Research Article

Correlation Between ECG Changes and 2D Speckle Tracking Echocardiography with Coronary Angiography in Non-ST Segment Elevation Myocardial Infarction Patients

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The clinical presentation of acute coronary syndrome is variable Patients with suspected NSTE-ACS are a heterogeneous group. Coronary occlusion may or may not be present. To correlate 2D speckle tracking echocardiography with coronary angiography results in non-ST segment elevation myocardial infarction patients and test its ability to predict culprit lesion. It is a prospective study where 100 patients with non-ST elevation myocardial infarction were enrolled in the study where regional wall motion score index was obtained by echocardiography then 2D speckle tracking echocardiography was done and territorial longitudinal strain for each vessel was obtained and finally coronary angiography was done. By using the bull's eye view of the territorial LS values obtained from the 17 myocardial segments to predict the culprit artery for each patient the sensitivity for prediction of culprit LAD was 93.3 %, specificity was 92.7 %, For LCX; sensitivity was 82.7 %, specificity was 92.9 % and for RCA; sensitivity was 84 %, specificity was 93.3 %. Longitudinal strain imaging by 2D speckle-tracking might help in the work-up of non-ST elevation myocardial infarction patients. In addition, it may be helpful to localize coronary artery stenosis in a given perfusion territory.

Keywords: NSTEMI, 2D speckle tracking, territorial longitudinal strain, culprit artery, regional wall motion abnormalities.

ABBREVIATIONS

2D: 2 dimensional, ACS: acute coronary syndromes, ASE: American society of echocardiography, CAD: coronary artery disease, CKMB: creatine kinase myocardial band, ECG: electrocardiography, NSTE-ACS: non-ST elevation acute coronary syndromes, LAD: left anterior descending, LCX: left circumflex, NPV: negative predictive value, NSTEMI: non-ST elevation myocardial infarction, PPV: positive predictive value, RCA: right coronary artery, SPSS: segmental peak systolic strain, STEMI: ST elevation myocardial infarction, STE: speckle tracking echocardiography, TLS: territorial longitudinal strain, UA: unstable angina, WMA: wall motion abnormalities.

INTRODUCTION

Acute coronary syndrome (ACS) represents an umbrella of ischemic myocardial disease and diagnoses encompassing unstable angina (UA), non–ST-elevation myocardial infarction (NSTEMI), and ST-elevation myocardial infarction (STEMI). UA and NSTEMI for all intents and purposes share similar pathophysiology but at increasing severity. At the time of the initial emergency department presentation, they may be completely indistinguishable and therefore should be approached and treated similarly (Amsterdam *et al.*, 2014).

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In the acute setting, echocardiography is useful to identify wall motion abnormalities that may be the consequence of acute myocardial ischemia in patients with non-diagnostic ECG changes and ongoing chest pain (Peels *et al.*, 1990). Echocardiographic findings precede electrocardiographic abnormalities and angina. Presence and severity of myocardial dysfunction can be documented rapidly, so that echocardiography is an important modality for risk stratification in the emergency room (Lewis, 2005).

In acute ischemic chest pain, the primary role of rest echocardiography is to assess the presence and extent of regional wall motion abnormalities, encountered in different types of myocardial injury (ischemia, stunning, hibernation or necrosis). Echocardiography alone cannot distinguish between ischemia and infarction; however, the absence of wall motion abnormalities, especially in patients with ongoing or prolonged chest pain > 45 min), excludes major myocardial ischemia (Lancellotti *et al.*, 2014).

Ischemic myocardial tissue will have a different strain pattern than normal myocardium, as it has less movement than normal myocardium. This change seems to occur immediately upon occlusion of the artery. Strain echocardiography appears to be superior to regional WMA in detection of coronary occlusion as it gives an objective measurement (Rowland-Fisher *et al.*, 2016).

There is a variety of ways to demonstrate this strain deformation. A very convenient way is a display that uses a polar map or "bull's-eye". Such a recording provides both a global and regional assessment of the whole left ventricle (Geyer *et al.*, 2010). In the normal recording, all of the segments are red and have values in the twenties or high tens. The advantages of strain or strain rate are that they avoid some of the limitations of wall motion analysis, such as tethering, off-axis false positives and negatives and the difficulties in analyzing subtle wall motion. There are studies showing that strain is more sensitive than wall motion for detecting myocardial ischemia. The recordings are inherently quantitative. It is technically feasible to record strain with stress studies. The strain values are closer to assessing true regional contraction than either wall motion or tissue Doppler. There is evidence to suggest that strain may assist in assessing viability either at rest or with stress (Blessberger *et al.*, 2010).

Radial strain measures thickening (positive strain) whereas longitudinal and circumferential strain measures shortening (negative strain). Radial and circumferential strains are measured in the parasternal short axis while longitudinal strain is measured from apical views (Amundsen *et al.*, 2006).

The distinction between non-transmural and transmural necrosis after myocardial infarction is clinically important, because an increase in the degree of infarct transmurality is associated with a greater number of infarct-related

complications, such as LV dysfunction, arrhythmia, and an increased incidence of sudden death (Marwick *et al.*, 2007).

Speckle-tracking strains have increased sensitivity and specificity in comparison with tissue Doppler for determining the transmural extent of a myocardial infarction. (Gjesdal *et al.*, 2007). Also, it may offer a rapid and sensitive tool to determine which patients with NSTEMI would benefit from urgent revascularization. With the advent and implementation of increasingly sensitive troponin assays, it is likely that there will be an increased proportion of patients with abnormal troponin values who do not require urgent revascularization. Currently, the evaluation of these patients with focused echocardiography may be able to identify an obvious wall motion abnormality; however, in the earliest phase of MI there is microvascular obstruction that does not lead to resultant wall motion abnormalities on conventional echocardiography. The microvascular obstruction results in impaired function of the longitudinally-oriented subendocardial fibers of the LV prior to the development of any overt wall motion changes (Bergerot *et al.*, 2014).

AIM OF WORK

To correlate 2D speckle tracking echocardiography with coronary angiography in non-ST segment elevation myocardial infarction patients and test its ability to predict culprit lesion.

PATIENTS AND METHODS

A single centre observational study was conducted at the Coronary Care Unit on National Heart Institute from February 2018 to January 2019. One hundred patients who had a first episode of non- ST elevation acute myocardial infarction (NSTEMI) were enrolled in this research.

Patient fulfilled the following criteria for diagnosis of non-ST-elevation myocardial infarction (NSTEMI) where the ECG showed ST-segment depression, T-wave inversion or both or even no significant changes with positive cardiac biomarkers (Troponin I > 100 ng/l) and (CKMB > 25 U/l). All patients signed an informed consent and the study was approved by local ethics committee.

Exclusion criteria were previous documented MI either STEMI or NSTEMI, bundle branch block, previous cardiac surgery, any rhythm other than sinus rhythm, poor echocardiographic window, renal function impairment and any cognitive damage.

All patients were subjected to: medical history taking with emphasis on; Age, Gender, Risk factors for CAD including smoking, hypertension and diabetes mellitus and BMI then physical examination and ECG were done and their blood

pressure and heart rate were recorded and blood was drawn for laboratory tests, including serum creatinine, hemoglobin, troponins and CKMB.

Transthoracic echocardiography was done using Philips "epic 7" machine where conventional echocardiography was performed and regional wall motion abnormalities were assessed using the 17-segment model from the ASE. Each segment was given a wall motion score as follows: normal 1; hypokinetic 2; akinetic 3; and dyskinetic 4. For each territory a regional wall motion score index is calculated which is defined as the sum of wall motion scores of the segments comprising a perfusion territory divided by the number of segments in this territory. Then speckle Tracking Echocardiography (STE) was done where the images were acquired in apical views and longitudinal strain was calculated. The software automatically calculated the peak longitudinal strain for each individual segment in a 17-segment LV model, expressed as bull's eye (figure 1). The territorial longitudinal strain (TLS) was calculated for each major coronary artery (left anterior descending artery (LAD), left circumflex artery (LCX) and right coronary artery (RCA) as the average peak systolic longitudinal strain in segments belonging to the theoretical perfusion territory of the artery. Then Coronary angiography and reperfusion were done immediately, culprit vessel was determined and the results were correlated with that of speckle tracking. All patients signed an informed consent and the study was approved by local ethics committee.
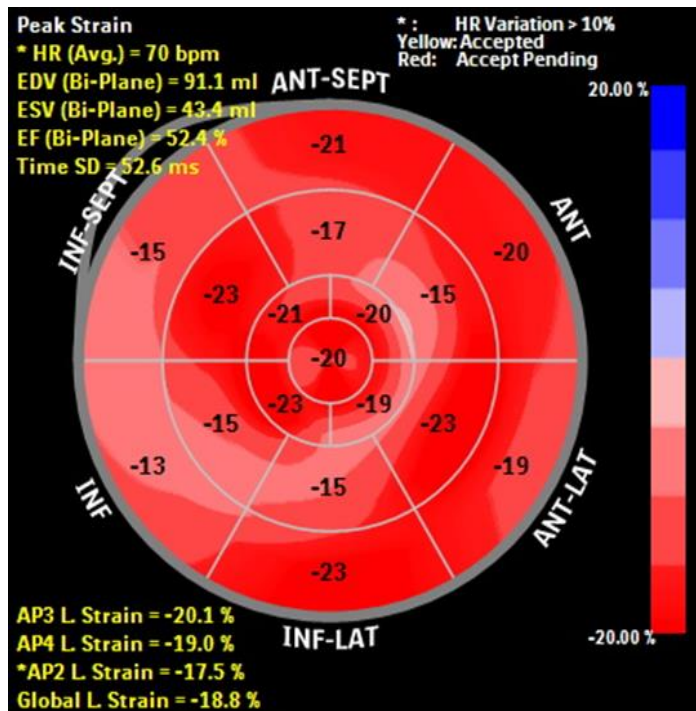

Figure 1: Speckle tracking bull's eye view

RESULTS

Patients characteristics and risk factors

The mean age of the studied population was 56.61± 7.21 years, it ranged from 41 to 74 years. 64 patients of the studied population were males (64 %) and 36 of them were females (36 %). The mean BMI was 28.04 ± 4.39 kg /m2, it ranged from 19 to 32 kg /m2.

Smoking was common among the studied patients, 58 patients in the study were smokers (58 %), 81 patients were diabetics (81 %), 87 patients had hypertension (87 %) (table 1).

Table 1: Baseline Demographic and Clinical Characteristics of the Study Population

Clinical characteristics	Mean ± SD
Age, y	56.61±7.21
BMI, kg/m^2	28.04±4.39
Male gender	64 (64%)
Female gender	36 (36%)
Risk factors for CAD	
HTN	87 (87%)
DM	81 (81%)
Current Smoker	58 (58%)

Data are presented as number (%), mean ± SD

Clinical and Hemodynamic Characteristics on Admission

The mean time from onset of symptoms till admission was 24 ± 8 hours, it ranged from 6 to 72 hours. The mean SBP for the studied patients was 136 ± 17 mmHg, it ranged from 90 to 220 mmHg while mean DBP was 82 ± 12 mmHg, DBP ranged from 50 to 120 mmHg. Mean heart rate was 76 ± 12 beats/min., it ranged from 55 to 130 beats/min, (table 2).

Table 2: Clinical and Hemodynamic Characteristics on Admission

Variable	Mean ± SD
Onset of symptom, hours, median	24±8
Hemodynamics	
Heart rate, bpm	76±12
Systolic blood pressure, mmHg	136±17
Diastolic blood pressure, mmHg	82 ±12

Data are presented as number (%), mean ±SD

ECG findings

The ECG changes were in the form of recent ST depression or T wave inversion /flattening or both, 24 patients showed ST depression (24 %), 27 patients showed T wave inversion /flattening (27 %), 17 patients showed both ST depression and T wave inversion / flattening (17%), while 32 patients showed no changes at all (32 %), (table 3).

Table 3: ECG Characteristics on Admission

ECG	No. of patients
Normal ECG	32 (32%)
ST segment depression	24 (24%)
T wave inversion	27 (27%)
ST depression and T wave inversion /flattening	17 (17%)

Laboratory findings and cardiac enzymes

Troponin I and CKMB were positive in all patients (100 %), with mean troponin I value 263 ± 14 ng/dl and mean CKMB value was 48 ± 6 U/l, while mean hemoglobin on admission was 13.2 ± 1.2 g/dl, it ranged from 8.8 to 16.2 g/dl and mean baseline creatinine on admission was 0.8 ± 0.3 mg/dl, it ranged from 0.5 to 1.4 mg /dl. (table 4).

Table 4: The main laboratory findings on Admission

Laboratory findings	Mean ±SD
Hemoglobin %	13.2±1.2
Troponin I, ng/dl	263±14
CKMB U/l	48±6
Baseline serum creatinine, mg/dl	0.8 ± 0.3

Data are presented as number (%), mean ±SD

Speckle tracking findings

Using the bull's eye 17 segment model, only one culprit vessel was identified for every patient by using the territorial longitudinal strain which is the average peak systolic longitudinal strain in segments belonging to the theoretical perfusion territory of the artery and considering the culprit with the least negative value.

The culprit identified by STE was left anterior descending artery (LAD) in 45 patients of which 42 patients were true positive as identified by coronary angiography, while in the other 3 patients were false positive.

For left circumflex (LCX) it was identified as a culprit by STE in 29 patients of which 24 patients were true positive while the other 5 patients were false positive.

For right coronary artery (RCA) it was identified as a culprit by STE in 26 patients of which 21 patients were true positive while the other 5 patients were false positive.

Angiographic findings

One culprit vessel is identified in every patient, the actual culprit vessel is identified by coronary angiography and used as a reference for results correlation with territorial longitudinal strain analyzed by speckle tracking echocardiography. Culprit vessel was identified as left anterior descending artery (LAD) in 46 patients (46%), left circumflex (LCX) in 29 patients (29%), and right coronary artery (RCA) in 25 patients (25%).

Correlation between speckle tracking and coronary angiography findings

We used the bull's eye view of the territorial LS values from the 17 myocardial segments to predict the culprit artery for each patient, repeating the analysis several times with cut-off values -16% for impaired regional LS. A cut off value of -16% yielded moderate agreement between the predicted and actual culprit artery considering the culprit territory with the least negative value. Using this method, we correctly identified culprit LAD in 42 out of 46 (91.3%), LCX in 24 out of 29 (82.7%), and RCA in 21 out of 25 patients (84 %).

The sensitivity for prediction of culprit LAD was 93.3 %, specificity was 92.7 %, the positive predictive value was 91.3 %, the negative predictive value was 94.4 % and accuracy was 93 %. For detection of culprit LCX sensitivity was 82.7 %, specificity was 92.9 %, the positive predictive value was 82.7 %, the negative predictive value was 92.9 % and accuracy was 90 %. For detection of culprit RCA sensitivity was 84 %, specificity was 93.3 %, the positive predictive value was 80.7 %, the negative predictive value was 94.5 % and accuracy was 91 %. So, the highest sensitivity was for prediction of culprit LAD (93.3%) and the lowest was for prediction of culprit LCX (82.7 %) and the highest specificity was for prediction of culprit RCA (93.3%) and the lowest specificity was for prediction of culprit LAD (92.7 %) and the highest accuracy was for detecting culprit LAD (93 %) and lowest one was for detection of culprit LCX (90 %) Table 5, Figure 2 and Figure 3. The overall sensitivity of bull's eye strain to detect culprit vessel is ranging from 82.7 to 93.3 % while overall specificity is ranging from 92.7 to 93.3 % and the accuracy ranged from 91- 93% for the 3 vessels.

Table 5: Sensitivity, specificity, accuracy, positive and negative predictive values for prediction of culprit artery by speckle tracking echocardiography

	LAD (%)	LCX (%)	RCA (%)
Sensitivity	93.3	82.7	84
Specificity	92.7	92.9	93.3
PPV	91.3	82.7	80.7
NPV	94.4	92.9	94.5
Accuracy	93	90	91

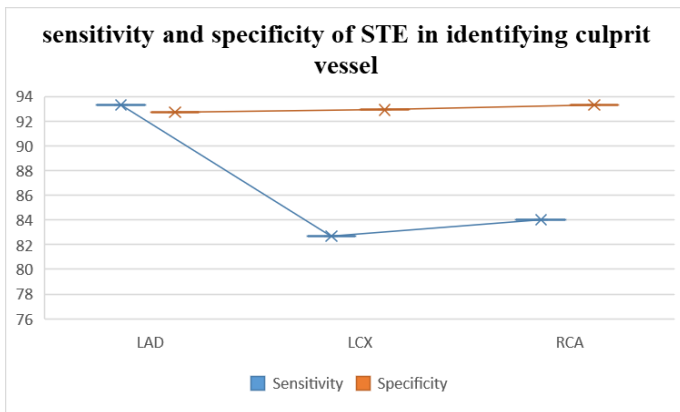PPV: positive predictive value, NPV: negative predictive value

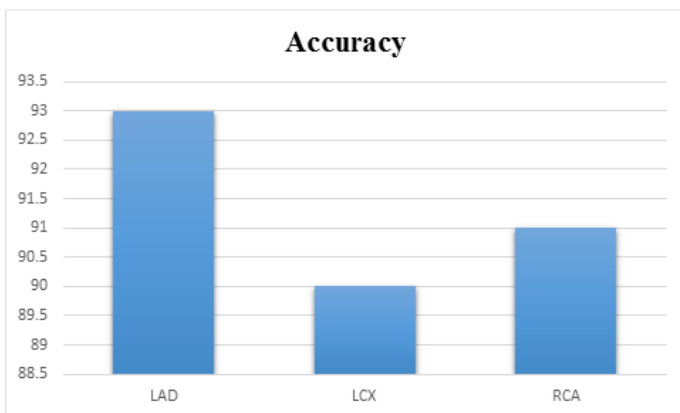**Figure 2:** sensitivity and specificity of STE in identifying culprit vessel

Figure 3: accuracy of STE in detection of culprit vessel

DISCUSSION

Two-dimensional (2D) strain imaging is a novel echocardiographic technique for obtaining strain measurements. It analyzes motion by tracking speckles in the ultrasonic image in two dimensions. It is simple to perform, and requires only one cardiac cycle to be acquired; further processing and interpretation can be done after image data acquisition. Because it is not based on tissue Doppler measurements, it is angle independent (Perk *et al.*, 2007).

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. (Christian *et al.*, 1992). Previous experimental studies have demonstrated an excellent correlation between extent of regional systolic dysfunction and ischemic risk area (Buda *et al.*, 1986).

A substantial fraction of patients with non-ST-elevation acute coronary syndrome NSTE-ACS 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. Strain

echocardiography is a validated and accurate measure of regional systolic LV function. Importantly, in current clinical practice, there exists no other instant diagnostic method to uncover acute coronary occlusion when ECG fails, STE is accepted as a diagnostic method in ACS cases for evaluation of myocardial wall motion at rest and during stress (Eek *et al.*, 2010).

So, the aim of our study was to test if territorial longitudinal strain by speckle tracking echocardiography (STE) can offer non-invasive assessment of significance of coronary artery lesion in NSTE-ACS.

The mean age of our studied population was 56.61± 7.21 years, 64 % of the studied population were males and 36 % of them were females. 58 % of the patients in our study were smokers, 81 % of patients were diabetics, 87 % of patients had hypertension. the mean SBP for the studied patients was 136 ± 17 mmHg, mean DBP was 82 ± 12 mmHg and mean heart rate was 76 ± 12 beats/min

In a study done by Sarvari *et al.*, 2013 who studied NSTEMI patients with significant CAD, 22 % were smokers, 67 % were hypertensives, 22 % were diabetics, mean age was 63.3±9.3. 88 % of patients were males and 12 % were females. mean heart rate was 66 ± 11 beats/min, mean SBP, was 151± 24 mmHg and mean DBP was 78 ±11 mm Hg.

Also, in Grenne *et al.*, 2010. Among NSTEMI patients with coronary occlusion the mean age was 60.5±13.0 years, 67 % were males while 33 % were females, 48 % were smokers, 38 % were hypertensives, 11 % were diabetics, mean SBP was 138±25, mean DBP was 80 ± 14, mean heart rate was 71±15.

And in Caspar *et al.*, 2017 The patients' mean age was 58.4 ± 12.8 years, 60.3 % were males, 60.3 % were hypertensives, 32.8 % were diabetics, 46.6 % were smokers.

We used the bull's eye view of the regional LS values from the 17 myocardial segments to predict the culprit artery. The territorial longitudinal strain (TLS) was calculated for each major coronary artery (left anterior descending artery (LAD), left circumflex artery (LCX) and right coronary artery (RCA) as the average peak systolic longitudinal strain in segments belonging to the theoretical perfusion territory of the artery and their results are correlated with that of the coronary angiography where coronary occlusion was defined as TIMI (Thrombolysis in Myocardial Infarction) flow grade 0 or 1, while significant coronary artery stenosis was considered as a > 50% reduction of vessel diameter in at least 1 major coronary artery. A cut off value of -16 % yielded moderate agreement between the predicted and actual culprit artery. Using this method and cut off value we correctly identified culprit LAD in 91.3%, LCX in 82.7%, and RCA in 84 %.

Our coronary angiography (CA) results identified LAD as a culprit in 46 % of patients, LCX in 29 % of patients, RCA in 25 % of patients. While in Grenne *et al.*, 2010. The culprit on CA was LAD in 19 % of patients, LCX in 25 % of patients, RCA in 24 % of patients and 5 % were multivessel disease. While in D'Andrea *et al.*, 2011 Who studied STE among NSTEMI patients, the culprit on CA was LAD in 45.5 % of patients, LCX in 22.2 % of patients, RCA in 32.7 % of patients.

In our study the sensitivity for prediction of culprit LAD was 93.3 % and specificity was 92.7 %. For LCX sensitivity was 82.7 % and specificity was 92.9 %. For RCA sensitivity was 84 % and specificity was 93.3 %. So, the highest sensitivity was for prediction of culprit LAD (93.3%) and the lowest was for prediction of culprit LCX (82.7 %) and the highest specificity was for prediction of culprit RCA (93.3%) and the lowest specificity was for prediction of culprit LAD (92.7 %).

Casper *et al.*, 2017 who studied NSTEMI patients, a TLS was used to predict culprit artery correlated with results of coronary angiography yielding a sensitivity of 91% and a specificity of 86% for culprit LAD lesions, for LCX lesions yielded a sensitivity of 87% and a specificity of 81.4%. and for RCA lesions yielded a sensitivity of 82% and a specificity of 78%.

Anwar and Ashraf, 2013 compared the regional wall motion score and regional LS of the 17 myocardial segments for 25 patients with suspected or known CAD (excluding previous MI) for the diagnosis of significant CAD. The findings were validated against the results of coronary angiography. A cut-off regional LS value of -11% was used to differentiate normal from abnormal segments. Their results are in positive concordance with that of our study with sensitivity rates for the diagnosis of LAD, LCX and RCA based on LS were 68.5%, 69.3%, and 68%, respectively. The corresponding specificity rates were 77.1%, 76%, and 78%, respectively.

Shimoni *et al.*, 2011 studied patients with CAD. they studied sensitivity and specificity for segmental peak systolic strain (SPSS) for each coronary territory which correspond to territorial longitudinal strain (TLS) which was used in our study. Their results showed good overall sensitivity for SPSS but a lower overall specificity. For LAD sensitivity and specificity for SPSS was 74 % and 51 % respectively. for LCX sensitivity and specificity for SPSS was 77 % and 64 % respectively. for RCA sensitivity and specificity for SPSS was 79 % and 57 % respectively.

Feigenbaum *et al.*, 2012 demonstrated that longitudinal strain is more sensitive than radial strain to detect ischemia, since the RWMA reflects radial thickening rather than longitudinal deformation This data might explain why longitudinal strain is more sensitive than RWMA.

Moaref *et al.*, 2016 concluded in their case-control study that STE could be effective in diagnosis of patients with Non-ST-segment Elevation Acute Coronary Syndrome (NSTE-ACS) and planning strategies for their treatment.

On the contrary, in a study done by Grenne *et al.*, 2010 on 111 patients with NSTEMI demonstrated that territorial circumferential strain was better than territorial longitudinal strain in predicting culprit lesion and identifying acute coronary occlusion. Which was attributed probably to the helical structure of myocardial fibers, with subendocardial fibers having a dominant longitudinal direction, whereas mid-myocardial fibers are more circumferentially oriented. With increasing severity, ischemia and necrosis propagate in a transmural wave front extending from the endocardium to the epicardium. Nonocclusive coronary lesions probably cause predominantly subendocardial ischemia with impaired longitudinal function. In contrast, acute coronary occlusions cause transmural ischemia with both longitudinal and circumferential dysfunction.

Also, a study done by Dahlslett *et al.*, 2014 on NSTEMI patients demonstrated that territorial strain was inferior to global longitudinal strain's in separating patients who have significant coronary stenoses from those who haven't. This was somewhat surprising because ischemic heart disease most commonly presents with regional LV dysfunction Which was explained by that territorial strain was based on anatomic perfusion territories and these anatomic territories may not necessarily apply to the actual perfusion territory of an individual patient, because of both misalignment of image planes and individual variations in the perfusion territory of the coronary arteries. The affected territory may thus be split between two or three of the studied territories. Most important, territorial strain values are based on only five or six segments, making territorial strain a much less robust parameter than global strain, which is calculated on the basis of 17 segments.

CONCLUSION

the present study suggests that myocardial longitudinal strain imaging by 2D speckle-tracking might be of help in the diagnostic work-up of non-ST elevation myocardial infarction patients. In addition, the territorial longitudinal strain may be helpful to localize coronary artery stenosis in a given perfusion territory.

CONFLICTS OF INTEREST: none.

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