



Egyptian Society of Cardiology
The Egyptian Heart Journal

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ORIGINAL ARTICLE

Role of 2D speckle tracking echocardiography in predicting acute coronary occlusion in patients with non ST-segment elevation myocardial infarction



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Received 21 July 2016; accepted 16 October 2016

Available online 1 November 2016

KEYWORDS

2D speckle tracking echocardiography;
Non ST segment elevation acute coronary syndrome;
Acute coronary occlusion

Abstract *Background:* A substantial fraction of patients with non ST-elevation acute coronary syndrome have an occluded culprit vessel on coronary angiography. Acute coronary occlusion often results in myocardial infarction and loss of systolic function. Identification of these patients may have considerable impact on treatment and prognosis.

Aim: The study aims at investigating role of 2D speckle tracking echocardiography as a non-invasive predictor of acute coronary artery occlusion in patients with non ST-segment elevation myocardial infarction.

Patients: This study was carried on 60 patients with first attack non ST segment elevation myocardial infarction who were admitted to coronary care unit of Ain Shams University Hospitals. All patients underwent thorough history taking, full clinical examination, 12 leads surface ECG, full 2D, M-mode and Doppler echocardiographic study, two-dimensional speckle tracking strain study and coronary angiography.

Results: 2D derived peak global longitudinal strain had a highly significant relationship in prediction of the presence of total occlusion, and also number of segments with reduced strain (functional risk area by strain) had a highly significant relationship in prediction of the presence of total occlusion. In this study, 2D derived peak longitudinal strain sensitivity and specificity were 68.9% and 77.7% respectively at a cutoff value of -15.5 while number of segments with reduced longitudinal strain sensitivity and specificity were 63.6% and 77.7% respectively at a cutoff value of 5 segments.

Conclusion: Both global and regional peak longitudinal systolic strain can offer accurate, feasible, and non-invasive predictor for acute coronary artery occlusion in patients with non ST elevation myocardial infarction who may benefit from early revascularization.

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Peer review under responsibility of Egyptian Society of Cardiology.

<http://dx.doi.org/10.1016/j.ehj.2016.10.005>

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1. Introduction

ST-segment-Elevation Myocardial Infarction (STEMI) and non ST-elevation acute coronary syndrome (NSTEMI-ACS) share the same pathology, complications, and risk factors.¹

It is well known that electrocardiogram (ECG) is pivotal to early risk stratification of patients with chest pain. ST-segment elevation predicts acute coronary occlusion with high specificity. When ST elevation is present, treatment is aimed at reperfusion by opening the occluded coronary artery, either by thrombolytic or by percutaneous coronary intervention. This strategy, which reduces infarct size and salvages viable myocardium, has led to a dramatically improved prognosis in ST elevation myocardial infarction (STEMI).²

However, ECG has limited ability to detect acute coronary occlusion, with a sensitivity of 70%. Hence, 30% of patients with acute coronary occlusion do not develop ST-segment elevation, and are diagnosed as non ST-elevation acute coronary syndrome.³

In non ST elevation myocardial infarction (NSTEMI) it is believed that either one or more vessel is transiently occluded or that the blood flow is critically reduced in a patent vessel i.e. subtotal occlusion. In addition there is lack of supportive evidence in favor of emergency angioplasty in patients with NSTEMI.⁴ For these reasons, doing emergent angiography and angioplasty is not mandatory in all patients with NSTEMI, according to current American Heart Association (AHA) guidelines.⁵

However, studies have shown that in patients with NSTEMI, myocardial function deteriorates and the damage becomes irreversible as the time to angiography and revascularization increases, especially in those who have occluded coronaries on angiogram.⁶ So identification of these patients may have considerable impact on treatment and prognosis.

Acute coronary occlusion is followed by rapid changes in LV systolic function that can be quantified by echocardiography.⁷

Myocardial strain quantification by speckle tracking echocardiography has been well validated, using sonomicrometry and tagged contrast magnetic resonance as reference methods. It is a validated and accurate measure of regional systolic LV function.⁸ It has also been shown to be superior to visual assessment of wall motion in detection and quantification of regional systolic function.⁹ Strain and other deformation parameters are sensitive tools for detection of ischemia.¹⁰

We hypothesized that global and regional left ventricular 2D strain by speckle tracking echocardiography (STE) facilitates an early and accurate non-invasive tool to predict the presence of acute coronary artery occlusion in patients with non ST-segment elevation myocardial infarction (NSTEMI).

So the aim of this study was to investigate role of 2D speckle tracking echocardiography as a non-invasive predictor for the presence of acute coronary artery occlusion in patients with non ST-segment elevation myocardial infarction.

2. Patients

This study included 60 patients presented to the coronary care units of Ain Shams University Hospitals with first attack acute

non ST segment elevation myocardial infarction. The diagnosis of non ST elevation myocardial infarction was based on ESC 2007 guidelines¹¹; prolonged chest pain lasting for > 20 min, electrocardiographic changes in the form of ST segment depression and/or T wave inversion in two or more consecutive leads (in some cases of acute coronary syndrome the ECG shows no abnormality) and elevation of serum levels of cardiac biomarkers such as troponins and creatine kinase-MB value more than twice than that of the highest reference laboratory value.

Exclusion criteria: we excluded patients with history or ECG evidence of old myocardial infarction, previous coronary artery bypass graft (CABG) surgery or percutaneous coronary artery intervention, the presence of ventricular arrhythmias, pacing, or pre-excitation syndrome and hemodynamic instability. Patient with poor echocardiographic images was also excluded.

3. Methods

The patients were subjected to detailed history taking, clinical examination, electrocardiogram, necessary laboratory tests, peak set of CK-MB was recorded, conventional M-mode, 2D and Doppler trans-thoracic echocardiography, offline 2D speckle tracking echocardiography with assessment of longitudinal strain, and coronary angiography.

3.1. Transthoracic echocardiography

After stabilization (amelioration of chest pain), within the first 48 h of the onset of chest pain and prior to coronary intervention, conventional echocardiographic Doppler study, as well as 2D-speckle tracking imaging was performed for all patients using Vivid 7, General Electric Healthcare (GE Vingmed, Norway) equipped with harmonic M4S variable frequency phased-array transducer and echo Pac software for offline analysis.

Images were obtained with patients in the left lateral position at end-expiration according to the recommendations of the American Society of Echocardiography¹² and connected to single lead ECG. All standard measurements were obtained in the parasternal long- and short-axis views; apical 4-chamber, 2-chamber, and apical long axis views.

Quantification of the LV dimensions was done using M-mode echocardiography, and then using the biplane (modified Simpson method).

Assessment of ventricular regional wall motion abnormalities was done using a 16-segment model.¹³ Segmental wall motion was judged by an experienced cardiologist as normal 1; hypokinetic 2; akinetic 3; and dyskinetic 4. Wall motion score index (WMSI) represents the average value of analyzed segments.

3.2. 2D-speckle tracking echocardiography

Longitudinal strain imaging by 2D-speckle tracking echocardiography was done with high quality ECG gated images from the apical four-chamber, two-chamber and three-chamber views, all were obtained at nearly identical heart rates. The gain settings were optimized. The depth was reduced so that the LV occupied most of the image sector. Care was taken

to avoid foreshortening of the LV, the gray-scale frame-rate was kept between 50 and 90 frames/s; minimum three cardiac cycles were obtained for each loop. All the images were obtained in breath-hold to avoid any breathing artifacts. All images were stored in cine-loop format and data were transferred to a workstation for further offline analysis using the Echopac Software (Echo-Pac version 7.0.0 (GE Vingmed)). In order to measure the timing of cardiac events, LV inflow (mitral) and outflow (aortic) velocities were recorded using Pulsed wave Doppler.

3.2.1. Image analysis

In the end-systolic frame, endocardial border was traced manually in its entirety, in the three apical views. The software then generated a region-of-interest (ROI) to include the entire myocardial thickness. The width of the ROI was manually adjusted as required. Care was taken to avoid including bright, echogenic pericardium in the ROI. The software then tracked the myocardial speckles frame-by frame and generates moving images displaying the tracking. Visual inspection of the moving image allowed the operator to determine the adequacy of the tracking. When the tracking was not accurate, the operator returned back and readjusted the ROI or an altogether new ROI was selected.

The software then divided the LV myocardium into six segments in each view and generates segmental and global longitudinal strain. As the myocardium usually shortened in longitudinal direction during systole, the longitudinal strain was displayed below the baseline. From these curves, peak systolic longitudinal strain was recorded for each of the myocardial segments.

The strain values for all the segments were recorded and averaged to obtain the global longitudinal strain (GLS), and also Bull's eye display of the regional and global longitudinal strain was generated, an example is shown in Fig. 1.

GLS was defined to be reduced if it is less negative than -16 .¹⁴ Peak longitudinal strain was considered reduced for basal segments if it is less negative than -10.9% , for mid segments if it is less negative than -12.6% and for apical segments if it is less negative than -14.1% .¹⁵

All echocardiographic and strain analyses were performed separately and blinded to other patient data.

3.3. Coronary angiography

Coronary angiography was performed on clinical indication by standard (Judkins) technique, using digital imaging acquisition and storage. Revascularization was not part of the study protocol and was performed on clinical indication. Compliant to current guidelines, complete revascularization was attempted.

Cine loops in multiple angles were stored, and all analyses were performed in retrospect by a single experienced invasive cardiologist, blinded to the results of the echocardiographic analyses.

Thrombolysis In Myocardial Infarction flow (TIMI flow) was noted, and acute occlusion was defined as TIMI flow 0 or 1. Acute occlusions were differentiated from chronic total occlusions by angiographic appearance (thrombus, collaterals, and calcification), and by the ease with which a guide wire could be crossed.

3.4. Statistical analysis

All demographic, clinical, and technical data were collected and tabulated using the "Data Collection Form" and entered into a computerized database. Statistical Package for Social Sciences (SPSS version 15.0) was used for analyses.

The data were summarized using descriptive statistics: mean, standard deviation, minimal and maximum values for quantitative variables and number and percentage for qualitative values. Statistical differences between groups were tested using Chi Square test for qualitative variables, and independent sample t test for quantitative normally distributed variables while Nonparametric Mann Whitney test was used for quantitative variables which are not normally distributed.

Correlations were done to test for linear relations between variables. Receiver operating characteristic (ROC) curve analysis was done to test the validity of speckle tracking in diagnosing total occlusion of one coronary artery in patients with NSTEMI. *P* value was considered significant if < 0.05 .

4. Results

The mean age of the studied patients was 56.3 ± 9.66 years, and it ranged from 31 to 80 years. 78.3% of them were males (47 patients) and 21.7% were females (13 patients).

Of the 60 patients who presented with acute non ST segment elevation myocardial infarction, 33 (55%) had acute coronary occlusion in one of their coronaries on coronary angiography and 27 (45%) did not have acute coronary occlusion on coronary angiography.

Baseline demographic, clinical and laboratory data for patients with and without acute coronary artery occlusion are presented in Table 1.

4.1. Echocardiographic data

There were no significant differences between the two groups regarding LV dimensions and WMSI. However patients with total occlusion (group A) had significantly lower mean value of LVEF assessed by modified Simpson's method, and they also had significantly attenuated mean value of global longitudinal strain (GLS), as demonstrated in Table 2.

Incidence of reduced GLS (defined as GLS less negative than -16) was more in patients who had total occlusion in one coronary artery (group A) than in patients who didn't have total occlusion (group B), as 60% of group A patients had reduced GLS while only 33.3% of group B patients had reduced GLS, as shown in Table 3.

Number of LV segments with reduced strain (functional risk area by strain) was significantly higher in group A (patients who had total occlusion in one CA) compared to group B (who didn't have total occlusion) 6.6 segments versus 3.7 segments respectively, as shown in Table 3.

Using the ROC curve, the cutoff value of GLS was found to be -15.5% with a sensitivity of 68.9%, specificity of 77.7%, positive predictive value 70% and negative predictive value 57.7% in the detection of total occlusion on coronary angiography. Also the cutoff value for the number of segments with reduced strain was found to be 5 segments with sensitivity of 63.6%, specificity of 77.7%, positive predictive value 71% and negative predictive value 60% (Table 4; Fig. 2).

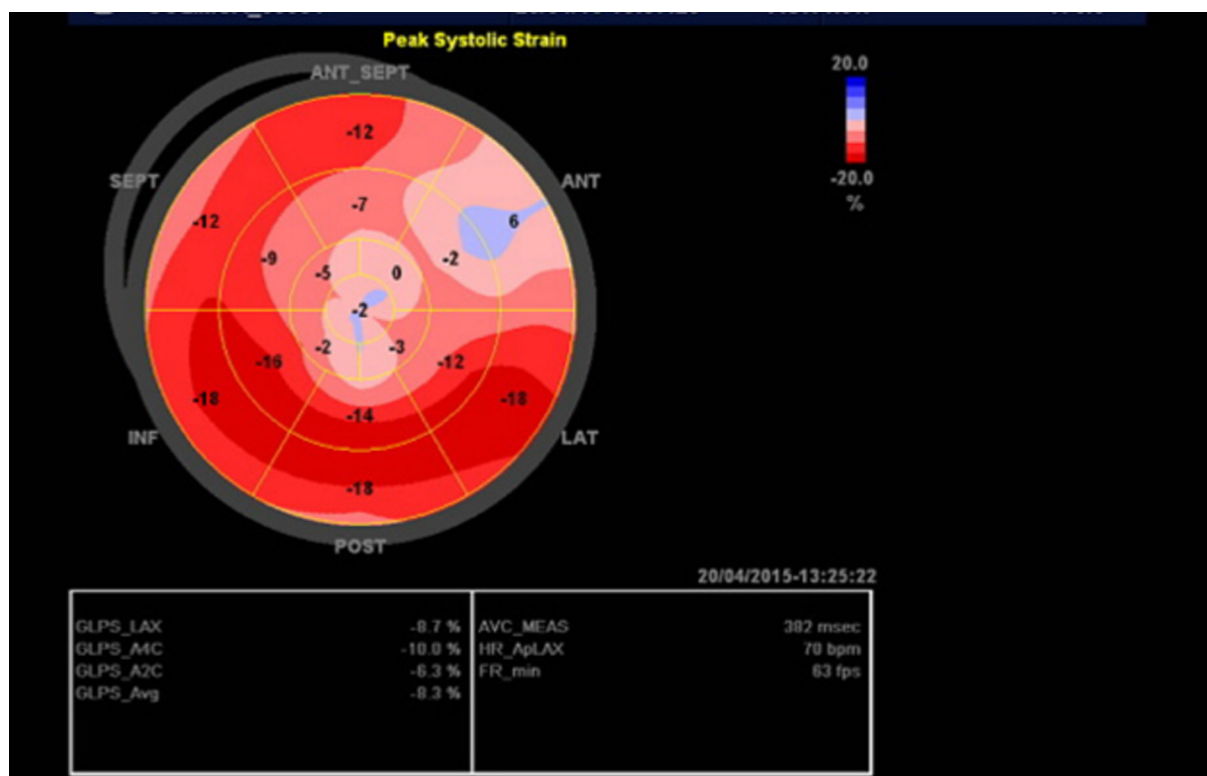


Figure 1 Example of a patient from group A with NSTEMI whose coronary angiography revealed total occlusion of a large marginal branch, and bull's eye plot of strain values demonstrate a markedly reduced GLS (-8.3%) and a functional risk area of nine adjacent segments with reduced strain values.

5. Discussion

Patients with diagnosis of NSTEMI-ACS are a heterogeneous population with different risks of mortality, morbidity, and recurrence in long- and short-term follow-up. In these patients, choosing the treatment strategy depends on the presence or absence of coronary occlusion.¹

Studies have shown that in more than a quarter of NSTEMI-ACS cases, an occluded culprit artery was detected in angiography further reinforcing that coronary artery occlusion can occur despite the absence of ST elevation in standard 12-lead ECG. In this group, urgent reperfusion should be considered.¹⁶ Electrocardiography (ECG) or cardiac biomarkers cannot exactly distinguish acute occlusion. Therefore, finding available, simple, fast methods seems to be necessary.¹⁷

Speckle tracking echo (STE) is a relatively new non-invasive imaging technique that permits assessment of global and regional myocardial function independently from both cardiac translational movements and beam angle in a short time.⁸ STE is accepted as a diagnostic method in ACS cases for evaluation of myocardial wall motion at rest and during stress.¹⁰

One major determinant of final infarct size is the size of the ischemic risk area, defined as the area of the left ventricle supplied by the infarct related artery. Previous experimental studies have demonstrated an excellent correlation between extent of regional systolic dysfunction and ischemic risk area. ST-segment deviations in the ECG, on the other hand, have

demonstrated only modest correlation with both ischemic risk area and final infarct size.³

This study aimed at investigating role of 2D speckle tracking echocardiography as a non-invasive predictor for the presence of acute coronary artery occlusion in patients with non ST-segment elevation acute coronary syndrome.

The current study has shown that around 55% of the patients presented with NSTEMI had acute occlusion of a coronary artery on angiography. In a study carried out by *Aijaz & Hanif* around 39% of the NSTEMI patients who underwent angiography had coronary occlusion.¹⁸ The reason for having lower coronary total occlusion prevalence in their study might be explained by different patient selection criteria as their patients had NSTEMI within the preceding four weeks; however, our patients were in acute stage and about half of their patients were outpatients in whom acute event had passed earlier. This might affect the angiographic findings in the sense that coronary lesions might have become recanalized with initial medical therapy. Further studies have shown variable findings and, depending upon the difference in patient selection, the percentage of occluded coronaries was found to be around 29%¹⁹ to 63%.²⁰

In the current study there was no significant difference between the two groups regarding age or sex distribution. Also there was no significant difference regarding incidence of different risk factors in the two groups.

In concordance with our results *Eek and his colleagues* found no difference between NSTEMI patients who had total

Table 1 Baseline demographic, clinical and laboratory characteristics of the study groups.

	Group A (had acute total occlusion in any coronary artery) (n = 33)	Group B (did not have total occlusion) (n = 27)	P value
Age (years) (Mean ± SD)	54.97 ± 8.67	57.33 ± 10.77	NS
Gender			
Male (n, %)	27 (81.81%)	20 (74.07%)	NS
Female (n, %)	6 (18.18%)	7 (25.92%)	
Hypertension (n, %)	24 (72.72%)	16 (59.25%)	NS
Diabetes (n, %)	17 (51.51%)	9 (33.33%)	NS
Dyslipidemia (n, %)	18 (54.54%)	10 (37.03%)	NS
Smoking (n, %)	19 (57.57%)	14 (51.85%)	NS
DBP (mmHg) (Mean ± SD)	85 ± 10	80 ± 13	NS
SBP (mmHg) (Mean ± SD)	147 ± 25	140 ± 23	NS
CK total (n/ml) (Mean ± SD)	802.79 ± 845	639.41 ± 859.14	NS
CK MB (n/ml) (Mean ± SD)	113.24 ± 102.54	81.04 ± 83.52	NS
Patients presented with normal surface ECG (n, %)	3 (9.1%)	6 (22.2)	0.05*

Table 2 LV dimensions and functions by echocardiography in the study groups.

	Group A (had acute total occlusion in any coronary artery) (n = 33)	Group B (did not have total occlusion) (n = 27)	P value
LVEDD (mm) (Mean ± SD)	52.79 ± 7.01	51.44 ± 6.61	NS
LVESD (mm) (Mean ± SD)	35.82 ± 7.48	33.93 ± 5.04	NS
EF (%) (Mean ± SD)	49.09 ± 9.24	56.7 ± 9.81	0.003
WMSI (Mean ± SD)	1.23 ± 0.3	1.23 ± 0.22	NS
GLS (%) (Mean ± SD)	-13.78 ± 4.08	-16.94 ± 3.88	0.007

occlusion and those who didn't have regarding age distribution and regarding incidence of different risk factors, However males were more common in the those who had total occlusion (88% VS 69%, P = 0.03) in their results.³

In a study carried out by *Aijaz & Hanif*, important predictors for the presence of total occlusion in the initial analysis included male gender, higher age and having diabetes. They stated that most of these, except age, were found to be non-significant in the adjusted model.¹⁸ The difference may be explained by the larger number of patients (703 patients) included in their study and different selection criteria.

In our study we found that incidence of ST changes in multiple ECG leads were more in patients who had total occlusion than those who didn't have total occlusion with a statistically significant difference, while there was no statistically significant difference between the two groups in the peak levels of CPK and CK-MB.

In concordance with our findings *Aijaz & Hanif* found no significant difference in the peak level of Troponin I between NSTEMI patients with any occluded coronary artery and those without occlusion.¹⁸ In another study carried out by *Jung & his colleagues*, on 205 NSTEMI patients to investigate the predictors of total occlusion of the infarct related artery in patients with NSTEMI, total occlusion of the IRA in patients with acute NSTEMI was associated with higher levels of CK-MB, and ST changes in multiple ECG leads²¹, and the partial difference between our results and their results regarding the relation between total occlusion and CK-MB level may be due to the relatively small sample size in our study.

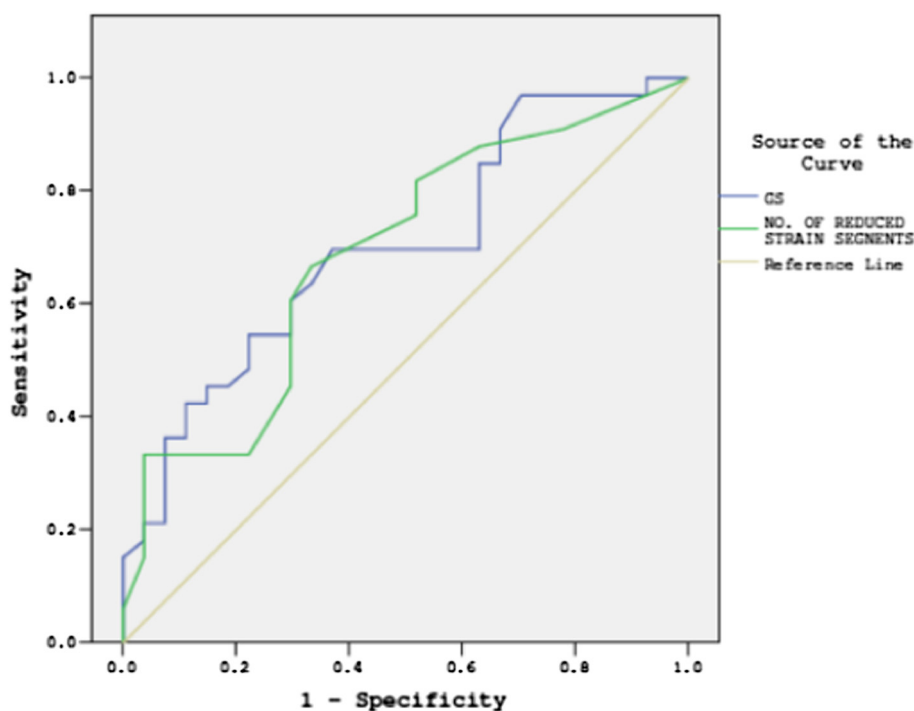
In the current study LVEF by modified Simpson's was significantly lower in patients who had total occlusion compared to patients who didn't have total occlusion while there was no significant difference between the two groups regarding WMSI.

Table 3 Global and regional LV 2D strain.

	Group A (had acute total occlusion in any coronary artery) (n = 33)	Group B (did not have total occlusion) (n = 27)	P value
GLS (%) (Mean ± SD)	-13.78 ± 4.08	-16.94 ± 3.88	0.007
GLS			
Reduced (n, %)	20 (60.6%)	9 (33.3%)	0.035
Normal (n, %)	13 (39.4%)	18 (66.7%)	
No of LV segments with reduced strain (Mean ± SD)	6.64 ± 4.1	3.78 ± 3.48	0.012

Table 4 Coordinate of the ROC curve.

Variable	AUC	<i>p</i> -value	Cutoff	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
GS	0.702	0.007	-15.5	68.9	77.7	70	57.7
No. of segments with reduced strain	0.689	0.012	5	63.6	77.7	71	60

**Figure 2** Graph showing ROC curve of GLS and no. of segments having reduced strain in the presence of total occlusion.

Aijaz & Hanif found that major predictors of having an occluded vessel in NSTEMI patients were older age of the patient and low LVEF.¹⁸ Also Eek & his colleagues studied 150 patients with NSTEMI; their echocardiographic parameters of LV systolic function showed statistically significant difference between patients with and without acute coronary artery occlusion by LVEF and WMSI, and patients with acute occlusion had impaired global LV systolic function compared with patients without occlusion.³

Similar to our results, Grenne & his colleagues found that patients with NSTEMI due to acute coronary occlusion had poorer left ventricular ejection fraction with statistical significant difference than those who didn't have total occlusion.⁶

In this study, NSTEMI patients with acute occlusion had significantly lower global longitudinal strain (*p* value < 0.007), 60% of them had reduced GLS (less negative than -16%) and number of LV segments with reduced strain (functional risk area by strain) was significantly higher in these patients compared to those who didn't have acute coronary occlusion.

Eek and his colleagues studied STE and its ability to identify coronary obstruction in patients with NSTEMI in 2010. They performed echocardiography and angiography for 150 cases. Their results showed a significant difference between the patients with and without coronary obstruction regarding

global and segmental LV function in echocardiography. They also demonstrated that STE results could be useful for choosing patients who may benefit from urgent revascularization.³

In the current study, the cutoff value of GLS using ROC curve was found to be -15.5% with a sensitivity of 68.9%, specificity of 77.7%, positive predictive value 70% and negative predictive value 57.7% in the detection of total occlusion in NSTEMI patients. The cutoff value for the number of segments with reduced strain was found to be 5 segments with sensitivity of 63.6%, specificity of 77.7%, positive predictive value 71% and negative predictive value 60%.

In the study carried out by Eek and his colleagues, speckle tracking derived global strain had a highly significant relationship in prediction of the presence of total occlusion, its sensitivity and specificity in detection of coronary artery occlusion in NSTEMI-ACS were 67% and 71% respectively, and the NPV and PPV were 0.87, and 0.38 respectively at cutoff -16.3%. They also stated that functional risk area (number of segments with reduced strain) can predict the presence of total occlusion, the sensitivity and specificity of number of segments with reduced strain in detection of coronary artery occlusion in NSTEMI-ACS were 85% and 70% respectively, and the NPV and PPV were 0.44, and 0.38 respectively at cutoff 4 segments.³ There was agreement between this study

and Eek's but the cutoff value of number of segments with reduced strain was different due to difference in defining reduced peak longitudinal strain (PLS) of different cardiac segments as in ours we considered PLS reduced for basal segments if it is more than -10.9% , for mid segments if it is more than -12.6% and for apical segments if it is more than -14.1% while in Eek's functional risk area was defined as adjacent cardiac segments with PLS greater than -14% for all LV segments.

6. Conclusion

Both global and regional peak longitudinal systolic strain can offer accurate, feasible, and non-invasive predictor for acute coronary artery occlusion in patients with non ST elevation myocardial infarction. Patients who had GLS less negative than -15.5% and five or more LV segments with reduced strain, most probably had acute total occlusion in one of their coronary arteries.

2D strain can be considered as a part of routine echocardiography in evaluation of NSTEMI patients, and it is a non-invasive method for early detection of the presence of total occlusion to identify patients who may benefit from early reperfusion.

7. Study limitations

Relatively small number of the patients was included and they are from a single medical center. So, larger multicenter and multivendor studies are needed to evaluate more the use of 2D strain in the setting of NSTMI patients. Prior MI was an exclusion criterion in this study, myocardial strain often remain depressed in patients with previous myocardial infarctions, even after successful revascularization, so detecting new coronary artery occlusion may be more challenging in this population. As all patients were in sinus rhythm, no conclusion can be drawn on patients with atrial fibrillation or other arrhythmias. Moreover, we did not study strain rate, post systolic strain or post systolic strain index in our patients which need further studies as they may help in detection of total occlusion.

Conflict of interest

No conflict of interest.

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