting the restoration of myocardial function in patients with coronary artery disease (CAD) following percutaneous coronary revascularization.

Patients and Methods: Our study prospectively enrolled 27 patients. Only 24 patients completed the study protocol while, unfortunately, three died during follow up. Included patients were diagnosed with CAD based on previous diagnostic coronary angiography (CA) done before. They have impaired systolic function and regional wall motion abnormality (RWMA) on transthoracic echocardiography (TTE) and were eligible for percutaneous coronary intervention (PCI).

Results: From all Tissue Doppler Imaging-Pulsed wave (TDI-PW) derived parameters, only mean IVCPv and mean S wave velocity of dysfunctional segments at baseline correlate significantly with changes in LVEF (global functional recovery) with revascularization. The mean of both IVCPv and the S wave of defective segments varied significantly at baseline among patients who showed significant improvement in LVEF 6 months after revascularization versus those patients who didn't exhibit significant improvement (2.8±0.4 vs. 3.5±0.8 for IVCPv, and 4.5±0.9 vs 5.8±1.1 for S wave, p value <0.05 and <0.01 respectively). There was significant moderate positive correlation between mean IVCPv and mean S wave velocity at baseline and changes in LVEF (global functional recovery) with revascularization (p value<0.05 and <0.01 respectively).

Conclusions: It could be concluded that in patients with CAD, the resting IVCPv & S wave by TDI pattern accurately predicts the recovery of global systolic function with high pulse pressure variation (PPV) but not the regional function.

Keywords: Global systolic function, Tissue doppler imaging, Coronary artery disease.

INTRODUCTION

The primary cause of death globally now is coronary artery disease (CAD) (45% of all Cardiovascular deaths) accounting for 12% of all deaths globally [(1)].

Despite the debate aroused by ISCHEMIA trial regarding revascularization of people with ischemic heart disease who are stable [(2)], there is upward interest in percutaneous treatment of patients with recent or recurrent acute coronary syndromes (ACS) due to enhancements in observational evidence that effective treatment of CAD is connected to important changes in heart function and outcome [(3)]. The rationale for the recanalization is the expected increase of recovery of hibernating myocardium allows for the restoration of left ventricular (LV) function [(4)].

Since it was discovered that chronic left ventricular dysfunction can be reversed and that the presence of viable myocardium is a predictor of LV dysfunction improvement in CAD patients, the concept of hibernating myocardium, It is characterized as an ischemic myocardial fed by a constricted coronary artery, in which the ischemic cells are still alive but the contraction is chronically compromised [(5, 6)], has made a significant contribution to clinical cardiology [(7)].

Myocardial viability could be assessed by multiple modalities in patients with CAD. Nuclear imaging and more recently cardiac magnetic resonance imaging are expensive, and frequently inaccessible. Low dose dobutamine echocardiography relies more on operator experience. 2-D echocardiography is the most prevalent imaging modality for the evaluation of global and segmental ventricular function. However, conventional evaluation of wall motion by visual assessment of myocardial thickening is relatively subjective, qualitative method, and is operator dependent [(8)]. Therefore, most of the currently used modalities for myocardial viability assessment are time consuming, expensive or operator-dependent [(9)].

Tissue Doppler imaging (TDI) makes it possible to measure the velocities of myocardial tissue. To begin with, high temporal resolution measurements of the highest tissue velocities during systole and diastole a chosen myocardial section were made using TDI to quantify myocardial motion [(10-11)].

The pre-ejection phase myocardial velocity display by TDI typically consists of an initial A brief inward and outward wall movement is indicated by a positive wave that is followed by a little negative wave. Pre-ejection velocity analysis is dependent on the blood flow to the studied segment [(12)]. Persistence of the initial

Received: 17/09/2022
Accepted: 17/11/2022

positive wave in dysfunctional segments following reperfusion in animal models of induced acute myocardial infarction (MI) shows non-transmural necrosis [13].

As a result, TDI can measure wall motion. Low systolic tissue velocities are correlated with aberrant wall motion on angiography or echocardiography [14]. Reduced regional perfusion causes a drop in tissue velocities, which rise with reperfusion and distinguish between transmural and nontransmural infarction [15–17].

The aim of the current work was to determine the effectiveness of tissue Doppler imaging echocardiography in predicting the restoration of myocardial function in patients with CAD following percutaneous coronary revascularization.

PATIENTS AND METHODS

This prospective study included a total of 24 patients diagnosed with CAD, attending at Department of Cardiology, Faculty of Medicine, Suez Canal University Hospitals.

Our study prospectively enrolled 27 patients. Only 24 patients completed the study protocol while, unfortunately, three died during follow up.

Inclusion Criteria: Patients diagnosed with CAD based on previous diagnostic coronary angiography (CA) done before. They have impaired systolic function and regional wall motion abnormality (RWMA) on transthoracic echocardiography (TTE) and were eligible for percutaneous coronary intervention (PCI).

Exclusion Criteria: Patients with poor echogenic window, proved non-viability by any image modality, significant valvular heart disease or preserved systolic function at baseline.

Transthoracic echocardiography (TTE) was performed at baseline using General Electric Vivid 7 (GE Ultrasound, Horten, Norway) machine equipped with the TDI mode with 2–2.5 MHz transthoracic transducers were used. The American Society of Echocardiography (ASE) recommendations were followed regarding measurements of dimensions and global systolic function.

The conventional 2-D measurements included: Left ventricular end diastolic dimension (LVEDD), Left ventricular end systolic dimension (LVESD), and global LV systolic function. Tissue Doppler Imaging Pulsed Wave derived parameters (TDI-PW) of dysfunctional segments; namely Isovolumic contraction peak velocity (IVCPv), Systolic wave (S wave), Acceleration time (AT), Isovolumic contraction time (IVCT), Contraction time (CT), and Isovolumic relaxation time (IVRT) were identified and recorded on DVDs for offline analysis.

The 16-segment model was used with exclusion of apical segments (due to poor TDI image quality) and scoring system was followed on grading segments' dysfunction and wall motion scoring index (WMSI) was calculated for each patient. All the patients had undergone revascularization by PCI with a drug-eluting stents.

After 6 months, another follow-up echocardiography was done with all same baseline measurements were recorded again and were compared with baseline data.

Ethical Approval:

Suez Canal University's Ethical Institutional Review Board authorized the project. After being informed of the research's aims, all study participants provided signed consent. The Declaration of Helsinki for Humans, the global medical association's code of ethics, was followed throughout the course of this study.

Statistical analysis:

The statistical package for the social sciences (version 24.0; SPSS Inc., Chicago, Illinois, USA) software for Windows was used to analyze the data. Categorical data were reported as a percentage, whereas continuous variables were expressed as mean$\pm$SD. To compare the means of variables at baseline and after 6 months, a paired samples t-test was performed.

For the comparison of qualitative data, a X^2-test was employed. The correlation between two quantitative variables was evaluated using Pearson's correlation. In order to forecast values of one variable based on the values of two or more additional variables, multivariable regression analysis was performed.

As measured by [true positive true negative measurements]/total number of measurements, the TDI-derived VIC's accuracy in predicting the restoration of regional contractile function was calculated. Global function recovery was taken into account if the LVEF rose by 5% or greater after six months. Statistical significance was defined as a P value 0.05.

RESULTS

Patients characteristics

Table (1) shows twenty-seven patients (11 females, 13 males, and 3 died during follow up). The mean age was 57 years. The left ventricular ejection fraction (LVEF) at baseline ranged from 35% to 52% (mean was 48.5%) which dramatically improved with revascularization to a mean of 54.8% (P value<0.001). Dyslipidemia, hypertension, smoking and diabetes were prevalent risk factors among patients representing (75%, 66%, 54% and 42% respectively).

Seven patients have single vessel disease, six individuals have two vessel disease, and about half of patients (45.8%) have three vessel illness. The total score for each segment—normal (1), hypokinetic (2), akinetic (3), and dyskinetic (4)—was used to create the wall motion score index. total number of segments depicted (12 segment). It improved significantly 6 months post revascularization from 1.59 to 1.12 (P value< 0.001).

Table (1): Baseline main characteristics:

Parameters	Baseline characteristics
Age (years) (mean ±SD)	57.1 (±9.1)
Gender	
• Males (%)	13 (54.2)
• Females (%)	11 (45.8)
BMI (Kg/m^2)	27.1 (±3.5)
Smoking (%)	13 (54.2)
Hypertension (%)	16 (66.7)
Diabetes Mellitus (%)	10 (41.7)
Dyslipidemia (%)	18 (75)
Family History (%)	1 (4.2)
Single Vessel-CAD (%)	7 (29.2)
Two Vessel-CAD (%)	6 (25)
Three vessel-CAD (%)	11 (45.8)
Heart rate (bpm) at baseline (mean ±SD)	77 (±10)
LVEF % (mean ±SD)	48.5 ±5 (range, 35 to 52)
Wall motion score index	1.59 (±0.3)

BMI; Body mass index, bpm; beat per minute

From all TDI-PW derived parameters, only mean IVCPv and mean S wave velocity of dysfunctional segments at baseline correlate significantly with changes in LVEF (global functional recovery) with revascularization as shown in **Table 2**.

Table (2): Changes in conventional echocardiography parameters at baseline and at 6 months post revascularization among patients:

Parameters	Baseline (mean ±SD)	At 6 months (mean ±SD)	P-Value*
LAD (mm)	39.75 (±2.5)	43.13 (±3.9)	0.0001
LVEDD (mm)	50.04 (±7.5)	56.46 (±4.5)	0.0001
LVESD (mm)	43.75 (±8.9)	40.75 (±4.9)	0.071
EF%	48.58 (±4.8)	54.75 (±4.9)	0.0001
FS%	26.53 (±3)	29.26 (±2.8)	0.0001
WMSI**	1.59 (±0.3)	1.12 (± 0.3)	0.0001

EF, ejection fraction; FS, fraction shorting; LA, left atrial diameter; LVEDD, left ventricular end diastolic dimension; LVESD, left ventricular end systolic dimension; WMSI, wall motion score index.

TDI-derived parameters and recovery of global function (LVEF):

The mean of both IVCPv and the S wave of defective segments varied significantly at baseline among patients who showed significant improvement in LVEF 6 months after revascularization versus those patients who didn't exhibit significant improvement (2.8±0.4 vs. 3.5±0.8 for IVCPv, and 4.5±0.9 vs 5.8±1.1 for S wave, p value <0.05 and <0.01 respectively) as shown in **Table 3**.

Table (3): Relationship between mean TDI parameters of dysfunctional segments for all patients at baseline versus recovery of global systolic function.

Parameter	Δ LVEF [%]*	Mean ±SD**	P value
IVCPv (cm/s)	No recovery	2.8 (±0.4)	0.03
	Recovery	3.5 (±0.8)	
S wave(cm/s)	No recovery	4.5 (±0.9)	0.005
	Recovery	5.8 (±1.1)	
IVCT (m/s)	No recovery	89.6 (±16)	0.1
	Recovery	103.75 (±25)	
CT (m/s)	No recovery	266.9 (±22)	0.2
	Recovery	278.8 (±22)	
AT (m/s)	No recovery	40.1 (±8.7)	0.3
	Recovery	43.8 (±8.5)	
TP (m/s)	No recovery	121.6 (±20.9)	0.3
	Recovery	130.6 (±24.9)	
IVRT (m/s)	No recovery	128.7 (±31.3)	0.8
	Recovery	125.9 (±28.4)	

AT, acceleration time of isovolumic contraction; CT, contraction time; IVCPv, isovolumic contraction peak velocity; IVCT, isovolumic contraction time; IVRT, isovolumic relaxation time; S wave, contraction wave velocity; TP, time to peak isovolumic contraction.

There is significant moderate positive correlation between mean IVCPv and mean S wave velocity at baseline and changes in LVEF (global functional recovery) with revascularization (p value<0.05 and <0.01 respectively). With sensitivity, specificity, and accuracy of 87%, 77%, and 83%, respectively, the mean systolic (S) velocity demonstrated a threshold value of 4.6 cm/s (AUC=0.833, CI=0.664 -1.000, P value=0.007) or greater for prediction of recovery of global systolic function. With a sensitivity, specificity, and accuracy of 85%, 70%, and 79%, respectively, the mean IVCP velocity demonstrated a threshold value of 2.86 cm/s (AUC=0.789, CI=0.603-0.975, P value=0.02) or greater for prediction of recovery of global systolic function **(Table 4).**

Table (4): Relationship between mean TDI parameters of dysfunctional segments for all patients at baseline versus recovery of global systolic function.

Parameter		Δ LVEF		
		Improved (≥5%)	**Not improved (<5%)**	**Total**
IVCPv (cm/s)	Positive (≥ 2.86)	12	3	15
	Negative (< 2.86)	2	7	9
	Total	14	10	24
S wave (cm/s)	Positive (≥ 4.6)	13	2	15
	Negative (< 4.6)	2	7	9
	Total	15	9	24

IVCPv: isovolumic contraction peak velocity, S wave: contraction wave velocity.

Multivariable regression analysis showed that only IVCPv and mean S wave velocity of dysfunctional segments are independent predictors of global functional recovery (LVEF) with overall sensitivity, specificity and accuracy of mean IVCPv were 85%, 70% and 79% respectively. While that of S wave velocity were 87%, 77% and 83% respectively. For the mean IVCPv; the positive predictive value (PPV) was 80% and the negative predictive value (NPV) was 77% versus 87% and 77% for S wave **(Figure 1A, 1B).**

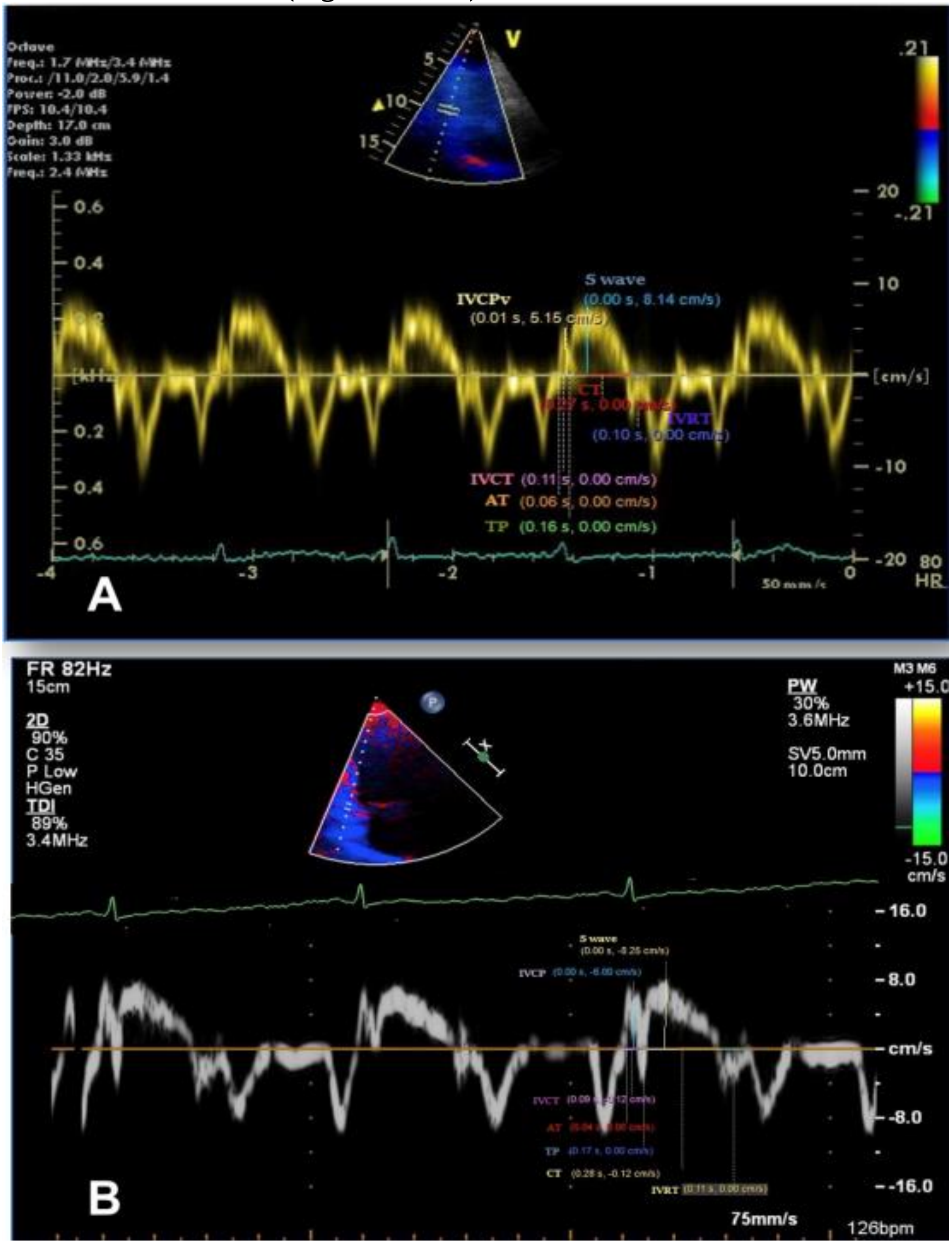

Figure (1): A, B. A case of occlusion-RCA before (A) and after Percutaneous coronary intervention, (B) tissue Doppler imaging (TDI): shows changes in TDI parameters values before and after PCI in basal inferior wall.

DISCUSSION

Heart failure (HF) has a considerable morbidity and death rate, and one of the main underlying causes is CAD with ensuing left ventricular (LV) dysfunction. Over the past several decades, therapeutic studies to better the outcomes of these patients have undergone a significant evolution. They now take a multifaceted strategy to symptom relief, ventricular function improvement, reinfarction prevention, and the avoidance of abrupt cardiac death [18-19].

The possible recovery of hibernating myocardium to enhance LV function is the driving force for the closure of coronary blockage [5].

Tissue Doppler imaging, which can evaluate several distinct cardiac contraction characteristics, has also been demonstrated to have potential accuracy for objective viability evaluation, making it one of the promising echocardiography methods for myocardial viability assessment [20].

This study's main goal was to determine the usefulness of tissue Doppler imaging echocardiography-derived pulsed wave parameters to forecast left ventricular contractile recovery in patients undergoing percutaneous coronary revascularization. The objectives of study were; (1) To address the correlation between parameters of TDI and improvement of both LV global and regional function after Percutaneous Coronary Revascularization, and (2) To determine sensitivity, specificity and accuracy of TDI in predicting myocardial recovery.

Conventional echocardiography and systolic function:

A rise in LVEF of ≥ 5% was deemed to represent global systolic recovery. Recanalization of the occluded vessel(s) was linked to a significant improvement in LVEF ≥5% (recovery), which went from 48.6±4.8 at baseline to 54.7±4.9 six months after PCI ($p < 0.001$) and as shown by a considerable increase in the resting wall motion score index, which went from 1.59±0.3 at baseline to 1.12±0.3 after six months ($p < 0.001$).

Cardona *et al.*[21] showed an increase in LVEF (31.3 ± 7.4 % vs. 37.7 ± 8 %; $p < 0.001$) 6 months after PCI. In addition, the number of segments with perfusion problems has been greatly reduced (0.5 ± 1 vs. 0.2 ± 0.5; $p = 0.043$). This came in agreement with another study **El Shafey *et al.***[4] who used tissue doppler imaging to assess LV function before and after PCI to chronic total occlusion. A third study by **Hossain *et al.***[22] showed substantial improvement in LVEF with an increase in LVEDD and LVESD following treatments from (54.3±5.8) to (56.2±4.7), p value (<0.001).

A considerable improvement in LV systolic function is related with effective coronary occlusion closure, by either reducing LV remodeling while maintaining LV function and providing collateral arteries that aid in regaining the contractility of the hibernating myocardium and provide protection against future occurrences, PCI of infarct associated arterial blockage might recover LVEF [22].

Our findings were in agreement with those of **Rashid *et al.*** [23], who found that the cutoff value for mean systolic (S) velocity was 4.83 cm/sec or more (as opposed to 4.6 cm/sec in our study) to predict the recovery of global systolic function with 100% sensitivity, 90% specificity, and accuracy of 97.5%, 100%, and 0.986 respectively.

Within one month of study enrollment, participants were randomized to undergo either the best possible medical care or coronary artery bypass graft (CABG) surgery, according to **Penicka *et al.*** [24] in comparison to the other three approaches, they stated that in the medically treated group, TDI-derived +Vic demonstrated great sensitivity and specificity for recognizing viable myocardium. +Vic has a high sensitivity and specificity for the prediction of this functional recovery, 66% of the defective myocardium segments diagnosed in the CABG group had functional recovery after 6 months. Additionally, they demonstrated that having a positive Vic was a substantial and independent predictor of a considerable rise in LVEF [24].

CONCLUSION

It could be concluded that in patients with CAD, the resting pattern of myocardial IVCPv & S wave by TDI reliably predicts the recovery of overall systolic function with high PPV but not regional function. In conventional practice, TDI pre-ejection velocity detection is a practical, largely reproducible, and conveniently accessible approach.

Supporting and sponsoring financially: Nil.
Competing interests: Nil.

REFERENCES

1. **Lloyd-Jones D, Adams R, Carnethon M *et al.* (2009):** Heart Disease and Stroke Statistics—2009 Update. Circulation, 119(3): 21. doi: 10.1161/CIRCULATIONAHA.108.191261.
2. **Maron D, Judith S, Sean M *et al.* (2018):** International Study of Comparative Health Effectiveness with Medical and Invasive Approaches (ISCHEMIA) trial: Rationale and design. American Heart Journal, 201: 124-135.
3. **Fefer P, Knudtson M, Cheema A *et al.* (2012):** Current Perspectives on Coronary Chronic Total Occlusions: The Canadian Multicenter Chronic Total Occlusions Registry. J Am Coll Cardiol., 59(11):991–7.
4. **El Shafey W, Montaser S, Badran H *et al.* (2015):** Assessment of left ventricular function before and after a percutanous coronary intervention to chronic total coronary occlusion: Doppler tissue imaging study. Menoufia Med J., 28(2):400-405.
5. **Conti C (1991):** The stunned and hibernating myocardium: A brief review. Clin Cardiol., 14(9):708–712.
6. **Camici P (2004):** Hibernation and heart failure. Heart, 90(2):141–143.

7. **Heusch G (1998):** Hibernating myocardium. Physiol Rev., 78: 1055–1085.
8. **Abraham T, Dimaano V, Liang H (2007):** Role of tissue Doppler and strain echocardiography in current clinical practice. Circulation, 116(22):2597–2609.
9. **Penicka M, Bartunek J, Wijns W *et al.* (2004):** Tissue Doppler Imaging Predicts Recovery of Left Ventricular Function after Recanalization of an Occluded Coronary Artery. J Am Coll Cardiol., 43(1):85–91.
10. **Hoffmann R, Lethen H, Marwick T *et al.* (1996):** Analysis of interinstitutional observer agreement in interpretation of dobutamine stress echocardiograms. J Am Coll Cardiol., 27(2):330–336.
11. **Picano E, Lattanzi F, Orlandini A *et al.* (1991):** Stress echocardiography and the human factor: The importance of being expert. J Am Coll Cardiol., 17(3):666–669.
12. **Edvardsen T, Urheim S, Skulstad H *et al.* (2002):** Quantification of left ventricular systolic function by tissue Doppler echocardiography: Added value of measuring pre-and postejection velocities in ischemic myocardium. Circulation, 105(17):2071–2077.
13. **Pislaru C, Bruce C, Belohlavek M *et al.* (2001):** Intracardiac measurement of pre-ejection myocardial velocities estimates the transmural extent of viable myocardium early after reperfusion in acute myocardial infarction. J Am Coll Cardiol., 38(6):1748–1756.
14. **Gorcsan III J, Gulati V, Mandarino W *et al.* (2017):** Color-coded measures of myocardial velocity throughout the cardiac cycle by tissue Doppler imaging to quantify regional left ventricular function. Am Heart J., 131(6):1203–1213.
15. **Derumeaux G, Loufoua J, Pontier G, Cribier A, Ovize M**(2001): Tissue Doppler Imaging Differentiates Transmural From Nontransmural Acute Myocardial Infarction After Reperfusion Therapy. Circulation ,103(4):589–596.
16. **Derumeaux G, Ovize M, Loufoua J *et al.* (2000):** Assessment of nonuniformity of transmural myocardial velocities by color-coded tissue Doppler imaging: characterization of normal, ischemic, and stunned myocardium. Circulation, 101(12):1390–1395.
17. **Derumeaux G, Ovize M, Loufoua J *et al.* (1998):** Doppler tissue imaging quantitates regional wall motion during myocardial ischemia and reperfusion. Circ., 97:1970–1977.
18. **Klatsky A, Oehm R, Cooper R *et al.* (2003):** The early repolarization normal variant electrocardiogram: Correlates and consequences. Am J Med., 15:171–177.
19. **Zoghbi W, Narula J (2015):** Myocardial viability and remodeling: Does size matter? JACC Cardiovasc Imaging, 8(10):1235–1237.
20. **Partington S (2014):** Multimodality imaging in the assessment of myocardial viability. Heart Fail Rev., 16(4):381–395.
21. **Cardona M, Martín V, Prat-Gonzalez S *et al.* (2016):** Benefits of chronic total coronary occlusion percutaneous intervention in patients with heart failure and reduced ejection fraction: insights from a cardiovascular magnetic resonance study. J Cardiovasc Magn Reson., 18: 78. doi: 10.1186/s12968-016-0287-5
22. **Hossain M, Rahman A, Siddique M *et al.* (2013):** A study of changes in various echocardiographic parameters in patients with chronic stable angina undergoing percutaneous coronary intervention (PCI). University Heart Journal, 9(2):99-106.
23. **Rashid H, Abu El-Enien H, Ibraheem M (2014):** The predictive value of tissue Doppler for left ventricular recovery and remodeling after primary percutaneous coronary intervention. Journal of Cardiology & Current Research, 1(6):159-164.
24. **Penicka M, Tousek P, De Bruyne B *et al.* (2007):** Myocardial positive pre-ejection velocity accurately detects presence of viable myocardium, predicts recovery of left ventricular function and bears a prognostic value after surgical revascularization. Eur Heart J., 28:1366-1373.