ORIGINAL ARTICLE

Left Ventricle Pressure Strain Loop as Predictor of Left Ventricular Function Recovery in Patients with Acute Coronary Syndrome

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Abstract

Background: ***Acute coronary syndrome (ACS) is among the primary reasons for morbidity and mortality worldwide.***

Aim: ***To detect the myocardial stunning recovery in cases with ACS after revascularization with a non-invasive LV pressure strain loop (PSL) as a novel technique for quantitative assessment of myocardial work instead of traditional ejection fraction.***

Patients and methods: ***This was a prospective cohort study that enrolled 50 consecutive cases who have been presented by ACS for PCI, either STEMI or NSTE-ACS, managed with primary percutaneous coronary intervention (PCI) and treatment that is dependent on medical guidelines. Results: At monitoring, there were statistically significant differences in ejection fraction, global work index, global work efficiency, and LV global longitudinal strain in comparison to the values, with p-values of 0.005, 0.005, 0.001, 0.005, 0.001, 0.005, and 0.05, respectively. ROC curve analysis proved good discriminating power of the myocardial work index between LVEF <40% and >40%, where the area under the ROC curve (AUC) = 0.832 with SE 0.024 (95% Confidence interval 0.712–0.892. Z statistic = 5.286, p < 0.001. Cutoff point <800 with sensitivity = 87.5% and specificity = 78.8%.***

Conclusion: ***We concluded that left ventricular PSL may be considered a novel non-invasive method for the quantitative evaluation of myocardial work and recovery of myocardial stunning in cases with acute coronary syndrome after revascularization instead of traditional ejection fraction.***

Keywords: LV pressure strain loop; LV function recovery; patient with ACS

1. Introduction

Acute coronary syndrome is among the primary reasons for morbidity and mortality worldwide.[1]

Left ventricular dysfunction that results from acute myocardial infarction is partially due to myocardial stunning and irreversible damage, which might be reversible. The main indicator for higher cardiovascular death and morbidity is the persistence of severe LV dysfunction following AMI.[2] Improvements in ST-segment elevation myocardial infarction (STEMI) management have significantly enhanced the identification of ST-segment elevation myocardial infarction cases. .[3] Nevertheless, myocardial stunning may lead to a delay in the recovery of regional myocardial work subsequent to myocardial reperfusion.[4] This results in transient left ventricular dysfunction, which typically recovers to a partial extent within 3 to 6 months of the STEMI.[5]

Myocardial stunning (viability) has been detected following myocardial infarction using a variety of imaging techniques.[6,7] Currently, global left ventricular myocardial work index (GLVMWI)[8] was utilized to assess LV systolic function in STEMI cases[9] and their correlation with myocardial glucose metabolism. [8]

In our investigation, our goal was to estimate the recovery of myocardial stunning in cases with ACS after revascularization with non-invasive LV-PSL as a novel method for quantitative assessment of myocardial work instead of traditional ejection fraction.

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2. Patients and methods

This was a prospective cohort study that enrolled 50 consecutive cases that have been presented by ACS for PCI, either STEMI or NSTE-ACS, at the cardiology department, catheterization laboratory, at Al-Azhar University hospitals from July 2023 till February 2024. AMI diagnosis was defined by elevation of serum troponin, presence of clinical symptoms, and/or typical electrocardiographic changes, regarding the fourth universal AMI definition.[10]

Inclusion criteria: All patients presented by ACS for pressure strain loop, either STEMI or NSTE-ACS, were from both genders and within 24 hours of revascularization.

Exclusion criteria: Poor echo window; Patients with pacemakers, ICDs, and CRTs; cases with a prior history of myocardial infarction; cases who have undergone CABG or percutaneous coronary intervention; and cases having arrhythmia (e.g., full left bundle branch block, atrial fibrillation), valvular heart illness, and cardiomyopathy.

All Cases were subjected to the following:

General outlines

Signed informed consent was obtained from each patient. Ethical acceptance has been gained from the ethical and research committee, Faculty of Medicine, Al-Azhar University. Brief medical history taking that is fully re-obtained after patient revascularization. Brief general and local clinical examination that is fully re-obtained after patient revascularization. A resting twelve-lead surface electrocardiogram (ECG) and a long strip to detect heart rhythm and rate were performed in all cases.

Conventional Echocardiography

Echocardiography was carried out within 24 hours after revascularization and two months after the intervention. A comprehensive TTE using GE Healthcare Vivid-E95 (GE Healthcare Vivid-E95 - GE Healthcare, Horten, Norway), GE M5Sc-D XD Clear (Sector) 1.4-4.6 MHz for 2D, and GE 4V-D Probe (Volume) 1.5-4.0 MHz standard echocardiographic measurements were obtained following the most recent EACVI/ASE guidelines. In order to acquire sufficient images in various standard views, all cases were evaluated while at rest in the left lateral decubitus position. The study was ECG-gated and also saved as cine loops with a frame rate of between 60 and 110 frames per second for offline quantification. The Echo PAC 203 workstation (GE Healthcare) was used to store and analyze all images. Prior to the operation, the brachial artery's diastolic and systolic blood pressures will be assessed with a cuff sphygmomanometer. The parasternal and apical views have been attained & saved in cine-loop format, including two-dimensional, color, pulsed-wave, and continuous-wave Doppler images, in addition to standard M-mode.

Line Analysis protocol

Analysis has been performed offline utilizing Echo PAC 203 workstation software (Horten, GE Healthcare, Norway) utilizing Simpson's biplane method; left ventricle end-diastolic volume (LVEDV) and end-systolic volume (LVESV) have been evaluated from apical four- & two-chamber views, and the LV ejection fraction (EF) has been computed. 2-dimensional speckle tracking analyses have been conducted on images of the 4-chamber, 2-chamber, and long-axis apical views to quantify the global longitudinal strain (GLS) of the left ventricle. Left ventricle global longitudinal strain and non-invasively determined blood pressure were combined to calculate GLVMWI utilizing a vendor-specific module (Echo Pac version 203 software, General Electric Medical Systems, Horten, Norway). The left ventricle endocardial border was manually traced in apical long-axis, 2-chamber, and 4-chamber views to measure left ventricle GLS utilizing 2D-speckle tracking echocardiography. The diastolic and systolic left ventricle pressures were estimated non-invasively using the brachial cuff blood pressure recordings of cases. The period of the following phases of the cardiac cycle—LV ejection, isovolumic relaxation, and isovolumic contraction—was determined by recognizing the timing of the closing and opening of mitral and aortic valves from the apical long-axis view. Left ventricle global longitudinal strain data of the entire cycle of the heart, left ventricle pressures, and cardiac event periods were combined by the software to create a case-specific, non-invasive left ventricle pressure-strain curve. The subsequent GLVMWI was computed: GWI is the total work carried out within the left ventricle PSL from the closure of the mitral valve to the opening of the valve. Global work efficiency (GWE) is determined by dividing the sum of constructive work in all left ventricle sections by the sum of wasted and constructive work in all left ventricle sections.

Statistical analysis

For the purpose of conducting the analysis of the data that was recorded, the statistical package for social sciences, version 23.0 (SPSS Inc., Chicago, Illinois, states), was utilized. The quantitative data has been expressed as mean ± SD & ranges when the distribution was parametric (normal). In contrast, non-parametric variables have been measured using the median and the interquartile range (IQR) as their statistical measures. A variety of qualitative factors are additionally expressed in the form of percentages and numbers. For the purpose of determining whether or not the data are normally distributed, the Shapiro-Wilk Test and the Kolmogorov-

Smirnov Test have been applied. The following tests have been done: Paired sample t-test, Pearson's correlation coefficient (r), Positive

= elevation in the independent variable results in elevation in the dependent variable, Negative = elevation in the independent parameters results in reduction in the dependent. The confidence interval has been established at 95%, and the margin of error accepted has been set to five percent. So, the p-value was considered significant as the following: Probability (P-value): P-value ≤0.05 was considered significant, P-value ≤0.001 was deemed as highly significant, and P-value > 0.05 was deemed insignificant.

3. Results

The research involved fifty patients, thirty-seven men (74%) and thirteen women (26%). The age ranged between 48 and 69 years, with an average age of 58.66±6.61. (Table 1).

Table 1. General characteristics distribution within group under investigation.

GENERAL CHARACTERISTICS	TOTAL NUMBER=FIFTY)
AGE (YEARS)	
RANGE	48-69
MEAN± STANDARD DEVIATION	58.66±6.61
SEX	
FEMALE	13 (TWENTY-SIX PERCENT)
MALE	37 (74.0%)

The most frequent risk factors for patients were smoking (44%), followed by a family history of coronary artery disease (44%), hypertension (38%), and dyslipidemia (18%). (Table 2)

Table 2. Risk factors distribution among study groups.

RISK FACTORS	NO.	%
SMOKER	22	44.0%
FAMILY HISTORY OF CORONARY ARTERY DISEASE	22	44.0%
HYPERTENSION	19	38.0%
DYSLIPIDEMIA	9	18.0%
DIABETES MELLITUS	3	6.0%

There were statistically significant higher values of LV end-systolic and end-diastolic volumes in follow-up compared with baseline values, with p-values of 0.026 and 0.038, correspondingly. (Table 3)

Table 3. Comparison among Baseline and Follow-Up regarding LVEDV (ml) and LVESV (ml).

	BASELINE (N=50)	FOLLOW UP (N=50)	PAIRED SAMPLE T-TEST		BASELINE (N=50)
RANGE	37-92	45-123			
MEAN±SD	69.24±9.72	72.30±19.08	3.060	2.138	0.026*
LEFT VENTRICULAR END-DIASTOLICVOLUME (ML)					
RANGE	97-181	89-175			
MEAN ±SD	119.04±14.13	124.58±19.34	5.540	2.135	0.038*

p-value > 0.05 is insignificant; *p-value < 0.05 is significant; **p-value < 0.01is highly significant

A statistically significant difference has been detected regarding ejection fraction in follow-up compared with baseline, with a p-value (p-value < 0.005). (Table 4)

Table 4. Comparison among baseline and monitoring regarding left ventricular ejection fraction (%).

LEFT VENTRICULAR EJECTION FRACTION (%)	BASELINE (N=50)	FOLLOW UP (NUMBER=FIFTY)	PAIRED SAMPLE T-TEST MD	t-test	P-VALUE
RANGE	33-47	31-59			
MEAN ±SD	40.58±3.64	43.38±6.67	2.800	2.930	0.005*

A statistically significant difference has been detected regarding LV GLS (%) in follow-up compared to baseline, with a p-value (p-value < 0.001). (Table 5)

Table 5. Comparison among Baseline and Follow Up regarding LV GLS (%).

LEFT VENTRICULAR GLOBAL LONGITUDINAL STRAIN (%)	BASELINE (n=50)	FOLLOW UP (n=50)	PAIRED SAMPLE T-TEST MD	LEFT VENTRICULAR GLOBAL t-test	BASELINE P-VALUE
RANGE	-17_-11	-22_-11			
MEAN ±SD	-14.98±1.35	-16.56±2.79	1.580	3.422	<0.001**

There was a statistically significant difference with regard to the global work index (mmHg%) in follow-up compared to baseline, with a p-value (p-value < 0.001). (Table 6)

Table 6. Comparison among Baseline and Follow Up regarding Global Work index (mmHg%).

GLOBAL WORK INDEX (MMHG%)	BASELINE (NUMBER=FIFTY)	FOLLOW UP (N=50)	PAIRED SAMPLE T-TEST MD	t-test	P-VALUE
RANGE	505-1136	470-1825			
MEAN ±SD	748.50±174.98	1005.70±436.91	257.200	4.280	<0.001**

There was a statistically significant difference regarding global work efficiency in follow-up compared to baseline, with a p-value (p-value < 0.05). (Table 7)

Table 7. Comparison among Baseline and Follow Up regarding Global Work efficiency (mmHg%).

GLOBAL WORK EFFICIENCY (MMHG%)	BASELINE (N=50)	FOLLOW UP (NUMBER=FIFTY)	PAIRED SAMPLE T-TEST MD	t-test	P-VALUE
RANGE	61-85	60-97			
MEAN±SD	75.92±5.96	80.48±9.70	4.560	3.037	0.004*

There was a statistically significant association between the amount of alteration of LV ejection fraction (%) with the amount of change of global work index (mmHg%) and the amount of change of global work efficiency (mmHg%), with a p-value (p-value < 0.05). (Table 8) (Figure 1) (Figure 2).

Table 8. Correlation between amount of change of global work index (mmHg%) and amount of change of global work efficiency (mmHg%) with amount of change of left ventricular ejection fraction (%), using Pearson's correlation coefficient.

		AMOUNT OF CHANGE OF GLOBAL WORK INDEX (MMHG%)	AMOUNT OF CHANGE OFGLOBAL WORK EFFICIENCY (MMHG%)
AMOUNT OF CHANGE OF LEFT VENTRICULAR EJECTION FRACTION (%)	r-value	-0.415	-0.308
	P-VALUE	0.007*	0.023*

Using: Pearson's correlation coefficient (r)

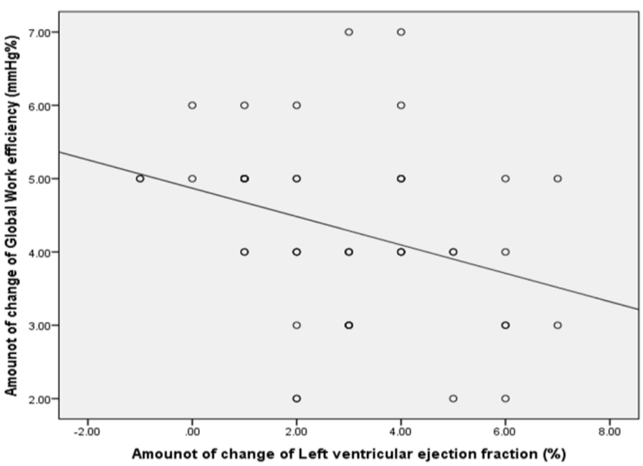

Figure 1. Scatter plot between amount of change of global work efficiency (mmHg%) and amount of change of left ventricular ejection fraction (%).

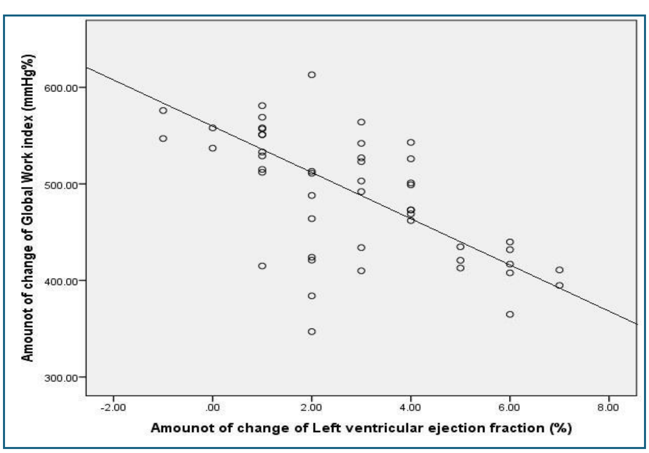

Figure 2. Scatter plot between amount of change of global work index (mmHg%) and amount of change of Left ventricular ejection fraction (%).

ROC curve analysis proved good discriminating power of the (myocardial work index) between LVEF <40% and >40% where Area under the ROC curve = 0.832 with SE 0.024 (95% Confidence interval 0.712–0.892. Z statistic =5.286, p<0.001. Cutoff point <800 with sensitivity = 87.5% and specificity= 78.8%

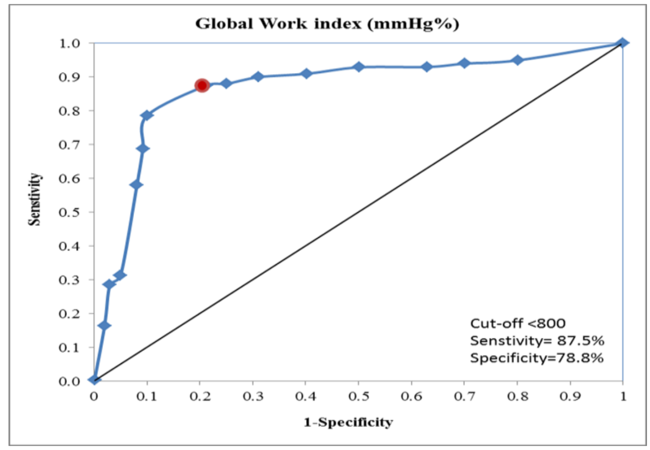

Figure 3. Receiver-operating characteristic (ROC) curve for prediction of stunning, utilizing myocardial work index.

4. Discussion

Cardiovascular imaging has long dreamed of being capable of providing a quick, non-invasive, and accurate evaluation of MW. This goal has been coming for a long time. LVEF is the most frequently utilized parameter in daily practice due to its ease of accessibility. Nevertheless, a decade of research has demonstrated that the analysis of GLS is more effective than LVEF in detecting early subclinical myocardial dysfunction in a variety of pathological scenarios .[11] Nevertheless, the load-dependent limitation of these 2 variables could be partially alleviated through the measurement of MW, which generates a surrogate of left ventricular pressure over time utilizing left ventricular pressure non-invasively (assessed utilizing peripheral blood pressure synchronized) and echocardiography-derived valvular timing event. This surrogate considers the afterload exerted on the LV. Pressure-volume (PV) analysis is the most comprehensive method for describing cardiac function, providing a comprehensive understanding of cardiac mechanics and energetics. Nevertheless, pressure-volume analysis continues to be a time-consuming and highly invasive method, which prevents its integration into clinical practice.[12] It is intriguing that the area of this combined non-invasive left ventricular pressure–strain loop is associated with invasive metabolism and myocardial work.

Non-invasive assessments of myocardial function may play a crucial role in the progress of treatments and the estimation of prognosis. Nevertheless, its incremental prognostic validity in comparison to conventional echocardiographic variables is still unknown.[13]

Consequently, this investigation was launched with the objective of assessing the recovery of myocardial stunning in cases that have ACS following revascularization using a non-invasive left ventricular PSL as a novel approach to quantitatively evaluate myocardial work instead of the traditional ejection fraction.

This study has been performed at the Cardiology Department, Faculty of Medicine, Al-Azhar University Hospitals, from July 2023 till February 2024. The investigation has been carried out on 50 cases that had ACS within 24 hours from revascularization.

The study included thirty-seven men (74%) and thirteen women (26%). The age varied between 48 years and 69 years, with a mean age of 58.66±6.61 years. The most frequent risk factors for patients were smoking (44%), followed by a family history of coronary artery illness (44%), hypertension (38%), and dyslipidemia (18%). The most common presentation for patients was anterior STEMI (54%), and the most common angiographic result for patients was PCI to LAD (38%).

A few studies have investigated the value of myocardial work parameters in cases of AMI. Meimoun et al.[14]. have examined ninety-three cases with ST-segment elevation myocardial infarction managed by PCI and demonstrated a GWE of less than eighty-six percent within forty-eight hours of admission in 507 ST-segment elevation myocardial infarction cases. Ren et al.[15] assessed the alterations of myocardial function in thirty-three NSTE-ACS cases prior to and following percutaneous coronary intervention with a non-invasive left ventricular pressure-strain loop, and Coisne et al[11] who examined the clinical significance of myocardial work variables in cases with both NSTEMI and ST-segment elevation myocardial infarction (173 ST-segment elevation myocardial infarction and 71 NSTEMI) but following one month of MI onset to prevent early MI-related complications.

Our study revealed a statistically significant highest mean value of left ventricular end-systolic volumes in follow-up compared to baseline, with mean left ventricular end-systolic volume (ml) 69.24±9.72 at baseline and 72.30±19.08 at follow-up with p-value (p=0.026).

In our investigation, there was a statistically significant highest mean value of left ventricular end-systolic volume, ejection fraction, and global longitudinal strain (%) in monitoring in comparison with baseline.

Also, there was a statistically significant enhancement of global work efficiency (mmHg%) in follow-up 80.48±9.70 compared to baseline 75.92±5.96.

Our study illustrated a statistically significant correlation between the amount of change of LV ejection fraction (%) with the amount of change of global work index (mmHg%) and the amount of change of global work efficiency (mmHg%), with a p-value ($P < 0.05$).

Meimoun et al.[14], Lustosa et al.[16], and Ren et al.[15] all concurred with our findings and stated that the non-invasive LV pressure strain loop technology has the ability to accurately and early assess impairment of myocardial function in cases with STEMI and NSTEMI, as well as recovery of myocardial function following percutaneous coronary intervention and medical therapy optimization.

The minor variation in GWE thresholds among our investigation and Coisne et al.[11] is therefore explicable by the time when the GWE has been analyzed following AMI and by medical treatments optimization.

Additional research by Qin et al.[17], Edwards et al.[18], and Wang et al.[19] have illustrated that pressure strain loops could be utilized as a diagnostic tool for NSTE-acute coronary syndrome cases that have normal LVEF and no obvious segmental ventricular wall motion abnormalities. Additionally, it is believed that GWE is capable of accurately predicting severe coronary stenosis in NSTE-acute coronary syndrome cases, and its predictive value is better than that of GWI and GLS.

Qin et al.[17] used non-invasive left ventricle pressure–strain loops to estimate territorial MW efficiency (WE) in order to detect obstructive coronary artery stenosis in cases with non-obstructive or obstructive coronary artery stenosis NSTE-acute coronary syndrome, the latter of which includes or excludes obstruction. Territorial and global longitudinal strain (LS) analyses have been carried out prior to coronary angiography using speckle-tracking imaging. Constructive work (CW), wasted work (WW), myocardial work efficiency, and myocardial work index (MWI) were determined by LV pressure–strain circuits on a global and territorial scale. To identify obstructive coronary artery stenosis, optimal cutoff values of independent variables have been evaluated utilizing receiver operating characteristic curve analysis.

In our study, we used the ROC curve analysis of myocardial work index to predict improvement of EF > 40% and the cutoff point <800 with sensitivity = 87.5% and specificity= 78.8%.

4. Conclusion

The present study provides compelling evidence suggesting that left ventricular PSL can serve as a non-invasive novel technique for quantitatively estimating MW and evaluating the recovery of myocardial stunning in patients with ACS post-revascularization.

Disclosure

The authors have no financial interest to declare in relation to the content of this article.

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All authors have a substantial contribution to the article

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There are no conflicts of interest.

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