ECRONICON OPEN ACCESS

EC CARDIOLOGY
Research Article

Early Prediction of Myocardial Viability Following Acute Myocardial Infarction by Two-Dimensional Speckle Imaging

Mohamed Abdelmonem Aboutaha*, Neama Ali Elmeligy, Azza Ali Katta, Osama Sanad Arafa, Mohamed El Bordy, Mohamed Samir Hamada, Hany Abd El Salam Basiouny and Mohamed Mahrous Ali

Department of Cardiology, Benha University, National Heart Institute, Egypt

***Corresponding Author:** Mohamed Abdelmonem Aboutaha, Department of Cardiology, Benha University, National Heart Institute, Egypt.

Received: August 11, 2020; **Published:** November 28, 2020

Abstract

Background: Identifying the transmural extent of myocardial necrosis and the degree of myocardial viability in acute myocardial infarction (AMI) is important clinically.

Aim of the Study: The aim of this study was to assess myocardial viability using two-dimensional speckle tracking imaging (2D-STI) in patients with AMI.

Methods: 2D-STI was performed within three days of hospital admission and six months after primary percutaneous coronary intervention (PCI) in 50 patients with AMI, who had a left anterior descending coronary artery (LAD) culprit lesion. In addition, 25 patients who had minimal stenotic lesions (< 30% stenosis) on coronary angiography were also included in the control group. At six months dobutamine echocardiography was performed for viability assessment in seven segments of the LAD territory. According to the recovery of wall motion abnormality, segments were classified as viable or non-viable.

Results: A total of 288 segments were viable, and 62 were nonviable. There is statistical significant difference between the viable and nonviable segments in the peak systolic strain and the peak systolic strain rate measured within three days from acute myocardial infarction. AUC for peak systolic strain (0.957, p. < 0.001), 95%C.I. (0.937 - 0.976) showed that a cut off level of < -9 had sensitivity of 86.11 and specificity 87.1 for prediction of viable myocardium. AUC for peak systolic strain rate (0.87, p. < 0.001), 95%C.I. (0.809 - 0.931) showed that a cut off level of < -0.7 had sensitivity of 91.6 and specificity 74.19 for prediction of viable myocardium.

Conclusion: In patients with recent first acute MI, Strain and strain rate measurements are feasible, inexpensive, quantitative, and rapid methods that can predict myocardial viability with high sensitivity and specificity.

Keywords: *Acute Myocardial Infarction (AMI); Two-Dimensional Speckle Tracking Imaging (2D-STI); Percutaneous Coronary Intervention (PCI)*

Introduction

Primary percutaneous coronary intervention (PCI) refers to the technique of bringing a patient who presents STEMI directly into the cardiac catheterization laboratory to undergo mechanical revascularization using balloon angioplasty, coronary stents, aspiration thrombectomy, and other steps. It has replaced fibrinolysis as the preferred reperfusion strategy in patients with STEMI, provided it can be performed in a timely manner in high-volume PCI centres with experienced operators and 24-hour, 7-day catheterization laboratory

activation [1]. An essential criterion for revascularisation of patients with acute myocardial infarction (AMI) is the determination of viable sources of myocardium [2]. This can be measured using Dobutamine echocardiography, positron emission tomography (PET), F18-fluorodeoxyglucose (FDG), perfusion scans, 64-slice computed tomography (CT), and contrast-enhanced magnetic resonance imaging (MRI). Although numerous imaging modalities have been used, these methods are often restricted by their availability, cost, technical difficulty, subjective character or a combination of these factors [3]. In the acute setting, on the other hand, echocardiography is more readily available and feasible technique. Doppler's use of strain (deformation) quantifies regional myocardial deformation, which can show irregular myocardial function due to ischemia. Some investigators proposed that strain via tissue Doppler images (TVI) could serve as a marker of viability. Although TVI and Doppler strain measurements were most commonly used in this clinical setting, they are restricted by the Doppler angle dependence [4]. A system for measuring strain based on two-dimensional speckle tracking imaging (2D-STI) has been developed to remove the angle-dependence problem, which offers quantitative and angle-independent measurements for myocardial strain assessment [5].

Methods

Study population

This is a prospective observational study including 50 patients with first ST- segment elevation myocardial infarction (STEMI) in the anterior wall planned for primary PCI in National Heart Institute, in addition, there is 25 patients with normal coronary angiography as a control group.

Inclusion criteria

Patients are going to be included in this study if they present within 12 hours from the onset of symptoms (characteristic chest pain lasting for at least 30 minutes, not responsive to nitrates, with electrocardiographic ST-segment elevation of at least 0.2 mV in two or more contiguous leads, or new left bundle-branch block).

Exclusion criteria

Moderate and severe valvular heart disease, major cardiovascular disease, major arrhythmia, patients undergoing percutaneous coronary intervention (PCI) after 12 h of onset of symptoms, and patients requiring thrombolytic therapy rather than PCI.

All the patients are also will be subjected to all of the following:

- Full history taking.
- Full clinical examination.
- ECG at presentation.
- Primary PCI will be performed by a 24-hours on-call interventional team, according to standard clinical practice.

Echocardiography

Echocardiographic evaluation performed within three days of hospital admission, and six months after primary percutaneous coronary intervention (PCI) in all 50 patients and the control groups. Using X5-1 transducer, PHILIPS EPIQ 7C machine with 2D-STI of the

7 segments of LAD territory (mid and apical anterior wall, apical inferior wall, mid and apical lateral wall, mid and apical septum)this required apical 2, 3 and 4 chamber views, The endocardial border was traced in an end-systolic frame. The program automatically selected six equidistant tissue tracking regions of interest in the myocardium and changed the outer boundary roughly to the epicardial boundary. then images were transferred to ECHOPAC for offline analysis, at six months Dobutamine Echocardiography performed and interpreted by 2 professors specialilized in dobutamine echocardiography for viability assessment in seven segments of the LAD territory. The recovery of wall motion abnormality will mark parts of the LAD territories as viable or non-viable. The recovery of the regional wall motion abnormality was described as an improvement from akinesia or dyskinesia to normal or mild hypokinesia. A viable segment in echocardiography or dobutamine echocardiography six months after PCI was identified as recovery of the regional wall motion abnormality, while a non-viable segment was identified as no recovery of the regional wall motion abnormality.

Statistics

Statistical analyzes were performed using the Windows ver. 17.0 software package SPSS Statistics, A two-sided $P < 0.05$ was considered significant.

Continuous variables were measured using the independent t-test or Mann-Whitney U test, reported as mean ± SD. Categorical variables, presented as frequencies and percentages, were measured using the chi-square or, where applicable, Fisher 's exact test. To assess the predictive capacity of the continuous variables to define myocardial viability, a logistic regression model was employed. Correlations were conducted using the Pearson correlation coefficient for the reproducibility study. Similarly to the logistic model, the receiver operating characteristic (ROC) curves were also determined in order to predict myocardial viability between the different steps.

Results

The studied population were classified according to the results into two groups: viable group (38 patients) and non-viable group (12 patients) in addition to the control group (25 patients).

There was non-statistical significant difference between the three groups regarding baseline characteristics (Age and sex), clinical examination (Blood pressure, Heart rate), risk factors (Hypertension, DM, Dyslipidemia, Smoking), Door to balloon time and end diastolic volume.

But there was statistical significant difference between the three groups regarding time to door, End systolic volume, Ejection fraction, peak systolic strain and strain rate (both at baseline and after 6 months).

Angiographic findings

Infarction related artery

In the studied group, LAD was the infarction related artery in all patients.

In the control group, LAD was free of stenosis or less than 30% in all patients.

	STEMI (n = 50)		Control (n = 25)	P
	Viable (n = 38)	Non-viable (n = 12)		
Age (years)				
Min. - Max.	40 - 67	41 - 63	40 - 65	
Mean ± SD.	51.63 ± 8.58	51.67 ± 8.35	52.32 ± 6.63	0.941
SBP				
Min. - Max.	110 - 160	100 - 190	110 - 160	
Mean ± SD.	132.6 ± 12.23	145 ± 31.19	133.6 ± 12.21	0.077
DBP				
Min. - Max.	70 - 100	60 - 120	70 - 90	
Mean ± SD.	83.68 ± 6.75	90 ± 20.89	82.8 ± 6.78	0.120
HR				
Min. - Max.	70 - 104	60 - 110	70 - 94	
Mean ± SD.	87.58 ± 8.2	84.33 ± 17.29	82.24 ± 6.96	0.108
HTN				
n (%)	20 (52.6)	10 (83.3)	13 (52)	0.139
DM				
n (%)	12 (31.6)	8 (66.7)	10 (40)	0.096
DLP				
n (%)	8 (21.1)	2 (16.7)	11 (44)	0.089
Smoking				
n (%)	22 (57.9)	8 (66.7)	11 (44)	0.367

Table 1: *Comparison between the studied groups according to baseline characteristics.*

	STEMI (n = 50)		P
	Viable (n = 38)	Non-viable (n = 12)	
Symptom to door			
Min. - Max.	30 - 300	140 - 330	
Mean ± SD.	167.4 ± 61.85	210.0 ± 58.15	0.040*
Door to balloon			
Min. - Max.	30 - 60	30 - 60	
Mean ± SD.	42.37 ± 11.55	46.67 ± 11.55	0.267

Table 2: *Comparison between the studied groups according to the time interval.*

Echocardiographic findings	STEMI (n = 50)		Control (n = 25)	P
	Viable (n = 38)	Non-viable (n = 12)		
End diastolic volume				
Min. - Max.	81.6 - 201	100.5 - 134.4	89.8 - 155.9	
Mean ± SD.	123.8 ± 29.65	117.7 ± 12.93	120.6 ± 17.57	0.712
End systolic volume				
Min. - Max.	32.5 - 79	46.6 - 77.5	26.9 - 63.1	
Mean ± SD.	52.48 ± 11.69	63.08 ± 11.81	45.8 ± 7.95	< 0.001*
Ejection fraction				
Min. - Max.	45 - 65	34 - 64	52 - 70	
Mean ± SD.	55.47 ± 6.83	45.83 ± 10.76	61.8 ± 4.65	< 0.001*

***Table 3**: Comparison between the studied groups according to echocardiographic findings.*

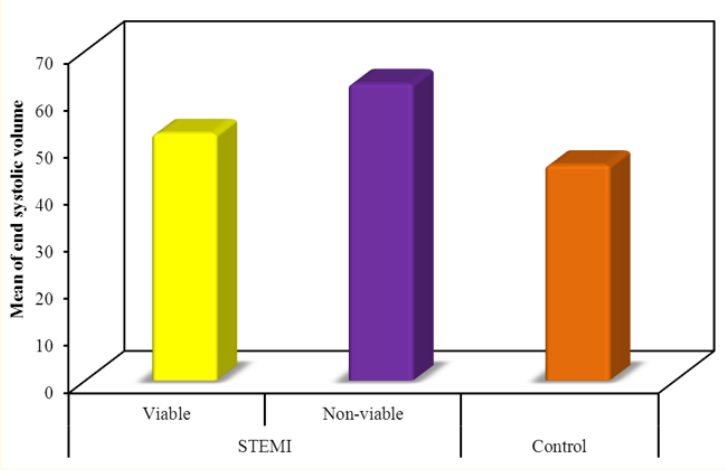

***Figure 1:** Comparison between the studied groups according to End systolic volume.*

Associated lesions

In the studied group, there was a significant lesions in LCX in 2 patients in the viable group and in 3 patients in the non-viable group, while RCA was significant in 4 patients in viable and 4 in non-viable groups.

There were no significant lesions in LCX or RCA in the control group.

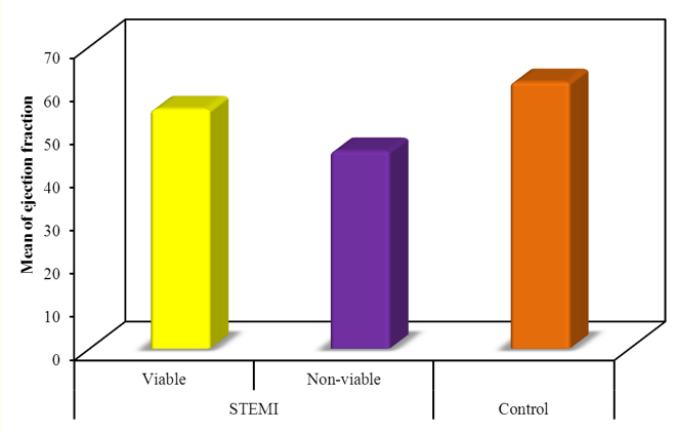

Figure 2: *Comparison between the studied groups according to Ejection fraction.*

	STEMI (n=50)				Control (n = 25)	
	Viable (n = 38)		Non-viable (n=12)			
	No.	%	No.	%	No.	%
IRA LAD	38	100	12	100	0	0
LCX	2	5.3	3	25	0	0
χ^2(^{FE}p)	3.947 (0.082)					
RCA	4	10.5	4	33.3	0	0
χ^2(^{FE}p)	3.53 (0.082)					

Table 4: *Comparison between the studied groups according to angiographic findings and associated lesion.*

2D-speckle tracking

7 segments of LAD territory were studied by 2D speckle tracking in all 50 patients in the studied group and 25 patients in the control group, then the segments were divided into viable and non-viable according to result of Dobutamine Echo done after 6 months from myocardial infarction.

Baseline Peak longitudinal systolic strain ranged from (-21 - -14) in the viable group with a mean (-13.03 ± 4.32), while in the non-viable group, it ranged from (-9 - -2) with a mean (-5.32 ± 2.31).

In the control group, it ranged from (-34 - -14) with a mean (-23.10 ± 3.96).

Baseline Peak longitudinal systolic strain rate ranged from (-2 - -0.7) in the viable group with a mean (-0.94 ± 0.23), while in the non-viable group, it ranged from (-1 - 0) with a mean (-0.51 ± 0.29).

In the control group, it ranged from (-2 - -1.2) with a mean (-1.38 ± 0.51).

After 6 months

Peak longitudinal systolic strain ranged from (-34 - -13) in the viable group with a mean (-17.35 ± 5.99), while in the non-viable group, it ranged from (-10 - -3) with a mean -(-6.81 ± 1.99).

Peak longitudinal systolic strain rate ranged from (-2 - -0.6) in the viable group with a mean (-1.06 ± 0.3), while in the non-viable group, it ranged from (-1 -0) with a mean (-0.55 ± 0.28).

		STEMI (n = 350)		Control (n = 175)	P
		Viable (n = 288)	Non-viable (n = 62)		
Strain	**Baseline**				
	Min. - Max.	-21 - -14	-9 - -2	-34 - -14	< 0.001*
	Mean ± SD.	-13.03 ± 4.32	-5.32 ± 2.31	-23.1 ± 3.96	
	After 6 months				
	Min. - Max.	-34 - -13	-10 - -3	---	< 0.001*
	Mean ± SD.	-17.35 ± 5.99	-6.81 ± 1.99	---	
Strain rate	**Baseline**				
	Min. - Max.	-2 - -0.07	-1 - 0	-2 - 1.2	< 0.001*
	Mean ± SD.	-0.94 ± 0.23	-0.51 ± 0.29	-1.38 ± 0.51	
	After 6 months				
	Min. - Max.	-2 - -0.6	-1 - 0	---	< 0.001*
	Mean ± SD.	-1.06 ± 0.3	-0.55 ± 0.28	---	

Table 5: *Comparison between the studied groups according to strain and strain rate.*

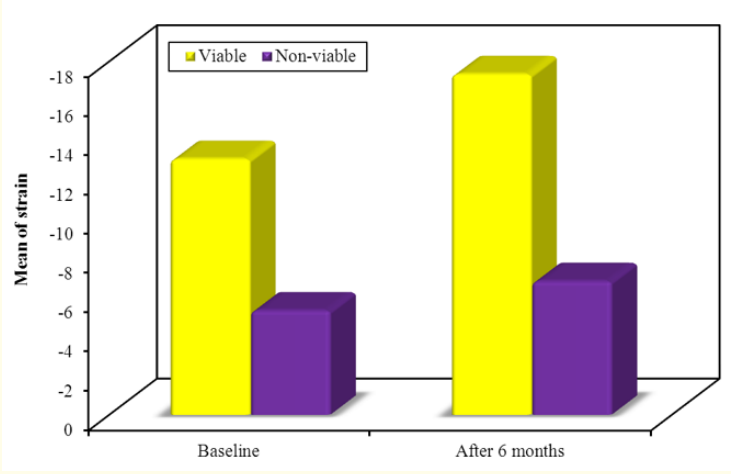

Figure 3: *Comparison between the studied groups according to strain.*

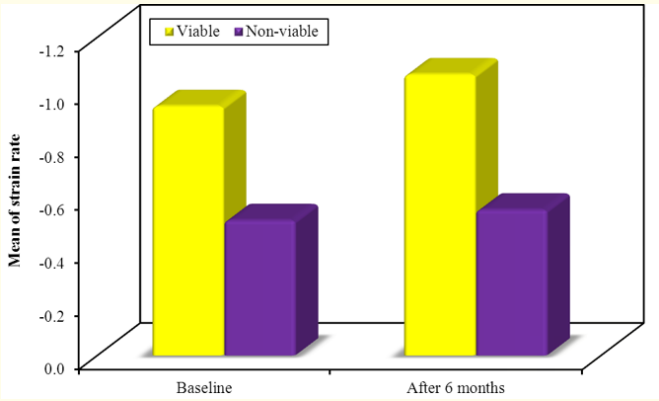

Figure 4: *Comparison between the studied groups according to strain rate.*

Prediction of viable segments

ROC curve done for baseline peak systolic strain and strain rate and revealed that:

- AUC for peak systolic strain (0.957, p. < 0.001), 95%C.I. (0.937 - 0.976) showed that a cut off level of <-9 had sensitivity of 86.11 and specificity 87.1 for prediction of viable myocardium.
- AUC for peak systolic strain rate (0.87, p. < 0.001), 95%C.I. (0.809 - 0.931) showed that a cut off level of <-0.7 had sensitivity of 91.6 and specificity 74.19 for prediction of viable myocardium.

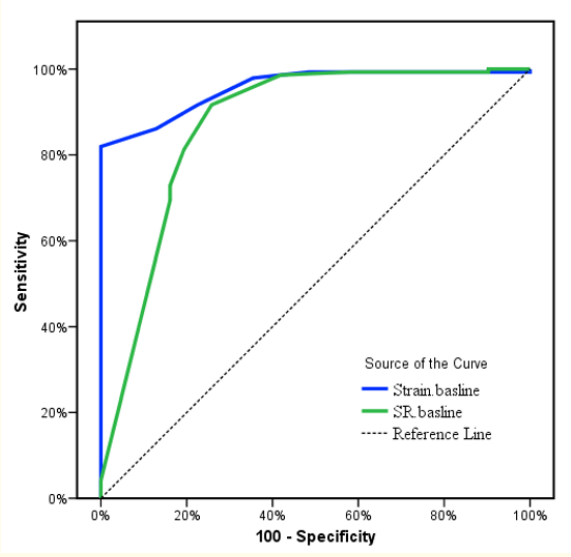

Figure 5: *ROC curve for Strain and Strain rate to predict viable vs non-viable.*

Baseline	AUC	P	95% C.I	Cut off	Sensitivity	Specificity	PPV	NPV
Strain	0.957	< 0.001*	0.937 - 0.976	≤-9	86.11	87.10	96.9	57.4
Strain rate	0.870	< 0.001*	0.809 - 0.931	≤-0.7	91.67	74.19	94.3	65.7

Table 6: *Agreement (sensitivity, specificity) for Strain and Strain rate to predict viable vs non-viable.*

Discussion

Assessing viability in AMI patients is important to determine the prognosis of patients and to determine if revascularisation is appropriate. Several modalities can be used to determine myocardial viability, such as 2-D echocardiography, contrast-enhanced MRI, 64-slice CT, and F18-FDG PET. Such modalities are comparable in their sensitivity and specificity [6].

The contrast-enhanced MRI and F18-FDG PET are, however, expensive and inaccessible to patients with acute conditions like AMI. The 64-slice CT has the threat of radiation, even recently this modality has been commonly practiced.

Assessing myocardial viability based on WMSI during dobutamine echocardiography is difficult and subjective. Therefore, more feasible, inexpensive, quantitative, and rapid methods to assess myocardial viability are needed, especially in patients with AMI. Tissue Doppler imaging enables the non-invasive assessment of myocardial strain in the LV. Measuring strain and strain rate using low-dose dobutamine echocardiography was feasible and their use in conjunction with WMS assessment improves the sensitivity of dobutamine echocardiography viability assessments [7].

Doppler-derived PSS was a clinical tool for the detection of contracting and thus viable myocardium in dog models. Moreover, in dog models of acute coronary occlusion, the LS ratio determined using Doppler echocardiography defined areas of active contraction and necrosis [8].

In addition, a previous study found an inverse association between the segmental strain and the transmural extent of the infarction in each segment, as calculated after coronary reperfusion using contrast-enhanced MRI. Analyzing segments using the peak systolic strain rate, as measured from the dobutamine stress echocardiography response based on automated strain rate imaging analysis, provides prognostic knowledge that is independent of and incremental to standard WMSI. Doppler imagery of tissue is however limited by angle dependence. Also, the resulting strain rate profiles tend to be noisy, and it can be difficult to measure. The 2D-STI overcomes these constraints. It is a new method for estimating tissue- tracking based motion using time-domain processing and measures strain independent of cardiac translation and angle dependence [9].

So, this study was conducted on 50 patients presented by first time Acute Myocardial Infarction and treated by Primary PCI, then echocardiography wad done for all patients with 2 D speckle tracking for early prediction of myocardial viability, finally stress Dobutamine echo done 6 months after for evaluation of myocardial viability as a gold standard and the myocardial segments were divided into viable and non-viable.

Regarding results of this study, there was no significant statistical difference between both studied group and control group regarding general characteristics and risk factors, But there was significant statistical difference between viable and non-viable groups regarding

symptom to door time, ejection fraction and end systolic volume, these results come in agreement with Jong Shin Woo et.al, who conducted a study in 2015 to predict myocardial viability early after myocardial infarction by two-dimensional speckle tracking imaging.

Also values of regional peak longitudinal strain and strain rate were higher in variable group in comparison to non-viable group both at baseline (-13.03 ± 4.32, -5.32 ± 2.31) and after 6 months (-17.35 ± 5.99, -6.81 ± 1.99) respectively with significant statistical difference ($p < 0.001$).

Also values of regional peak longitudinal strain rate were higher in variable group in comparison to non-viable group both at baseline (-0.94 ± 0.23, -0.51 ± 0.29) and After 6 months (-1.06 ± 0.30, -0.55 ± 0.28) respectively with significant statistical difference ($p < 0.001$).

Our results come in agreement with Shokr., *et al*. who conducted a study in 2016 to determine the relative accuracy of Tissue Doppler imaging (TDI)-based and STE-based measurements of myocardial strain and strain rate for the detection of myocardial viability before revascularization using SPECT imaging as a gold standard, and came to the result that lower strain and strain rate values exist at rest using STE in the non-viable segments compared to the viable groups of the corresponding territory and an increase of strain and strain rate values in response to LDD was detected in the viable group but not in the non-viable ones, and they found a cut-off point to predict myocardial viability using the ROC curve, at > -4.5% peak longitudinal systolic strain by STE at LDD chosen as a cut-off point, with a sensitivity of 87.24% and a specificity of 84.10% [10].

But in this study, the cutoff point to predict myocardial viability was > -9% peak longitudinal systolic strain by STE within 3 days of myocardial infarction with sensitivity 86.1 and specificity 87.1.

The possible explanation of the difference between both cut off levels may be due to that our measurements were done within 3 days of myocardial infarction (i.e. after revascularization) and that the patients included in Shokr., *et al*. study were known to have chronic ischemic heart disease with left ventricular systolic dysfunction but the patients included in this study had acute myocardial infarction for the first time. also, they used SPECT imaging as a gold standard instead of stress dobutamine echo.

Similarly, in 2013, Martin., *et al.* did a comparison between the speckle tracking echocardiography derived systolic longitudinal strain and the rest single photon emission computed tomography perfusion imaging to reach the ideal cut- offs for peak longitudinal systolic strain to distinguish the transmural scar on contrast-enhanced magnetic resonance imaging (ceCMR). Correlation of regional longitudinal systolic strain and DE on ceCMR has been found. The peak longitudinal systolic strain optimal cutoff -5.3 percent identified segments with > 75 percent delayed enhancement on ceCMR (83.1 percent sensitivity, 84.6 percent specificity). STE identified non-viable segments of LV. Similar to myocardial SPECT perfusion imaging, STE is more effective in detecting non-viable myocardium, which was consistent with our findings [11].

Also, the cut off value was lower possibly due to the difference in the studied groups. the patients included in Martin., *et al*. study had ischemic cardiomyopathy and LV ejection fraction < 40% and excluded patients who experienced myocardial infarction during the last 6 months prior to admission and Patients with acute coronary syndromes or any signs of acute myocardial ischemia, but in this study, we included patients with first time acute myocardial infarction.

The value of STE performed early after the first ST-segment elevation of myocardial infarction was assessed by Loïc Bière., *et al*. in 2014. with a view to predict infarction size and functional recovery at 3-month follow up. Longitudinal strain > -6.0 percent showed 96

percent specificity and 61 percent sensitivity within the infarcted area to predict a 3-month follow-up of the persistence of akinesia. Speckle tracking strain imaging done early after a STEMI is easy to use as a marker for persistent 3-month akinetic territories. and this was comparable to our findings, but with a lower cut off value and poor sensitivity.

The difference may be because they rely as a gold slandered for myocardial viability on Late gadolinium-enhanced cardiac magnetic imaging [12].

In 2012, Cimino S., *et al*. also tested whether GLS and RLS could also identify early myocardial dysfunction and transmural extent of the myocardial scar in patients with acute ST myocardial infarction (STEMI) and relatively preserved LV function, RLS was significantly lower in DE-segments compared to normal myocardial infarction (P, 0.0001). A RLS cut-off value of -12.3 percent by (ROC) curves identified DE segments (sensitivity 82 percent, specificity 78 percent), while a cut-off value of -11.5 percent identified transmural extent of DE (sensitivity 75 percent, specificity 78 percent) [13].

The higher cut off value in Cimino S., *et al*. study could be as they excluded patients whose LV ejection fraction < 40%.

Chan., *et al*. also found in 2006 that viable myocardium had higher strain rates than scar tissue after infusion with dobutamine. They indicated that an improvement in dobutamine strain and strain rate is a marker of myocardial viability, which was consistent with our findings [14].

Jong Shin Woo., *et al*. conducted a study in 2015 to predict myocardial viability early after myocardial infarction by two-dimensional speckle tracking imaging and reported that 2D-STI is feasible for assessing myocardial viability, and the peak systolic strain rate might be the most reliable predictor of myocardial viability in patients with AMI. ROC curves revealed the greatest ability of initial SSR to assess segmental myocardial viability. Using a cutoff of 0.72, the initial SSR had an 88 percent sensitivity and a 69 percent specificity to distinguish viable from non-viable segments [15].

These results came with agreement with our results with similar cut off value of peak systolic strain rate ≤-0.7 with sensitivity 91.67 and specificity 74.19.

Conclusion and Recommendation

In patients with recent first acute MI, Strain and strain rate measurements are feasible, inexpensive, quantitative, and rapid methods that can predict myocardial viability with high sensitivity and specificity.

Bibliography

1. O'Gara PT., *et al*. "2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: a report of the American College of Cardiology Foundation / American Heart Association Task Force on Practice Guidelines". *Circulation* 127.4 (2013): e362-e425.

2. Vartdal T., *et al*. "Early prediction of infarct size by strain doppler echocardiography after coronary reperfusion". *Journal of the American College of Cardiology* 49 (2007): 1715-1721.

3. Al Moudiet M and Sun ZH. "Diagnostic value of (18)F-FDG PET in the assessment of myocardial viability in coronary artery disease: A comparative study with (99m)Tc SPECT and echocardiography". *Journal of Geriatric Cardiology* 11 (2014): 229-236.

4. Habis M., *et al*. "Acute myocardial infarction early viability assessment by 64-slice computed tomography immediately after coronary angiography: comparison with low-dose dobutamine echocardiography". *JACC: Journal of the American College of Cardiology* 49 (2007): 1178-1185.

5. Amundsen B., *et al*. "Non-invasive myocardial strain measurement by speckle tracking echocardiography". *JACC: Journal of the American College of Cardiology* 47 (2006): 789-793.

6. Altiok E., *et al*. "Myocardial deformation imaging by two-dimensional speckle-tracking echocardiography for prediction of global and segmental functional changes after acute myocardial infarction: a comparison with late gadolinium enhancement cardiac magnetic resonance". *Journal American Society of Echocardiography* 27 (2014): 249-257.

7. Hanekom L., *et al*. "Incremental value of strain rate analysis as an adjunct to wall-motion scoring for assessment of myocardial viability by dobutamine echocardiography: A follow-up study after revascularization". *Circulation* 11 (2005): 3892-3900.

8. Lyseggen E., *et al*. "Myocardial strain analysis in acute coronary occlusion: A tool to assess myocardial viability and reperfusion". *Circulation* 112 (2005): 3901-3910.

9. Vartdal T., *et al*. "Early prediction of infarct size by strain doppler echocardiography after coronary reperfusion". *Journal of the American College of Cardiology* 49 (2007): 1715-1721.

10. Shokr Aly M., *et al*. "Myocardial Viability Assessment by Dobutamine Echocardiography using Tissue Doppler and Speckle-Tracking: Comparison with SPECT". *ARC Journal of Cardiology* 2 (2016): 1-12.

11. Martin H., *et al*. "Speckle tracking echocardiography derived systolic longitudinal strain is better than rest single photon emission tomography perfusion imaging for nonviable myocardium identification". *Biomedical papers of the Medical Faculty of the University* 157 (2013): 12-21.

12. Loïc B., *et al*. "Longitudinal Strain Is a Marker of Microvascular Obstruction and Infarct Size in Patients with Acute ST-Segment Elevation Myocardial Infarction". *Journal European PMC* 10 (2014): 1371.

13. Cimino S., *et al*. "Global and regional longitudinal strain assessed by two-dimensional speckle tracking echocardiography identifies early myocardial dysfunction and transmural extent of myocardial scar in patients with acute ST elevation myocardial infarction and relatively preserved LV function". *European Heart Journal- Cardiovascular Imaging* 14 (2013): 805-811.

14. Chan J., *et al*. "Differentiation of subendocardial and transmural myocardial infarction using two-dimensional strain rate imaging to assess short and long axis function". *Journal of the American College of Cardiology* 48.10 (2006): 2026-2033.

15. Jong Shin Woo., *et al*. "Early prediction of myocardial viability after acute myocardial infarction by two-dimensional speckle tracking imaging". *Journal of Geriatric Cardiology* 12 (2015): 474-481.

Volume 7 Issue 12 December 2020