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Original Article

Speckle tracking imaging as a predictor of left ventricular remodeling 6 months after first anterior ST elevation myocardial infarction in patients managed by primary percutaneous coronary intervention

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ABSTRACT

Acute myocardial infarction (AMI) remains a leading cause of morbidity and mortality worldwide. LV remodeling is an important factor in the pathophysiology of advancing heart failure (HF).

Aim of the work: To evaluate the value of speckle tracking imaging as a predictor of left ventricular remodeling 6 months after first anterior STEMI in patients managed by primary PCI.

Methodology: Eighty-five patients with first acute anterior STEMI underwent primary PCI. Patients were followed up for 6 months. **Echocardiography was done within 48 h** [1] Standard transthoracic 2D echocardiographic examination: LV internal dimensions and volumes, Left Ventricular EF, and Wall Motion Score Index: [2] LV peak systolic global longitudinal strain and Torsion dynamics were assessed. **Echocardiography was repeated at 6 months** LV volumes and EF were calculated. **LV remodeling** was defined as an increase in LV EDV $\geq$ 20% 6 months after infarction as compared to baseline data. Patients were then classified into **Group I**: did not develop LV remodeling. **Group II**: developed LV remodeling. Both groups were studied to determine predictors of LV remodeling.

Results: **At baseline** echocardiographic evaluation there was no statistically significant difference between both groups regarding both LVEDD and LVEDV, while there was statistically significant increase in both LV ESD and LV ESV, with statistically significant lower Ejection Fraction, in LV remodeling group. There was also statistically significant higher LV peak systolic GLS values in LV remodeling group, the best cut-off value was >−12.5 (Sensitivity 87%, Specificity 85%) and LV torsion was also statistically significantly lower in the LV remodeling group, with the best cut-off value for LV torsion was <9.5°, [Sensitivity 91%, Specificity 85%].

Independent predictors of LV remodeling after AMI: baseline WMSI > 1.8, baseline LV EF < 40, GLS > −12.5%, LV torsion < 9.5°, CK-MB > 500 U/L, baseline Thrombus grade > 4 and total ischemic time.

Conclusion: Average peak systolic GLS and LV torsion at echocardiography done early after myocardial infarction are independent predictors of LV remodeling after anterior STEMI and can be used to predict occurrence of LV remodeling after 6 months.

1. Introduction

Acute myocardial infarction (AMI) remains a leading cause of morbidity and mortality worldwide. It occurs when irreversible myocardial cell damage or death occurs.[1]

LV remodeling is an important factor in the pathophysiology of advancing heart failure (HF) and several studies support the role of measures of LV remodeling in the clinical investigation of novel HF treatments.[2]

1.1. Aim of the study

To evaluate the value of speckle tracking imaging as a predictor of left ventricular remodeling 6 months after first anterior STEMI in patients managed by primary PCI.

2. Materials and methods

A Cohort of 85 patients who presented with first acute anterior STEMI[3] to the cardiology department of Ain Shams university

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hospital, in the period between August 2015 and May 2016 and underwent primary PCI. Patients were followed up for 6 months.

Patients with previous AMI, previous PCI or CABG, cardiogenic shock, left main disease or with concomitant significant lesion in left circumflex and/or right coronary arteries, poor echogenicity with improper visualization of the endocardium were excluded from the study.

The study protocol was approved by Ain Shams university faculty of medicine ethical committee.

All patients received 300 mg Aspirin, 600 mg Clopidogrel prior to primary PCI.

[1] History: with special emphasis on

(A) Risk Factors: [(**Hypertension** defined as blood pressure of more than 140/90 mmHg and/or receiving oral anti-hypertensive agents. James et al.[4], (**Diabetis Mellitus** defined as elevated fasting blood sugar $\geq$ 126 mg/dl and/or being either on diet control or receiving hypoglycemic treatment. Tominaga [5], ***(Smoking), (Positive family history of premature CAD*** defined as having CAD or sudden death occurring in a first-degree relative before age of 65 years in females and 55 years in males. Scheuner et al.[6], ***(Dyslipidemia)*** By history or drug treatment. **(B) Chest Pain:** type, onset, pain to door time. **(C) Past History:** especially of previous ischemic events.

[2] Clinical Examination: with special emphasis on

(a) General Examination: ABP, heart rate and Killip class on presentation **Class I:** no evidence of HF, **Class II**: mild to moderate HF, **Class III** overt pulmonary edema, **Class IV**: cardiogenic shock De Geare et al.[7] ***(b) Local examination:*** with special emphasis on presence of third heart sound, mitral regurgitation, pulmonary venous congestion and ventricular septal rupture.

[3] 12 lead ECG: recorded within the first 10 min on presentation, 90 min post catheterization, then daily till discharge.

[4] Laboratory investigations**:** Total creatine kinase (CK), CK-MB, on admission then serially every 8 h for the first 24 h then once daily to detect peak enzymatic elevation and their return to normal.

[5] Primary intervention: Coronary intervention was performed via a trans-femoral approach. All the patients received 100 IU/kg intravenous Heparin bolus prior to PCI to LAD. The following data was recorded for each patient: **(a) Site of LAD occlusion**. **(b) TIMI Thrombus Grading:** Before and after the procedure. **Grade *0***: No cine-angiographic characteristics of thrombus, **Grade 1***:* Possible thrombus "Reduced contrast density, haziness, irregular lesion contour". **Grade 2***:* Definite thrombus, greatest dimensions < 1/2 the vessel diameter. **Grade 3:** Definite thrombus but with greatest linear dimension > 1/2 but < twice vessel diameter. **Grade 4:** Definite thrombus with the largest dimension > 2 vessel diameter. **Grade 5:** Total recent thrombotic occlusion Gibson et al.[8]

(C) TIMI flow prior to and after procedure: Grade 0 *(No Perfusion):* no ante-grade flow beyond the point of occlusion. **Grade 1** *(Penetration Without Perfusion):* The contrast material failed to opacify the entire coronary bed distal to the obstruction. **Grade 2** *(Partial Perfusion):* The rate of entry of contrast material into the vessel distal to the obstruction or its rate of clearance from the distal bed (or both) was perceptibly slower than its entry into or clearance from comparable areas not perfused by the previously occluded vessel. **Grade 3** *(Complete Perfusion):* normal flow filling the distal coronary bed completely. Ante-grade flow distal to the obstruction occurred as promptly as ante-grade flow proximal to obstruction Appleby et al.[9]

(D) **Myocardial Blush Grade (MBG)** prior to and after the procedure. Visual assessment of relative contrast opacification of the myocardial territory subtended by the IRA in relation to epicardial density. **MBG 0:** Absence of contrast opacification in the myocardial zone. **MBG 1***:* Minimal contrast opacification or persistent stain without washout. **MBG 2:** Reduced but clearly evident blush in the infarct zone compared to the contralateral non-involved territory. **MBG 3***:* The opacification of the myocardium cleared normally at the end of the washout phase, similar to that in the non-involved territory. Henriques et al.[10]

(E) All procedural details were recorded especially Use of balloon pre-dilatation, stent length and diameter.

[6] Echocardiography: Done within 48 h of hospital admission and included:

(A) **Standard transthoracic 2D echocardiographic examination:** using Vivid E9 machine with an M4S matrix sector array probe with a frequency of 2.5 Mega Hz ***(General Electric Vingmed Ultrasound, Horten, Norway)*** with machine-integrated ECG recording. Patients were examined in the left lateral position, Parasternal Long and short axis, Apical four and two chamber views were acquired with the following data recorded:-

[I] LV end diastolic diameter **(EDD)** and LV end systolic diameter **(ESD)** using short axis parasternal window at the level of papillary muscles and LVEF calculated by M-mode Kessler[11] LV end diastolic volume **(EDV)** and LV end systolic volume **(ESV)** using biplane Simpson's method.[12] **Left Ventricular EF** using biplane Simpson's method.[13] **Mitral Regurgitation:** Its presence and severity.[14]

[II] **LA diameter** in parasternal short axis view and **LA volume** which was estimated from apical 4 and 2 chamber images from the frame prior to mitral valve opening using modified Simpson's rule.[13]

[III] **Wall Motion Score Index:** The LV was divided into 16 segments. A semi quantitative scoring system **(1)** Normal, **(2)** Hypokinesia, **(3)** akinesia, **(4)** dyskinesia. **Global WMSI** was calculated = sum of the segment scores divided by the number of segments.[15]

[IV] **E/e' Ratio** [Mitral peak early filling velocity (by placing the Pulsed Doppler sample volume between the tips of the mitral leaflets/peak mitral lateral annular velocity (by placing the TDI Doppler sample at the basal lateral segment)].[16]

(B) **LV peak systolic global longitudinal strain by 2D speckle tracking**

[I] LV peak systolic global longitudinal strain was assessed using the automated function imaging "AFI" technique, which provides a new imaging modality based on 2D longitudinal strain imaging. Assessment of LV peak systolic GLS provided 1 value representing the overall peak systolic longitudinal strain of all individual LV segments. **[II] Longitudinal strain was calculated longitudinal strain (%) = [L (end-systole) – L (end-diastole)] / L (end-diastole) x 100%**; where L is the length of the ROI.[17]

- Myocardial tissue deformation (strain) was calculated using speckle tracking from 2D gray-scale images with the commercially available AFI technique (General Electric), For this analysis, a set of 3 longitudinal 2D image planes (apical long-axis, 2- and 4-chamber views) were used. Aortic valve closure timing was marked (to determine the end of systole) in the selected views, and 3 points were anchored inside the myocardial tissue, 2 placed at the basal segments along the mitral valve annulus and 1 at the apex. These points triggered the automatic process,

which analyzed myocardial motion by tracking features (natural acoustic tags). The percent of wall lengthening and shortening was displayed for each plane, representing longitudinal strain. The results of all 3 planes were combined in a single bull's-eye summary, which presented the analysis for each segment along with a global strain value for the LV.

- Non-Doppler 2D strain imaging was simple to perform. It required only one cardiac cycle to be acquired; further processing and interpretation was done after image data acquisition. Because it was not based on tissue Doppler measurements, images were angle independent.
- The AFI was performed through an offline analysis of 3 digitally stored 2D images (apical long axis, 2- and 4-chamber). The end-systolic frame was first defined in the apical long-axis (3-chamber) view, where the aortic valve was directly visible. Aortic valve closure time was marked. The R wave to aortic valve closure time was then measured by the software. Subsequently, the same R wave to aortic valve closure time distance was used as a reference on the other loops. The time distance was also checked against mitral valve opening, which was easily seen in any apical plane. This allowed accurate timing of systole, diastole, and aortic valve closure on all views.
- Within the end-systolic frames an estimation of the LV myocardium was traced in a click-to-point approach. After defining the mitral annulus and the LV apex with 3 index points at the end-systolic frame in each apical view, the automated algorithm traced 3 concentric lines on the endocardial border, the mid-myocardial layer and epicardial border, including the entire myocardial wall. The tracking algorithm followed the endocardium from this single frame throughout the cardiac cycle, and allowed for a further manual adjustment of the ROI to ensure that all myocardial regions are included throughout the cardiac cycle.
- The myocardium in each of the 3 standard apical planes was then automatically divided; the myocardium in each view was divided into three levels apical, mid and basal levels and each level comprised 2 segments of the two opposing walls. Conversion from 18 segments into 17 segments model was performed by averaging the strain values in the corresponding apical segments in the apical long axis and 4 chamber view.
- Finally, the automated algorithm, using a 17-segment model, provided the peak systolic longitudinal strain for each LV segment in a "bull's eye" plot, with the average value of peak systolic GLS for each view and the average value of peak systolic GLS for the complete LV. In general, longitudinal strain values are presented as negative values; a larger negative value indicates a larger extent of longitudinal strain. Mean frame rate of the obtained images was 70 frames per second (range 40–100).

(C) **Torsion dynamics:**

- Short axis images from the LV base at the level of the mitral valve leaflets and the LV apex were obtained from the parasternal or subcostal windows at the end expiration. The apical cut was defined by the smallest cavity obtainable, beyond the level of the attachment of the papillary muscles (by moving the probe downward and slightly laterally if needed). Torsion was measured from the 2D grey scale LV base and apex short axis images by speckle tracking echocardiography.[18]
- The frame rate was 60–100 frames per second and three cardiac cycles for each short axis level were stored in cine loop format for offline analysis using a dedicated software **EchoPAC PC 6.3.4, 7 software (General electric Vingmed Ultrasound, Horten, Norway).** After selecting a cardiac cycle of interest, the endocardial border of the short axis image was tracked manually, and the ROI was chosen to fit the whole myocardium, this was followed by automatic frame to frame tacking of the speckle pattern in the myocardium. The software allowed to check and validate the tracking quality and to adjust the endocardial border or modify the width of the ROI, if needed. Each short axis image was automatically divided into the corresponding standard segments.
- The software calculated the LV rotation from the apical and the basal short axis images as the average displacement of the standard segments by referring to the ventricular centroid, frame by frame. Counterclockwise rotations were marked as positive values and clockwise rotations, as negative values when viewed from the LV apex. LV torsion was defined as the net difference of LV rotation at the basal and apical planes (in degrees).

[7] Medications: Medical treatment was given to subjects as per hospital protocol:

[a] During hospitalization:

Aspirin was continued indefinitely and **Clopidogrel** (75 mg daily) was given for 1 year to all patients. **Oral β-blockers** and **ACEI** were initiated in the first 24 h and up titrated to the maximum tolerated doses unless contraindicated.

Aldosterone antagonist was given to patients who were already receiving an ACEI and β -blocker and who had an EF $\leq$ 40% and either symptomatic HF or DM with no contraindications. **High-intensity statin therapy** was initiated or continued in all patients with no contraindications.

Nitroglycerin was used to ameliorate symptoms and signs of myocardial ischemia, hypertension or HF, unless contraindicated.

[b] Six Months Echocardiographic Follow up:

All patients were subjected to echocardiographic evaluation of LV EDV, LV ESV and LVEF. **LV remodeling** was defined as an increase in LV EDV $\geq$ 20% **6 months after infarction** as compared to baseline data.[19,20]

Patients were divided according to 6 months echocardiography into two groups:

Group I: Included patients who did not develop LV remodeling.

Group II: included patients who developed LV remodeling.

Both groups were studied to determine predictors of LV remodeling.

[8] Statistical analysis:

Analysis of data was done by IBM computer using statistical program for social science (SPSS) version 16 as follows:

Description of quantitative variables as **mean, standard deviation (SD)** and range. Description of qualitative variables as **number and percentage**. **Unpaired *t*-test** was used to compare quantitative variables, in parametric data (SD < 50% mean).

Comparison between groups as regards qualitative variables was done by using **chi-square test**. **Fisher exact test** was used instead of chi-square when one expected cell is less than 5.

One way ANOVA (analysis of variance) test was used to compare more than two groups as regard quantitative variable. **Spearman correlation co-efficient test** was used to rank variables versus each other positively or inversely. **Receiver operator characteristic (ROC) curve** was used to find out the best cut-off value, and validity of certain variable.

P value > 0.05 non-significant (NS), P < 0.05 significant (S), P < 0.001 highly significant (HS).

Assessment of intra and inter observer variability were done on ten patients using Kappa Coefficient [0.88 and 0.92 respectively].

3. Results

85 patients with first acute anterior STEMI who underwent primary PCI to LAD with no significant lesion in other coronary artery were included initially in the study. During the 6 months follow up

period, 4 patients died so finally, 81 patients had the 6 months follow up echocardiography.

3.1. Demographic data

81 patients constituted the study population, mean age was 51.6 ± 9.6 years and 70 patients (86.4%) were males.

According to the presence of LV remodeling at 6 month follow up echocardiography, patients were divided into 2 groups. "Group I": Patients who did not develop LV remodeling [48 patients]. "Group II": Patients who developed LV remodeling [33 patients].

Both groups were matched regarding age, gender and cardiovascular risk factors Table 1.

3.2. Pain to door, door to balloon and total ischemic time

The LV remodeling group was found to have significantly longer pain to door [3.6 ± 2 versus 6 ± 1.7 h, P value 0.000 HS], door to balloon [31.9 ± 5 versus 38 ± 6.7 min, P value 0.000 HS], and total ischemic times [246 ± 120 versus 396 ± 108 min, P value < 0.0001].

3.3. Clinical examination and laboratory data

LV remodeling group had a statistically significant higher **Killip class,** higher **discharge heart rate,** higher **peak CK-total and CK-MB,** yet there was statistically significant lower blood pressure (Both systolic and diastolic) Table 2.

3.4. Angiographic data

The LV remodeling group showed significantly higher incidence of **ostial and proximal LAD occlusions**, significantly higher incidence of **thrombus grade 5**, **significantly higher incidence of TIMI "0**" flow before intervention**.**

There was no statistically significant difference between both groups regarding the use of **Pre-dilatation, stent length and stent diameter**.

The LV remodeling group showed significantly worse **TIMI flow both before and after** reperfusion, and significantly worse **MBG after reperfusion** Table 3.

Table 1
Comparison between both groups regarding demographic data "Both groups were homogenous regarding age, gender and different cardiovascular risk factors".

Variables	Non remodeling group (I) n = 48	Remodeling group (II) n = 33	P
Age (years)	50.9 ± 9	52 ± 10	0.46 NS
Gender			
Male	43(89.6%)	27(81.8%)	0.55 NS
Female	5(10.4%)	6(18.2%)	
Hypertension	18(37.5%)	12(36.4%)	0.45 NS
DM	17(35.4%)	13(39.4%)	0.34 NS
Smoking	31(64.6%)	19(57.6%)	0.59 NS
Family history of premature CAD	9(18.8%)	6(18.2%)	0.32 NS
Dyslipidemia	12(25%)	6(18.2%)	0.55 NS

Table 2
Comparing both groups for clinical examination and laboratory data.

Variables	Non remodeling group (I) n = 48	Remodeling group (II) n = 33	P
SBP (mmHg)	121 ± 12	112 ± 17	**0.004 S**
DBP (mmHg)	76 ± 7	70 ± 6.5	**0.003 S**
Discharge heart rate (b/m)	76 ± 10	81 ± 15	**0.05 S**
Killip class			
I	44(91.7%)	23(69.7%)	**0.03 S**
II	4(8.3%)	9(27.3%)	
III	0	1(3%)	
CK total (U/L)	2319 ± 1000	4330 ± 1500	**0.000 HS**
CK –MB (U/L)	231 ± 87	431 ± 127	**0.000 HS**

Table 3
Comparing both groups for coronary angiographic data.

Variables	Non remodeling group (I) n = 48	Remodeling group (II) n = 33	P
Site of lesion			**0.000**
Proximal	19(39.6%)	27(81.8%)	**HS**
Mid LAD	26(54.2%)	1(3%)	
Osteal	2(4.2%)	5(15.2%)	
Distal	1(2.1%)	0	
Stent length (mm)	22.1 ± 6	22.4 ± 4	0.44 NS
Stent diameter (mm)	3 ± 0.l6	3 ± 0.6	0.38 NS
Pre-dilatation	39(81.2%)	31(93.9%)	0.09 NS
Thrombus grade			
3	2(4.2%)	0	**0.02 S**
4	10(20.8%)	1(3%)	
5	36(75%)	32(97%)	
TIMI before			
0	36(75%)	32(97%)	**0.03 S**
1	11(22.9%)	1(3%)	
2	2(2.1%)	0	
3	0	0	
TIMI after			
0	0	0	**0.000**
1	0	8(24.2%)	**HS**
2	3(6.2%)	13(39.4%)	
3	45(93.8%)	12(36.4%)	
MBG			
0	0	5(15.2%)	**0.000**
1	5(10.4%)	20(60.6%)	**HS**
2	13(27.1%)	8(24.2%)	
3	30(62.5%)	0	

3.5. Regarding the echocardiographic data

3.5.1. ***Baseline data: [Table 4-A]***

Both groups were compared for **BASELINE** echocardiographic data, there was no statistically significant difference between both groups regarding both **LV EDD and LVEDV**, while there was statistically significant increase in both **LV ESD and LV ESV**, with statistically significant lower **Ejection Fraction,** and statistically significant larger **LAVI** and statistically significant higher grade of **mitral regurgitation** in LV remodeling group.

A statistically significant higher **baseline WMSI** could be observed **i**n the LV remodeling group, with best cut-off value of >1.8 above which remodeling is significantly more likely, [sensitivity 90%, specificity 88] Fig. 1.

There was no significant difference between both groups regarding assessment of diastolic function using trans-mitral inflow pattern parameters **"Mitral E wave, mitral A wave, DT and E/A ratio".**

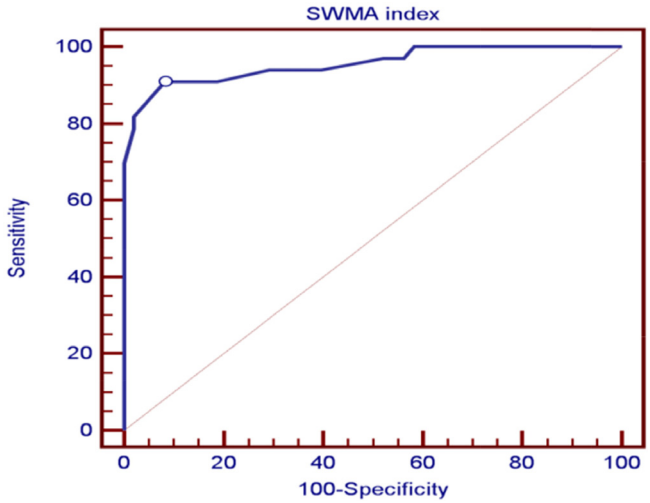

Fig. 1. ROC curve showing the Best Cut-off value of WMSI for detection of remodeling is 1.8 with sensitivity 90%, specificity 88%, positive predictive value 89%, negative predictive value 94%.

Yet, **the TDI mitral annulus velocities** showed significantly less both **lateral e' and septal e' waves**, and significantly higher **E/e' ratio** in LV remodeling group. [ie tissue Doppler parameters were worse in remodeling group at baseline echocardiographic assessment while pulsed wave Doppler was not].

The **average LV peak systolic GLS at baseline echocardiographic assessment** showed statistically significantly higher values in LV remodeling group, the **best cut-off value** for average LV peak systolic GLS > −12.5 (Sensitivity 87%, Specificity 85%) Fig. 2.

Moreover for **LV torsion at baseline echocardiographic assessment** was also statistically significantly lower in the LV remodeling group, with the best cut-off value for LV torsion was <9.5°, [Sensitivity 91%, Specificity 85%] Fig. 3.

Spearman correlation co-efficient test was used to study the correlation between average peak systolic LV GLS and LV torsion at baseline echocardiographic assessment and it was found to be positive i.e. the higher the LV torsion, the lower the average peak systolic LV GLS Fig. 4.

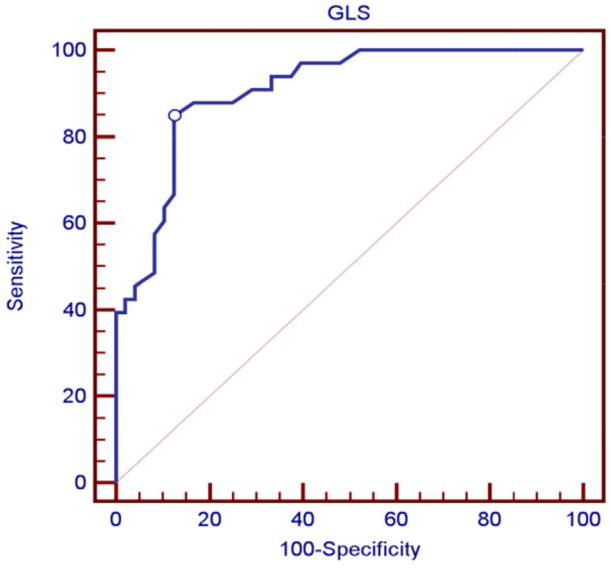

Fig. 2. Best cut-off point for average LV peak systolic GLS was >−12.5, sensitivity 87%, specificity 85%, positive predictive value 83% and negative predictive value 88%.

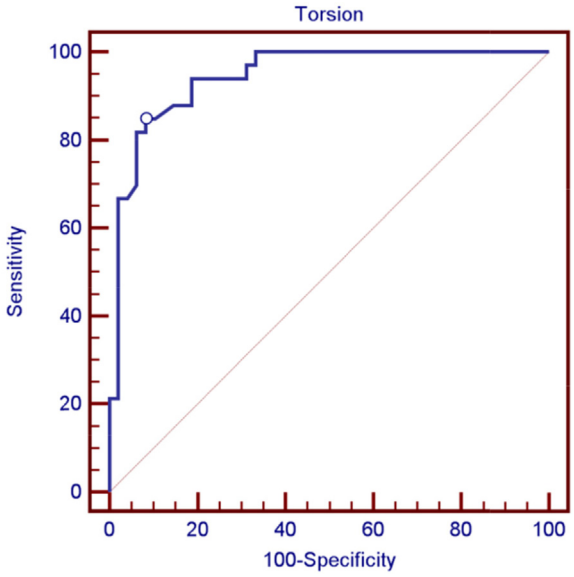

Fig. 3. Best cut-off value for LV torsion was <9.5°, sensitivity 91%, specificity 85%, positive predictive value 89% and negative predictive value 95%.

3.6. Six months follow up data

3.6.1. Echocardiographic

There was a statistically significant lower EF in the LV remodeling group [Table 4-B].

3.6.2. Independent predictors of LV remodeling after AMI

Multivariate logistic regression analysis to define the independent predictors of LV remodeling after MI revealed baseline WMSI > 1.8, baseline LV EF < 40, GLS > −12.5%, LV torsion < 9.5°, CK-MB > 500 U/L, baseline Thrombus grade > 4 and total ischemic time Table 5.

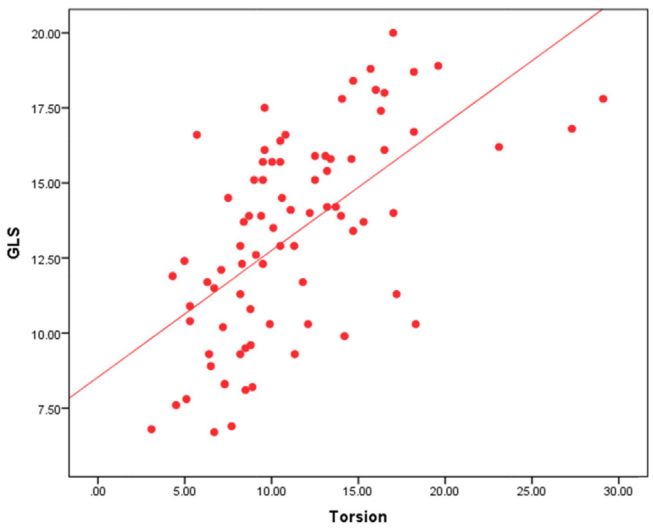

Fig. 4. Correlation between LV torsion and average peak LV GLS [r = −0.659, P = 0.000].

Table 4
Comparing both groups for echocardiographic data.

Variables	Non remodeling group (I) n = 48	Remodeling group (II) n = 33	P
A. Baseline echocardiographic data			
LV EDD (mm)	50 ± 4	52 ± 3.5	0.2 NS
LV ESD (mm)	35 ± 4	41 ± 5	**0.000 HS**
LV EDV (ml)	101 ± 26	111 ± 26	0.11 NS
LV ESV (ml)	52 ± 6	72 ± 6	**0.000 HS**
MR			
No	31 (64.6%)	8 (24.2%)	**0.001 HS**
Mild	17 (35.4%)	21 (63.6%)	
Moderate	0 (0.0%)	3 (9.1%)	
Severe	0 (0.0%)	1 (3.0%)	
LA volume index	33.7 + 8	38.8 ± 4	**0.000 HS**
WMSI	1.5 ± 0.3	1.9 ± 0.5	**0.000 HS**
Mitral E (cm/s)	80 ± 17	76 ± 19	0.85 NS
Mitral A (cm/s)	84 ± 22	82 ± 22	0.77 NS
E/A ratio	1 ± 0.3	1 ± 0.4	0.06 NS
DT (ms)	196 ± 30	185 ± 30	0.83 NS
Lateral e' (cm/s)	8.7 ± 2	7.2 ± 3	**0.02 S**
Septal e' (cm/s)	7.1 ± 2	5 ± 1.7	**0.000 HS**
E/e' ratio	10 ± 3	11.9 ± 3.4	**0.000 HS**
GLS%	-14.7 ± 7	-10 ± 4.5	**0.000 HS**
LV Torsion °	13.9 ± 3	7.5 ± 2	**0.000 HS**
6 months follow up echocardiographic data			
LV EDV (ml)	102 ± 24	148 ± 43	**0.000 HS**
LV ESV (ml)	50.6 ± 19	100 ± 37	**0.000 HS**
LVEF%	50.7 ± 6	32.8 ± 7	**0.000 HS**

Table 5
Independent predictors of LV remodeling after AMI.

Variables	Beta-coefficient	P	OR (95%CI)
Baseline WMSI > 1.8	0.57	0.002	2.1(1–12.7)
Baseline LVEF < 40%	0.44	0.003	1.8(0.8–11)
Baseline GLS > -12.5%	0.43	0.04	1.7(0.4–13.8)
Baseline Torsion < 9.5°	0.33	0.05	1.5(0.3–15)
Peak CK-MB > 500 U/L	0.28	0.05	1.4(−0.11 to 22)
Baseline Thrombus grade > 4	0.22	0.05	1.2(−0.3 to 20)
Total ischemic time	O.1	<0.0001	1.01(1.05–1.015)

4. Discussion

STEMI is the most serious presentation of atherosclerotic CAD carrying the most hazardous consequences,[21] caused by occlusion of a major coronary artery and primary PCI is the recommended reperfusion therapy over fibrinolysis if performed by an experienced team in a timely fashion.[22]

LV remodeling after AMI is a precursor of the development of overt HF and is an important predictor of mortality.[23]

In the present study, among the whole study population, LV remodeling occurred in 33 out of 81 patients (41.25%), 12 out of 57 patients (21.1%) with successful epicardial reperfusion (TIMI 3 flow), and in 8 out of 51 patients (15.7%) with successful myocardial reperfusion (MBG 2–3) (see Figs. 5–8).

These results goes in concordance with Bochenek and his colleagues 2011, they found that LV remodeling occurred in 42% of patients presented with anterior STEMI.[24]

It also goes in concordance with Hamdan and his colleagues 2010, they stated that LV remodeling occurred in 34.6% of patients with TIMI 3 flow after reperfusion and 17.6% of patients with (MBG 2–3).[20] And this emphasizes the importance of myocardial perfusion rather than epicardial coronary perfusion.[20]

4.1. CAD risk factors and LV remodeling

In the present study, both groups (LV remodeling and LV non-remodeling groups) were age and sex matched with homogenous risk factors of CAD.

In our study both smoking and hypertension were not associated with adverse LV remodeling, and this goes in concordance with Symons and his colleagues in 2015 and Parodi and his colleagues 2006 respectively.[25,26]

Diabetes was not associated with adverse remodeling in our study, Lamblin and his colleagues in 2012, found that DM was a major and independent predictor of subsequent HF but it was not associated with increased incidence of LV remodeling.[27]

4.2. Pain to door, door to balloon times and LV remodeling

Pain to door and door to balloon and total ischemic times in the present study were significantly longer in the LV remodeling group.

And this could be related to the more myocardial damage due to delayed reperfusion and points to the importance of early reperfusion as much as possible of both pain to door time through increasing people awareness of symptoms of AMI and door to balloon time through improvement of health care system.

And this was concordant with Bolognese et al.[23], Zaliaduonyte-Peksiene et al.[28], Barberato et al.[29] that showed a tendency towards longer time to reperfusion which is associated with LV remodeling, but without statistical significance.

4.3. Clinical examination and LV remodeling

Discharge heart rate was significantly lower in the LV non-remodeling group in the current study, this was concordant with the study of Joyce and her colleagues in 2013 that included 964 STEMI patients, they concluded that discharge heart rate was an independent predictor of adverse LV remodeling.[30]

In the current study there was a significantly higher Killip class in the LV remodeling group. Barberato and his colleagues study in 2013[29] found a non statistically significant difference between both groups with a trend towards higher Killip class in the LV remodeling group.

4.4. Cardiac enzymes and LV remodeling

Peak CK total and CK-MB in the present study were statistically significantly higher in the LV remodeling group and peak CK-MB > 500 U/L was found to be an independent predictor of LV remodeling and this is mostly related to the larger size of infarction in patients with LV remodeling. And this goes in concordance with both Bolognese et al.[23], and Mannaerts et al.[19]

4.5. Coronary angiographic data and LV remodeling

In the present study, proximal LAD occlusion was statistically significantly higher in the LV remodeling group while mid LAD was statistically significantly higher in the LV non-remodeling group. This could be related to the larger size of infarction in this location.

There were no previous studies correlating the LAD lesion location and LV remodeling but some studies showed the association between larger size of infarction and incidence of LV remodeling as Masci and his colleagues study in 2011,[31] that studied the relationship between location and size of AMI and LV remodeling and it concluded that anterior AMI patients had larger area at risk and infarction size than non-anterior AMI patients yielding worse regional and global LV function at baseline and follow-up.

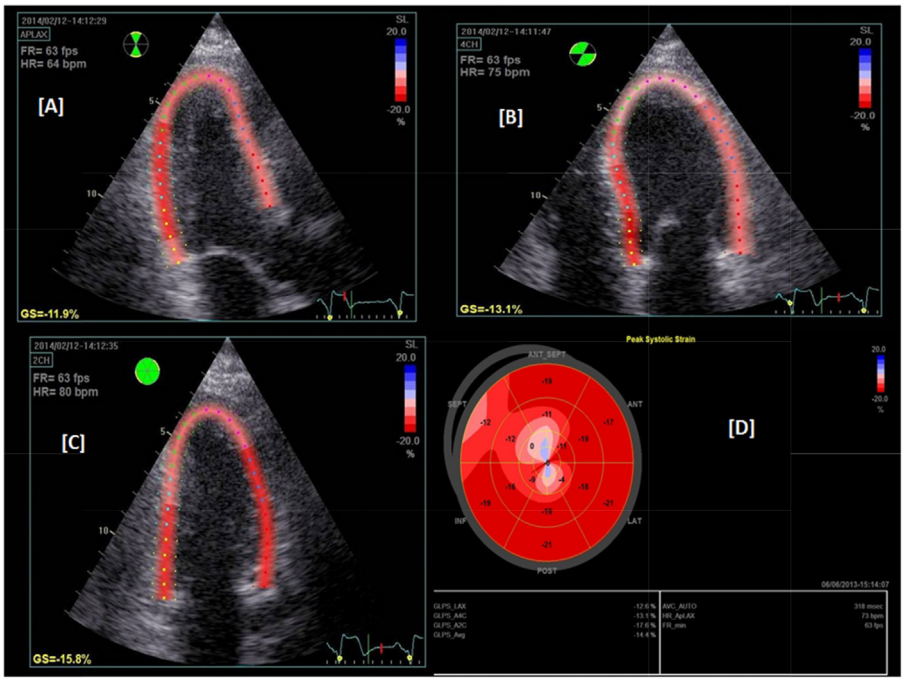

Fig. 5. [A] GLS in a patient from LV non-remodeling group in the apical long axis view showing GLS −11.9% in long axis view. [B] GLS in a patient from LV non-remodeling group in the apical 4 chamber view showing GLS −13.1% in 4 chamber view. [C] GLS in a patient from LV non-remodeling group in the apical 2 chamber view showing GLS −15.8% in 2 chamber view. [D] Bull's eye view showing peak systolic GLS −14.4% in a patient from the LV non-remodeling group.

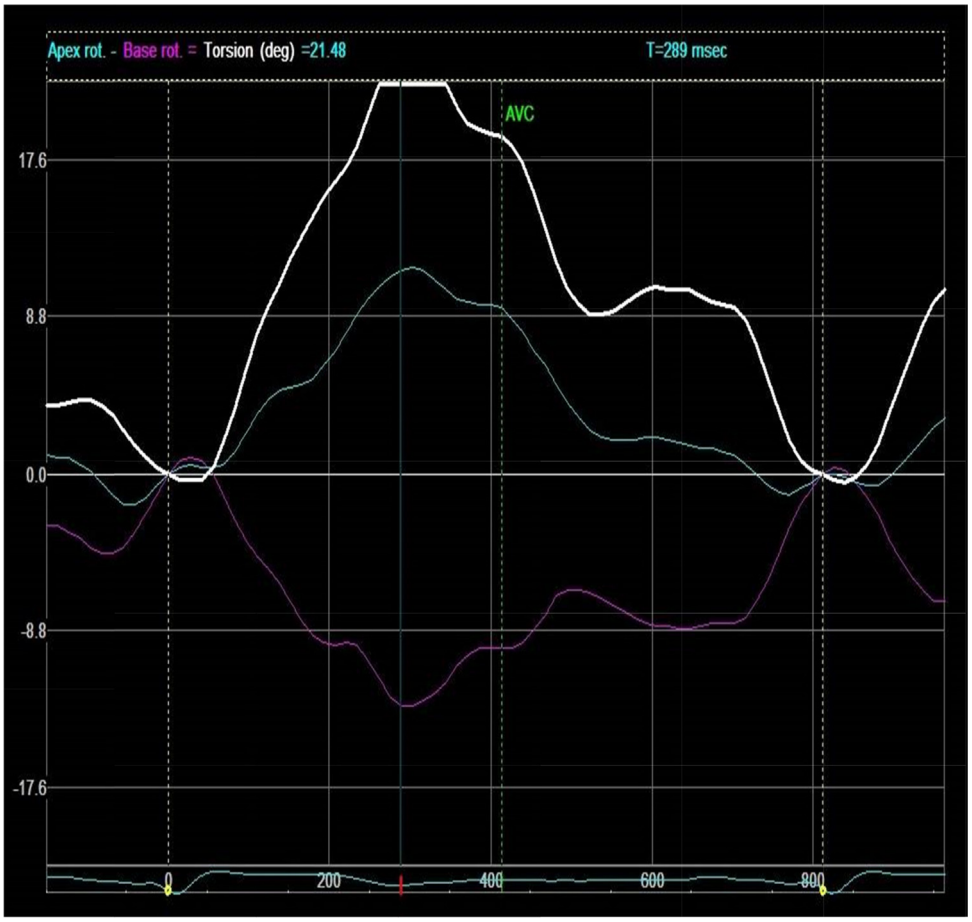

Fig. 6. LV torsion in a patient from LV non remodeling group 21.48 degree.

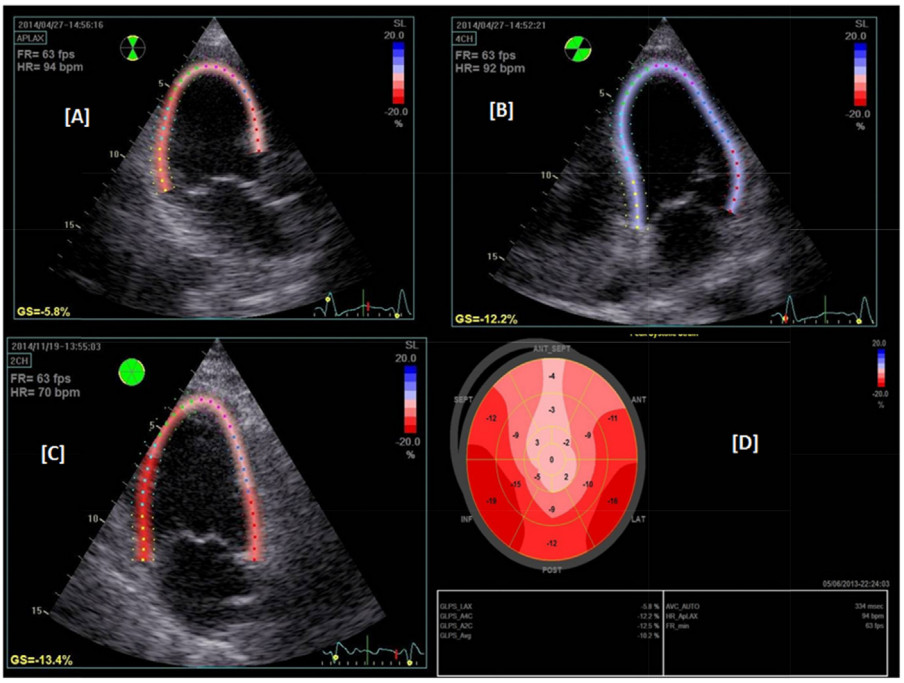

Fig. 7. [A] GLS in a patient from LV remodeling group in the apical long axis view showing GLS −5.8% in long axis view. [B] GLS in a patient from LV remodeling group in the apical 4 chamber view showing GLS −12.2% in 4 chamber view. [C] GLS in a patient from LV remodeling group in the apical 2 chamber view showing GLS −13.4% in 2 chamber view. [D] Bull's eye view showing peak systolic GLS −10.2% in a patient from the LV remodeling group.

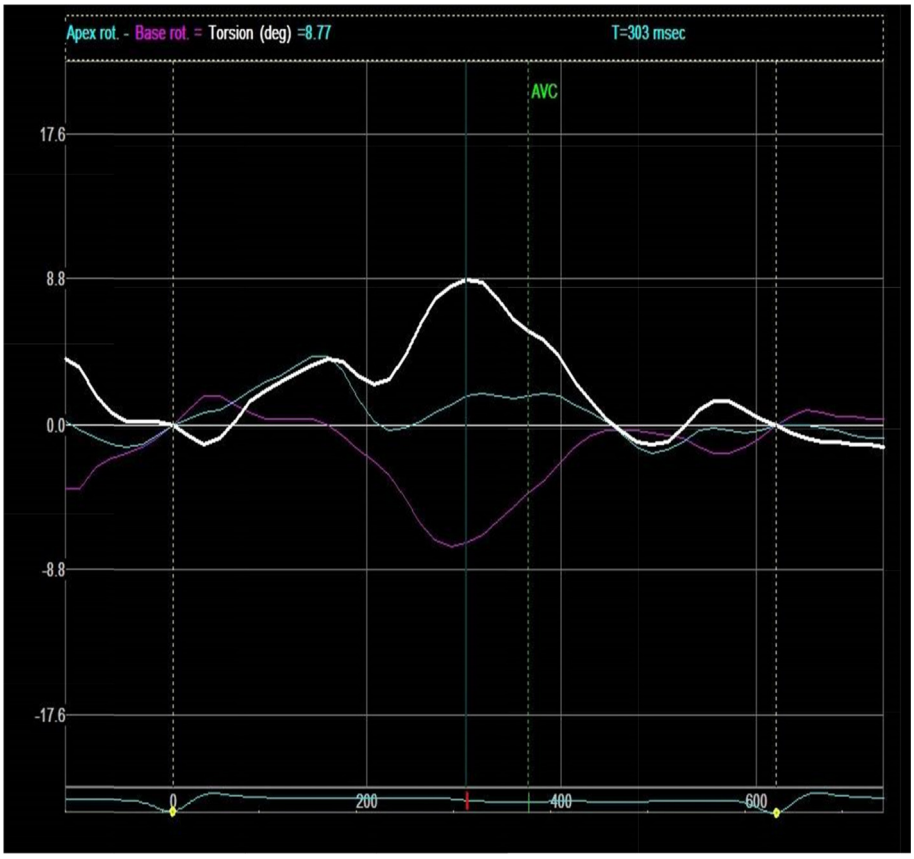

Fig. 8. LV torsion in a patient from LV remodeling group 8.77 degree.

Regarding TIMI flow there was a significantly worse TIMI flow after reperfusion in the LV remodeling group.

Galiuto and his colleagues in their study in 2008 concluded that TIMI flow < 3 after reperfusion was found to be an independent predictor of LV remodeling (OR; 5.6, P = 0.015).[32]

Moreover, **MBG** in the present study showed a significantly worse MBG in the LV remodeling group.

In Hamdan and his colleagues study in 2010, The presence of successful myocardial reperfusion (MBG 2–3) after primary PCI was associated with a significantly lower rate of remodeling than the absence of successful myocardial reperfusion (MBG 0–1) In univariate analysis, only (MBG 0–1) versus (MBG 2–3) was associated with increased risk of LV remodeling (OR; 9.3, 95% CI; 1.45–60.21, P = 0.019).[20]

However **pre-dilatation, stent length and stent diameter** showed non-statistically significant difference between both groups, the same results were found in Hamdan and his colleagues study in 2010.[20]

4.6. Echocardiographic data and LV remodeling

In the present study LV EDV showed non statistically significant difference between both groups being slightly larger in the LV remodeling group however **LV ESV and LVEF** by biplane Simpson's method showed statistically significant difference between both groups with larger LV ESV and lower LVEF in the LV remodeling group. This could be related to early affection of LV ESV after AMI that depends on myocardial fibers shortening while LV EDV depends on LV filling pressures and structural remodeling that occurs later.

And this was concordant with Bolognese and his colleagues study in 2002, that showed in the LV remodeling group that LVEDV was (119 ± 36 versus 126 ± 36 ml, P > 0.05), LVESV (74 ± 29versus 70 ± 28 ml, P < 0.001) and LVEF was (39 ± 9 versus 45 ± 10%, P < 0.001),[23] Zaliaduonyte-Peksiene and her colleagues study in 2014 that showed that in LV remodeling group that LV EDV was (83.7 ± 22.3versus 84.1 ± 20.3 ml, P > 0.05), LV ESV was (43.4 ± 14.3 versus 38.5 ± 13.3 ml, P < 0.05) and LVEF was (49.4 ± 7.9 versus 54.3 ± 7.8%, P < 0.001).[28]

Also In the present study LVEF < 40% was found to be an independent predictor of LV remodeling (OR; 1.8, 95%CI; 0.8–11, P value = 0.003).

In Galiuto and his colleagues study in 2008, with univariate analysis LVEF < 44.5% was found to be a predictor of LV remodeling (OR; 4.29, 95% CI; 1.71–10, P = 0.002).[32]

Moreover, **WMSI** in the present study showed a significantly higher value in the LV remodeling group. Multivariate analysis concluded that WMSI > 1.8 was found to be an independent predictor of remodeling (OR; 2.1, 95% CI; 1–12.7, P = 0.002), sensitivity (90%), specificity (88%), PPV (89%) and NPV (94%).

This was concordant with Zaliaduonyte-Peksiene and her colleagues in 2014 and Mannerts and his colleagues in 2004 in which WMSI was 1.65 ± 0.32 versus 1.49 ± 0.30 (P < 0.01) and 1.57 ± 0.28 versus 1.37 ± 0.23 (P < 0.04) in the LV remodeling group versus LV non-remodeling group respectively.[28,19]

Galiuto and his colleagues study in 2008, with univariate analysis, WMSI > 1.9 was found to be a predictor of remodeling with (OR; 4.29, 95% CI; 1.71–10, P = 0.002).[32] This seems logic enough as the higher the WMSI the bigger the akinetic areas with more loss of muscle and thus vulnerability to expansion and LV remodeling.

TDI of mitral annulus showed significantly higher values of lateral and septal e' in the LV non-remodeling group and significantly higher value of E/e' ratio in the LV remodeling group.

This could be related to dependence of LV EDV on structural remodeling and LV filling pressures suggesting larger LV EDV with higher LV filling pressure marked by higher E/e' ratio.

And this was concordant with Barberato and his colleagues study in 2013 in which lateral e' in the LV remodeling group was (6.9 ± 2 versus 8.5 ± 2 cm/s, P = 0.02) and E/e' ratio in the LV remodeling group was (13 ± 4 versus 8.5 ± 2, P < 0.001) but only E/e' ratio was an independent predictor of LV remodeling.[29]

The Average peak systolic GLS showed statistically significant difference between both groups with higher values in the LV remodeling group. Multivariate analysis showed that average peak systolic GLS > −12.5% was found to be an independent predictor of LV remodeling (OR; 1.7, 95% CI; 0.4–13.8, P = 0.04). The best cut-off value for average peak systolic GLS was >−12.5%, with sensitivity (87%), specificity (85%), PPV (83%) and NPV (88%).

Longitudinal strain is affected after AMI due to alteration of myocardial longitudinal fibers shortening, the more the damage of the myocardium, the more the affection of myocardial longitudinal fibers shortening resulting in lower values of GLS.

And this was concordant with Bochenek and his colleagues study in 2011, in which peak systolic GLS was found to be an independent predictor of LV remodeling with (OR, 1.19; 95% CI, 1.04–1.37, P = 0.005) and the best cut off value was >−12.5% (AUC, 0.77)[24] and in Zaliaduonyte-Peksiene and her colleagues study in 2014 in which peak systolic GLS in the LV remodeling group was found to be (−11.05 ± 4.1 versus −15.2 ± 3.2, P < 0.001) and it was found to be an independent predictor of LV remodeling (OR; 1.21, 95% CI; 1.05–1.48, P = 0.021).[28]

Moreover, Joyce and her colleagues study in 2013 found that LV peak systolic GLS >−14.9% compared to ≤−14.9% exhibited greater LV dilatation at 6 months with LVEDV (122 ± 44 versus 102 ± 34 ml, P < 0.001).[30]

LV torsion showed significantly higher values in the LV non-remodeling group. Multivariate analysis showed that LV torsion < 9.5° was found to be an independent predictor of LV remodeling (OR; 1.5, 95%CI-0.11–22, P = 0.05). The best cut-off value for LV torsion was <9.5°, with sensitivity (91%), specificity (85%), PPV (89%) and NPV (95%).

LV torsion is significantly impaired after AMI due to affection of both basal and apical rotation with more affection of LV torsion with larger myocardial damage and larger size of infarction.

Jang and his colleagues in their study in 2010 showed that LV torsion in the LV remodeling group was (6.7 ± 2.6° versus 8.8 ± 3.4°, P < 0.01)[34] and Nucifora and his colleagues study in 2010 showed that the amount of impairment of LV torsion predicts LV remodeling and LV torsion was an independent predictor of LV remodeling (OR; 0.77, 95% CI; 0.65–0.92, P = 0.003).[33,34]

4.7. Reverse LV remodeling

LV reverse remodeling occurred in 13 patients representing 27% of patients in LV non-remodeling group.

Spinelli and his colleagues study in 2013 studied 75 patients with first anterior STEMI, reverse LV remodeling occurred in 25 patients (33%) of patients.[35]

4.8. Independent predictors of LV remodeling

In the present study, 6 independent predictors of LV remodeling were found in the following descending order according to OR: ***[1] WMSI > 1.8*** with P value (0.002), odds ratio (OR) (95%CI) 2.1 (1–12.7). ***[2] LV EF < 40%*** with P value (0.003), OR (95% CI) 1.8 (0.8–11). ***[3] GLS > -12.5%*** with P value (0.04), OR (95% CI) 1.7 (0.4–13.8). ***[4] LV torsion < 9.5°*** with P value (0.05), OR (95% CI)

1.5 (-0.11–22). ***[5] CK-MB > 500 U/L*** with P value (0.05), OR (95% CI) 1.4 (-0.11–22). ***[6] Thrombus grade > 4*** with P value (0.002), OR (95% CI) 1.2 (-0.3–20). ***[7] Total ischemic time*** with P value (<0.0001), OR (95% CI) 1.01(1.05–1.015).

5. Study limitations

[1] The results were obtained from a single medical center, with a rather small sample size (81 patients). **[2]** Patients with Killip class IV (cardiogenic shock) were excluded from the study as it was not possible to measure LV torsion and LV peak systolic GLS at bedside. **[3]** Few patients with anterior STEMI had normal values of LV torsion and LV peak systolic GLS. **[4]** This study was concerned with LV remodeling that occurred after 6 months of MI, but it did not study the early LV remodeling that occurred early after MI. **[5]** Lateral e' wave velocity was used in calculation of E/e' ratio, however average lateral and septal e' in patients with anterior STEMI was supposed to be more accurate due to LV dysfunction and wall motion abnormality.

6. Conclusion

Average peak systolic GLS and **LV torsion** at echocardiography done early after myocardial infarction are independent predictors of LV remodeling after anterior STEMI and can be used to predict occurrence of LV remodeling after 6 months.

Conflict of interest

We have no conflict of interest to declare.

References

1. Bolooki HM, Askar A. Disease management project. *Cardiology, Acute Myocardial Infarction, Cleveland Clinic*. 2010.
2. Konstam MA, Kramer DG, Patel AR, et al.. Left ventricular remodeling in heart failure: Current concepts in clinical significance and assessment. *JACC Cardiovasc Imaging*. 2011;4:98–108.
3. Thygesen K, Alpert JS, White HD. The writing group on behalf of the joint ESC/ACCF/AHA/WHF task force for the universal definition of myocardial infarction. *Eur Heart J*. 2012;33:2551–2567.
4. James PA, Oparil S, Carter BL, Cushman WC, et al.. Evidence-based guideline for the management of high blood pressure in adults report from the panel members appointed to the eighth joint national committee (JNC 8). *JAMA*. 2014;311:507–520.
5. Tominaga M. Diagnostic criteria for diabetes mellitus. *RinshoByori*. 1999;47(10):901–908.
6. Scheuner MT, Setodji CM, Pankow JS, et al.. Relation of familial patterns of coronary heart disease, stroke, and diabetes to subclinical atherosclerosis: the multi-ethnicstudy of atherosclerosis. *Genet Med*. 2008;10:879–887.
7. De Geare VS, Grines LL, Boura JA, et al.. Predictive value of the Killip classification in patients undergoing primary percutaneous coronary intervention for acute myocardial infarction. *Am J Cardiol*. 2001;87(9):1035–1038.
8. Gibson CM, de Lemos JA, Murphy SA, et al.. Combination therapy with abciximab reduces angiographically evident thrombus in acute myocardial infarction: a TIMI 14 substudy. *Circulation*. 2001;103(21):2550–2554.
9. Appleby MA, Angeja BG, Dauterman K, et al.. Angiographic assessment of myocardial perfusion: TIMI myocardial perfusion (TMP) grading system. *Heart*. 2001;86(5):485–486.
10. Henriques JP, Zijlstra F, van 't Hof AW, et al.. Angiographic assessment of reperfusion in acute myocardial infarction by myocardial blush grade. *Circulation*. 2003;107(16):2115–2119.
11. Kessler KM. Ejection fraction derived by M-mode echocardiography: a table and comments. *CathetCardiovascDiagn*. 1979;5(3):295–299.
12. Lang RM, Bierig M, Devereux RB, et al.. Recommendations for chamber quantification: a report from the American society of echocardiography's guidelines and standards committee and the chamber quantification writing group, developed in conjunction with the European association of echocardiography, a branch of the European society of cardiology. *J Am Soc Echocardiogr*. 2005;18(12):1440–1463.
13. Otterstad JE, Froeland G, St John Sutton M, et al.. Accuracy and reproducibility of biplane two-dimensional echocardiographic measurements of left ventricular dimensions and function. *Eur Heart J*. 1997;18(3):507–513.
14. Zoghbi WA, Enriquez-Sarano M, Foster E, Grayburn PA, et al.. Recommendations for evaluation of the severity of native valvular regurgitation with two-dimensional and Doppler echocardiography. *J Am SocEchocardiogr*. 2003;16:777–802.
15. Broderick TM, Bourdillon PD, Ryan T, et al.. Comparison of regional and global left ventricular function by serial echocardiograms after reperfusion in acute myocardial infarction. *J Am SocEchocardiogr*. 1988;2:315–323.
16. Sawada SG, Segar DS, Ryan T, et al.. Echocardiographic detection of coronary artery disease during dobutamine infusion. *Circulation*. 1991;83:1605–1614.
17. Ryoung Choi E, Sung-Ji P, Choe YH, et al.. Early detection of cardiac involvement in Miyoshi myopathy: 2D strain echocardiography and late gadolinium enhancement cardiovascular magnetic resonance. *J Cardiovasc Magn Reson*. 2010;12:31.
18. Notomi Y, Lysyansky P, Setser RM, et al.. Measurement of ventricular torsion by two-dimensional ultrasound speckle tracking imaging. *J Am CollCardiol*. 2005;45:2034–2041.
19. Mannaerts HF, van der Heide JA, Kamp O, et al.. Early identification of left ventricular remodelling after myocardial infarction, assessed by transthoracic 3D echocardiography. *Eur Heart J*. 2004;25(8):680–687.
20. Hamdan A, Kornowski R, Lev EI, et al.. Impact of myocardial blush on left ventricular remodeling after first anterior myocardial infarction treated successfully with primary coronary intervention. *Isr MedAssoc J*. 2010;12:211–215.
21. Tosteson AN, Goldman L, Udvarhelyi IS, et al.. Cost-effectiveness of a coronary care unit versus an intermediate care unit for emergency department patients with chest pain. *Circulation*. 1996;94:143–150.
22. Windecker S, Kolh P, Alfonso F, et al.. The task force on myocardial revascularization of the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS). *Eur Heart J*. 2014;35:2541–2619.
23. Bolognese L, Neskovic AN, Parodi G, et al.. Left ventricular remodeling after primary coronary angioplasty. *Circulation*. 2002;106:2351–2357.
24. Bochenek T, Wita K, Tabor Z, et al.. Value of speckle-tracking echocardiography for prediction of left ventricular remodeling in patients with ST-elevation myocardial infarction treated by primary percutaneous intervention. *J Am SocEchocardiogr*. 2011;24:1342–1348.
25. Symons R, Masci PG, Francone M, et al.. Impact of active smoking on myocardial infarction severity in reperfused ST-segment elevation myocardial infarction patients: the smoker's paradox revisited. *Eur Heart J*. 2016;37:2756–2764.
26. Parodi G, Carrabba N, Santoro GM. Heart failure and left ventricular remodeling after reperfused acute myocardial infarction in patients with hypertension. *Hypertension*. 2006;47:706–710.
27. Lamblin N, Fertin M, de Groote P, et al.. Cardiac remodeling and heart failure after a first anterior myocardial infarction in patients with diabetes mellitus. *J Cardiovasc Med*. 2012;13(6):353–359.
28. Zaliaduonyte-Peksiene D, Simonyte S, Lesauskaite V, et al.. Left ventricular remodelling after acute myocardial infarction: Impact of clinical, echocardiographic parameters and polymorphism of angiotensinogen gene. *J Renin-Angiotensin-Aldosterone Syst*. 2014;15:286–293.
29. Barberato SH, Moraes de Souza A, Costantini CO, Costantini CR. Non invasive assessment of left ventricular filling pressure and remodeling after acute myocardial infarction. *Arq Bras Cardiol*. 2013;100(6):531–537.
30. Joyce E, Hoogslag GE, Leong DP, et al.. Association between discharge heart rate and left ventricular adverse remodelling in ST segment elevation myocardial infarction patients treated with primary percutaneous coronary intervention. *Heart*. 2013;99(8):556–561.
31. Masci PG, Ganame J, Francone M, et al.. Relationship between location and size of myocardial infarction and their reciprocal influences on post-infarction left ventricular remodeling. *Eur Heart J*. 2011;32:1640–1648.
32. Galiuto L, Garramone B, Scarà A. The extent of microvascular damage during myocardial contrast echocardiography is superior to other known indexes of post-infarct reperfusion in predicting left ventricular remodeling. *JACC*. 2008;51:552–559.
33. Nucifora G, Marsan NA, Bertini M, et al.. Reduced left ventricular torsion early after myocardial infarction is related to left ventricular remodeling. *CircCardiovasc Imaging*. 2010;3:433–442.
34. Jang JY, Woo JS, Kim WS, et al.. Serial assessment of left ventricular remodeling by measurement of left ventricular torsion using speckle tracking echocardiography in patients with acute myocardial infarction. *Am J Cardiol*. 2010;106(7):917–923.
35. Spinelli L, Morisco C, Assante di Panzillo E, et al.. Reverse left ventricular remodeling after acute myocardial infarction: the prognostic impact of left ventricular global torsion. *Int J Cardiovasc Imaging*. 2013;29(4):787–795.