Evaluation the Effect of Percutaneous Coronary Intervention of Left Anterior Descending Artery on Regional Myocardial Function Using Three-Dimensional Speckle Tracking Echocardiography

Mohamed Fathi Abdelghani (1)*,Mohey El Din Mansour El Abbady(2)*,Ahmed Abdel Raouf Mahdy(2)*

(1) Islamic cardiac center, Al-Azhar University, Cairo, Egypt

(2) Cardiology Department, Faculty of Medicine,Al-Azhar University, Cairo,Egypt.

*Corresponding Author:Mohamed Fathi Abdelghani, Email: drghani11@gmail.com,, Phone Number: 002-01101442969

Abstract

Background: Percutaneous coronary intervention (PCI) is an established procedure for the treatment of coronary artery disease. The aim of this work is to evaluate the effect of PCI of left anterior descending artery on regional myocardial function using three-dimensional speckle tracking echocardiography.

Methods: This cohort study was conducted on 60 patients with chronic coronary syndrome (stable angina). All patients were subjected to general and local examinations, resting surface 12 ECG leads, laboratory analyses(low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol, triglycerides, and creatinine level) and 3D Echocardiography before and 6 weeks after PCI.

Results: There was a highly statistically significant difference between pre and post PCI according to LAD territory by AS with p-value ($p<0.001$). There was no statistically significant difference between pre and post PCI according to LAD territory by 2D CS and LAD territory by 3D CS.There was a statistically significant difference between pre and Post PCI according to LAD territory by 2D LS and 3D LS ($p<0.001$, $P=0.012$ respectively).

Conclusions:3D-STE is a non-invasive applicable technique; it can detect changes of LV after revascularization even with normal ejection fraction.

Keywords: Percutaneous Coronary Intervention, Anterior Descending Artery, Myocardial Function, Speckle Tracking Echocardiography.

Introduction:

Percutaneous coronary intervention (PCI) is an established procedure for the treatment of coronary artery disease. Its usefulness in symptom relief is well established. However the effect of PCI on systolic and diastolic function in patients with preserved baseline left ventricular systolic function is unknown [1].

Regional wall motion abnormalities are frequently seen in coronary artery disease (CAD) and diastolic function is impaired before systolic dysfunction in these patients[2].

Reperfusion with percutaneous coronary intervention has been shown to improve the left ventricular systolic and diastolic functions. However duration of recovery period after the PCI is incompatible. Changes in regional ventricular functions may appear before alteration of global ventricular functions in CAD. Hence evaluation of regional systolic and diastolic function is important for early diagnosis[3].

The recent development of ultrasound systems with the capability to acquire real-time full volume data of the whole left ventricle makes it possible to perform speckle tracking in three dimensions, and thereby track the real motion of the myocardium. Instead of using two-dimensional templates to view two-dimension movement, cubic templates allow motion analysis of the entire ventricle in three-dimension[4].

A new technology called three-dimensional wall motion tracking (3D-WMT) is capable of providing three-dimensional (3D) images of the myocardium and obtains multiple measures of deformation, allowing for a complete assessment in very little time. Area strain (AS) is a novel method with a high potential for clinical applications. This new parameter combines an analysis of both the longitudinal and circumferential deformation of the left ventricle. This provides an estimate of the subendocardial surface deformation, which is inversely proportional to the radial [5].

The real-time 3-dimensional speckle-tracking echocardiography (3D-STE) can noninvasively and quantitatively assess the global and regional myocardial wall motion. The performance of this technology has been compared to the magnetic resonance imaging tagging technique [6].

Recent studies have shown that strain and strain rate in the assessment of myocardial systolic dysfunction was superior to conventional wall motion analysis and left ventricular ejection fraction (LVEF) [7].

One previous study reported that 3-dimensional global peak longitudinal strain (GPLS) derived from 3D-STE technology can detect subtle change of left ventricular (LV) longitudinal systolic function [8].

The aim of this work was to evaluate the effect of percutaneous coronary intervention of left anterior descending artery on regional myocardial function using three-dimensional speckle tracking Echocardiography.

Patients and Methods:

This cohort study was conducted on60 patients with chronic coronary syndrome (stable angina)came to Islamic cardiac center at Al-Azhar University for PCI to LAD on clinical basis indications

Patients with bad echo window or when complete echo study cannot be completed, when the follow-up cannot be done non-viable LAD territory, patient with acute coronary syndrome, with significant lesion other than LAD, with previous myocardial infarction, with atrial fibrillation (AF) or frequent ectopics, in active cardiac condition as decompensated heart failure, …… etc and other causes of cardiomyopathy as severe valvular heart disease, hypertrophic cardiomyopathy were excluded from the study.

All patients were subjected to: careful history taking, general and local examinations, the clinical dataincluding (HR,systolic blood pressure, diastolic blood pressure, and body mass index (BMI)), resting surface 12 ECG leads, laboratory analyses (low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol, triglycerides, and creatinine level) and echocardiography.

All the echocardiographic image acquisitions were performed in all the subjects before PCI and six weeks later after PCI.

Transthoracic echocardiography: Echocardiographic data were acquired with an ultrasound Vivid E9 system (GE Vingmed Ultrasound AS, Horten, Norway), which was equipped with two-dimensional 3.5-MHz transducer (M5S-D), three -dimensional 3.5-MHz transducer (4C-D), off-line speckle-tracking analysis software, and background processing workstation (Echo PAC BT 11.1.0, GE Medical System, Horten, Norway).
All the patients were examined in the left lateral decubitus position. Echocardiographic images were acquired from the standard views (parasternal long-axis, parasternal short axis at level of the great vessels, apical four–chambers, apical five–chambers and apical two-chambers). [9].
2D Speckle tracking echocardiography: 2D STE strain analysis was performed in each separate apical view to assess LV regional strains and then global longitudinal strain (GLS) was extracted using bulls eye display by averaging the peak strain values of 18 regional segments. The longitudinal strains were global strains that were measured as changes of the whole myocardium, not an averaged value of each segmental strain. Care was taken not to include the pericardium within the region. If two or more segments were inadequately tracked the entire tracking was excluded from analysis.
Three-dimensional echocardiography and measurements: Enter the 4D acquisition by using the 4D button on the keyboard or the assigned keys (medium, large) on the touch panel. Enter the multislice mode in order to get a comprehensive overview on how the LV fits into your chosen 4D sector size. Try to align the image as good as possible. The system will automatically align the image, but there is still the possibility to align the image manually by using the rotation knobs or trackball.

Low Dose Dobutamine Stress Echocardiography (LDDSE):for assessment viability in patient with impaired LV systolic function or patient with a kinetic myocardial segments

Angiographic assessment: The femoral or radial artery was punctured by the method of Seldinger when the CAG was performed on all patients.

PCI to LAD: PCI and stent implantation were performed in a standard manner. Drug-eluting stents (DESs) were used in all of the angioplasty procedures.

Statistical analysis
Data were analyzed using Statistical Program for Social Science (SPSS) version 26.0. Quantitative data were expressed as mean± standard deviation (SD). Qualitative data were expressed as frequency and percentage. The following tests were done: one-way analysis of variance (ANOVA) when comparing between more than two means, Post Hoc test: was used for multiple comparisons between different variables, Chi-square (X2) test of significance was used in order to compare proportions between two qualitative parameters, Pearson's correlation coefficient (r) test was used for correlating data, binary logistic regression was used to predict the outcome of categorical variable based on one or more predictor variables and receiver operating characteristic (ROC curve) analysis was used to find out the overall predictivity of parameter in and to find out the best cut-off value with detection of sensitivity and specificity at this cut-off value. P-value <0.05 was considered significant.

Results:

Demographic, clinical data, risk factors and LAD lesions distributionamong study group were illustrated in **Error! Not a valid bookmark self-reference.**.

Table 1: Demographic data, clinical data, risk factors and LAD lesions distribution among study group (n=60)

Demographic data	Total (n=60)
Age (years)	
Range	49 - 68
Mean±SD	57.78±4.73
Gender	
Female	24 (40.0%)
Male	36 (60.0%)
Clinical data and risk factors	**Total (n=60)**
Smoking	29 (48.3%)
HTN	41 (68.3%)
FH	9 (15.0%)
DM	23 (38.3%)
BMI classification	
Normal range	37 (61.7%)
Overweight	19 (31.7%)
Obese	4 (6.7%)
BMI	
Range	20.8 - 34.6
Mean±SD	24.38±3.12
LDL	
Range	95 - 180
Mean±SD	135.47±22.27
TG	
Range	100 - 280
Mean±SD	163.78±50.67
LAD lesions	**Total (n=60)**
Mid Lesion	15
Proximal lesions	14
Distal lesion	7
Mid and distal lesions	7
Proximal and mid lesion	6
Proximal subtotal lesion	4
Mid subtotal lesion	2
Paraosteal and proximal lesion	1
Proximal LAD and DI	4

HTN; hypertension, FH;Familial hypercholesterolemia,DM; diabetes mellitus;BMI; body mass index,LDL; low density lipoprotein,TG; triglyceride;LAD;left anterior descending artery

There is statistically significant difference between pre and post PCI according to ESV, EDV and LVEF, with p-value ($p>0.05$ NS).There was a highly statistically significant difference between pre and post PCI according to GLS by 2D**,**GAS with p-value ($p<0.001$)**.**There is no statistically significant difference between Pre PCI and Post PCI according to GRS by 2D and 3D**.** Table 2

Table 2: Comparison between conventional echo parameters pre and post PCI regarding ESV, EDV and LVEF and between Pre PCI and Post PCI according to GLS by 2D and 3D,GAS(n=60)

Conventional Echo of PCI	Range	Mean±SD	Paired Sample t-test			
			Mean Diff.	Change%	t-test	p-value
ESV						
Pre PCI	22 _ 102	57.38±20.90	-5.4	-9.4%	2.912	0.014
Post PCI	22 _ 95	51.98±19.70				
EDV						
Pre PCI	61 _ 190	127.00±33.29	-4.1	-3.23%	2.620	0.016
Post PCI	60 _ 185	122.90±33.19				
LVEF						
Pre PCI	40 _ 66	55.49±6.61	1.48	2.67%	-5.878	<0.001
Post PCI	44 _ 66	56.97±5.09				
GLS						
GLS by 2D						
Pre PCI	-14.6 _ 9.9	-11.07±3.17	-4.80	43.36%	6.218	<0.001
Post PCI	-19.4 _ 5.1	-15.87±3.17				
GLS by 3D						
Pre PCI	-16.9 _ -11	-13.72±1.42	-1.90	13.85%	2.559	0.039
Post PCI	-18.8 _ -12.9	-15.62±1.42				
GAS						
Pre PCI	-40.2 _ 23.6	-19.91±10.69	-5.30	26.62%	5.573	<0.001
Post PCI	-45.5 _ 18.3	-25.21±10.69				
GRS						
GRS by 2D						
Pre PCI	21.1 _ 261.5	39.76±19.64	1.04	2.62%	0.378	0.884
Post PCI	21.1 _ 261.5	40.80±19.63				
GRS by 3D						
Pre PCI	25 _ 46	37.59±5.37	1.28	3.41%	0.095	0.935
Post PCI	25 _ 52.9	38.87±6.36				

ESV;End-systolic volume,EDV;End-diastolic volume, PCI;Percutaneous coronary intervention LVEF; Left ventricular ejection fraction,GLS;Global Longitudinal Strain,3D;Three dimension, 2D;Two dimensional, GAS;Global area strain,GRS;Global redial strain

There is no statistically significant difference between pre and post PCI according to GCS and LAD territory by 2D and GCS by 3D.

There was a statistically significant difference between pre and Post PCI according to LAD territory by 2D LS and 3D LS (p<0.001, P=0.012 respectively). Table 3

Table 3: Comparison between pre-PCI and post-PCI according to GCS,LAD territory LS and LAD territory RS by 2D and 3D (n=60).

GCS	Range	Mean±SD	Paired Sample t-test			
			Mean Diff.	Change%	t-test	p-value
GCS by 2D						
Pre PCI	-28.9 _ -15.4	-21.28±2.75	-1.19	5.59%	0.965	0.741
Post PCI	-36.1 _ -16.5	-22.47±3.92				
GCS by 3D						
Pre PCI	-25 _ -17	-20.63±2.14	-1.20	5.82%	0.890	0.861
Post PCI	-31.3 _ -17	-21.83±3.70				
LAD territory LS						
LAD territory by 2D LS						
Pre PCI	-12.3 _ 11	-9.51±3.08	-6.30	66.25%	7.992	<0.001
Post PCI	-18.6 _ 4.7	-15.81±3.08				
LAD territory by 3D LS						
Pre PCI	-16.3 _ -8.7	-13.77±1.46	-2.10	15.25%	3.825	0.012
Post PCI	-18.4 _ -10.8	-15.87±1.46				
LAD territory RS						
LAD territory by 2D RS						
Pre PCI	25 _ 44.1	36.06±6.03	0.86	2.38%	1.786	0.678
Post PCI	25 _ 48.5	36.92±6.82				
LAD territory by 3D RS						
Pre PCI	27 _ 45	38.05±5.81	0.98	2.58%	0.986	0.711
Post PCI	27 _ 49.9	39.03±6.68				

GCS;Global circumferential strain;LAD;left anterior descending artery, 3D;Three dimension, 2D;Two dimensional, PCI;Percutaneous coronary intervention

There was a highly statistically significant difference between pre and post PCI according to LAD territory by AS with p-value (p<0.001). There is no statistically significant difference between pre and post PCI according to LAD territory by 2D CS and LAD territory by 3D CS. Table 4

Table 4: Comparison between Pre PCI and Post PCI according to LAD territory CS by 2D and 3D (n=60).

LAD territory CS	Range	Mean±SD	Paired Sample t-test			
			Mean Diff.	Change%	t-test	p-value
LAD territory by 2D CS						
Pre PCI	-25 _ -16	-20.32±2.34	-1.30	6.40%	0.104	0.897
Post PCI	-31.8 _ -16	-21.62±4.12				
LAD territory by 3D CS						
Pre PCI	-44 _ -16	-22.04±3.93	-0.13	0.59%	1.149	0.689
Post PCI	-44 _ -16	-22.17±3.99				
LAD territory by AS						
Pre PCI	-222.5 _ -12	-24.43±18.94	-4.70	19.24%	4.227	<0.001
Post PCI	-227.2 _ -16.7	-29.13±23.94				

LAD;left anterior descending artery, 3D;Three dimension, 2D;Two dimensional, PCI;Percutaneous coronary intervention, CS;coronary syndrome

Discussion

Percutaneous coronary intervention (PCI) is an established procedure for the treatment of coronary artery disease. Its usefulness in symptom relief is well established. However, the effect of PCI on systolic and diastolic function in patients with preserved baseline left ventricular systolic function is unknown **[1].**

A new technology called three-dimensional wall motion tracking (3D-WMT) is capable of providing three-dimensional (3D) images of the myocardium and obtains multiple measures of deformation, allowing for a complete assessment in very little time. Area strain (AS) is a novel method with a high potential for clinical applications. This new parameter combines an analysis of both the longitudinal and circumferential deformation of the left ventricle. This provides an estimate of the subendocardial surface deformation, which is inversely proportional to the radial **[5]**.

Myocardial strain can be measured using Doppler tissue imaging (DTI) echocardiography and 2DSTE. The DTI echocardiographic modality can produce the strain and strain rate using the myocardial velocities. Because angle dependency and regional strain, not global strain, are the major limitations of the DTI methods. This modality has seen limited clinical use**[10]**.

3D STE is an advanced imaging technique designed for LV myocardial deformation analysis based on 3D data sets. 3DSTE has the potential to overcome some of the intrinsic limitations of 2DSTE in the assessment of complex LV myocardial mechanics, offering additional deformation parameters (such as area strain) and a comprehensive quantitation of LV geometry and function from a single 3D acquisition. Albeit being a relatively young technique still undergoing technological developments, several experimental studies and clinical investigations have already demonstrated the reliability and feasibility of 3DSTE, as well as several advantages of 3DSTE over 2DSTE. This technique has provided new insights into LV mechanics in several clinical fields, such as the objective assessment of global and regional LV function in ischemic and non-ischemic heart diseasesMuraruet al.[11]**.**

Several studies assessed normal individual to find reference values for 3D strain by 3D STE as Muraru et al.[12]and Kleijn et al.[13].

Regarding, Echo parameters, our study coincides with ErcanErdoga et al.,**[14]**which carried on 129 patients with chronic total occlusion who underwent revascularization between April 2011 and November 2012 were included in this study. Echocardiographic assessments with two-dimensional speckle tracking echocardiography and real-time three-dimensional echocardiography were performed before the procedure and one month after the procedure. The left ventricular ejection fraction, left ventricular volumes, and three-dimensional systolic desynchrony index were quantified. The mean left ventricular ejection fraction significantly increased ($p<0.001$), while the left ventricular end-diastolic and end-systolic volumes significantly decreased.The global longitudinal strain showed a significant increase after successful revascularization.

Magdy et al. [15]study also showed a significant reduction in LVEDD and LVESD after PCI of CTO (3 months after the procedure) and showed highly significant increase in LVEF % after successful recanalization of CTO (3 months after the procedure). Our results were similar to these results but the assessment of LVEDd, LVESd and LVEF % in our study was six weeks after the procedure. In the present study, our results were in concordance with Megaly et al. [16]meta-analysis of 34 studies, which demonstrated that successful CTO PCI is associated with statistically significant increase in mean LVEF by 3.8% during a mean follow-up duration of 7.9 months. This improvement was consistent in further sensitivity and subgroup analyses. Furthermore, successful CTO PCI was associated with statistically significant reduction in LVESV indicating an improvement in LV remodeling. A previous meta-analysis of 34 studies with 2310 patients on the impact of CTO PCI on LV size and function that was performed by Hoebers et al. [17](30) showed a statistically significant increase in LVEF (4.44%) and decrease in LVEDV index (6.14 mL/m^2) as compared to baseline.

Regarding PCI according to GLS by 2D, our study result coincides with ErcanErdogaet al., [14]as the global longitudinal strain showed a significant increase after successful revascularization. Our study results also concides with Mahgoub, K. A. M. [18]**.**Which included (60) patients presenting with chronic total occlusion coronary artery disease at Al-Azhar University Hospitals, in the period between December 2015 and April 2018. The study compared the differences in Echocardiographic parameters before the procedure (pre-procedure) and one month after successful PCI to CTO (post- procedure). Two-dimensional (2D) and three- dimensional (3D) transthoracic Echocardiography (baseline and follow up study), 2D Global longitudinal strain (GLS) and 3D longitudinal strain (LS) speckle tracking echocardiography (base line and follow up study) were done.

Our study results coincides with the result ofWen H. et al.,[19]in which Standard echocardiography and 3D-STE were performed in 160 subjects with or without HF. Three-dimensional speckle-tracking echocardiography was measured with reliable tracking quality in 137 (86%) of the 160 subjects initially enrolled in this study: 30 healthy volunteers, 29, 37, 26, and 15 patients with Stage A, B, C, and D HF, respectively. Global strain values were automatically calculated by 3D wall motion tracking (3D-WMT) software. Although global longitudinal strain (LS), circumferential strain (CS), radial strain (RS), and LV ejection fraction (LVEF) showed the downward trend from normal controls to patients with Stage D HF, the difference did not reach statistical significance between normal controls and patients with Stage A HF. In contrast, they observed the progressive decrease in global AS from normal to Stage A HF to Stage D HF ($P < 0.05$). In addition, global AS showed an excellent correlation with LVEF, global LS and CS. The optimal cut-off value for global AS, to detect LV dysfunction (Simpson's rule-based LVEF <50%), was 229.23% at a sensitivity of 86.3% and at a specificity of 88.4%.

RegardingGCS value by 2D and GCS value by 3D and pre and Post PCI according to LAD territory by 2D LS, this indicates improvement in LAD territory by 2D LS than LAD territory by 3D LS.

Limitations: Single center using single vendor machine and software. 4D echocardiography assessment of left ventricle structure and function requires some technical skills in order to encompass the whole of LV cavity and walls while maintaining an adequate frame rate during the full volume acquisition. The 4D echocardiography has poor resolution than 2D, many pooled populations were excluded from the study due to difficult acoustic window and bad echogenicity which led to difficulty in identification of endocardial borders.

Conclusions:

3D-STE is a non-invasive applicable technique; it can detect changes of LV after revascularization even with normal ejection fraction.

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Conflict of Interest: Nil

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