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Evaluation of Left Ventricular Function after Percutaneous Recanalization of Chronic Coronary Occlusions: The Role of Two-Dimensional Speckle Tracking Echocardiography

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Abstract

Background: The recanalization of a chronic total coronary occlusion is the possible way to improve left ventricular (LV) function through the recovery of hibernating myocardium. **Aim:** The aim of this study is to evaluate the role of 2D speckle tracking in evaluation of the left ventricular (LV) systolic function in chronic total occlusion (CTO) patients before and at 1 day as well as 3 months after percutaneous coronary intervention (PCI). **Patients and Methods:** A prospective observational study included 40 patients diagnosed with coronary angiography to have a chronic total occlusion. Percutaneous coronary revascularization was performed according to standard practices with the femoral approach. Conventional 2D echocardiography was used to assess LV functions and wall motion abnormalities scoring index (WMAI). Using speckle-tracking echocardiography was to measure global longitudinal strain (GLS) and. Follow-up of patients was done at day 1 and 3 months later after PCI. **Results:** Forty patients were included in this study, with a mean age of 58.55 ± 7.98 years. GLS and WMAI difference at baseline and follow-up shows a positive correlation with left ventricular ejection fraction (LVEF) changes at baseline and follow-up ($p < 0.001$). Mean value of baseline GLS (−14.26 ± 0.93) significantly improved at follow-up as GLS was (−15.66 ± 0.92) with p-value < 0.001. Periprocedural complications were contrast induced nephropathy (CIN) in 2 (5%), Cardiac tamponade 1 (2.5%) and Emergency re-PCI 1 (2.5%). **Conclusion:** The results of this study provide evidence to support the clinical use of 2D-STE to monitor the early changes of LV function. In patients undergoing CTO revascularization, change in GLS was more sensitive predictors for LV function improvement at 3-month follow-up.

Keywords

Chronic Total Occlusions, Left Ventricular Function, Percutaneous Coronary Intervention, Ejection Fraction, Speckle Tracking Echocardiography

1. Introduction

Chronic total occlusion (CTO) is a common condition in patients with coronary artery disease, and represents one of the most challenging targets of lesion recanalization for percutaneous coronary interventions (PCIs) [1]. Chronic total occlusion (CTO) is defined as an occluded coronary artery presenting as thrombolysis in myocardial infarction (TIMI) with grade 0 or 1 flow with an occlusion duration of >3 months [2]. The rationale for the recanalization of a chronic total coronary occlusion is the possible improvement of left ventricular (LV) function through the recovery of hibernating myocardium [3]. Recanalization of CTO lesions by percutaneous coronary intervention (PCI) reportedly produces beneficial effects on symptoms, long-term survival, and incidence of coronary artery bypass grafting (CABG). However, mechanism of the beneficial effects of recanalization of CTO still remains unclear [4]. Two-dimensional speckle tracking echocardiography (2D-STE) allows for an angle-independent evaluation of myocardial strain, and provides comprehensive information on LV myocardial contractility. Thus, 2D-STE is superior in detecting subtle deteriorations of contractility. These advantages of 2D-STE are useful for the detection of subclinical recovery of dysfunctional but viable myocardium after CTO-PCI [5]. In this study we aimed to evaluate the role of 2D speckle tracking in evaluation of the LV systolic function in CTO patients at 1 day as well as 3 months after percutaneous coronary intervention.

2. Patients and Methods

This was a prospective observational longitudinal study that included 40 patients recruited from Al Agouza Charity Hospital from the period of July 2018 to February 2019 who have ischemic heart disease and diagnosed with coronary angiography to have a chronic total occlusion. Informed written consent was taken from patients after full explanation of the purpose and nature of the study. A chronic total occlusion (CTO) is defined as the complete obstruction of a coronary artery, exhibiting TIMI 0 or TIMI 1 flow, with an occlusion duration of >3 months [2]. Patients with CTO with an estimated duration of less than 3 months or an MI during the previous 30 days, patients with chronic kidney disease, rheumatic valvular heart disease, patients with lost follow up or patients with ejection fraction (EF) < 45% were excluded from the study. All patients included in the study were subjected to full medical history evaluation with special emphasis on history of Diabetes mellitus, Hypertension, dyslipidemia and Cigarette smoking. Clinical examination on admission with special emphasis on Heart rate, rhythm, Systolic and diastolic blood pressures at the time of the study. Twelve-lead resting surface was done to all patients. Laboratory evaluation with special emphasis on lipid profile and Kidney function tests. Percutaneous coronary revascularization was performed by operators experienced in the treatment of CTO according to their standard practices with the femoral approach. The operation was considered successful when the residual stenosis was ≤30% of the intraluminal diameter, with TIMI grade III flow and no in hospital complications (death, acute myocardial infarction, or emergency coronary surgery). DAPT was prescribed to all patients for at least 1 year after stent implantations. Revascularization was done through antegrade technique: 1) Antegrade wire escalation technique (AWE) either done by Sliding technique with Fielder group of wires or penetrating technique with ASAHI conquest and conquest pro wires or drilling technique. Attempts to cross CTO using specific guidewires according to the morphology of the cap. Generally, it starts with a soft and fine-tipped guidewire (1.0 g), coated with polymer. If the crossing is unsuccessful, a slightly heavier wire (4.0 g), also polymer coated, or a sharp, tapered 12-gauge wire was used. If the guidewire enters the true distal lumen (confirmed in two orthogonal projections), the micro catheter is advanced through the occlusion and the guidewire is replaced by a traditional one, followed by balloon angioplasty and stent implantation. If the guidewire comes out of the vessel architecture, it must be retracted and redirected. 2) Antegrade dissection reentry was done by using pilot and miracle wires with intentional use of the subintimal space to cross the occlusion in lesions more than 20 mm length.

An echocardiographic examination was performed by a single investigator according to the American Society of Echocardiography (ASE). Echocardiography was performed before PCI and at 1 day and 3 months after PCI using a Philips IE33 ultrasound machine with anM4S transducer according to the recommendations of the American Society of Echocardiography [5]. Imaging was performed using 2.5 MHz comprehensive two-dimensional cardiac ultrasound unit equipment; LV dimensions were measured with M-mode online from the parasternal projections. Measurements included Intraventricular Septal thickness, posterior wall thickness, LV diameter in end-systole and end-diastole. M-mode, 2-dimensional, and Doppler images were acquired during breath hold. Systolic LV function was assessed by tracing the LV end-systolic volume and end-diastolic volume in the apical 4- and 2-chamber views. LV ejection fraction (LVEF) was calculated by using the biplane Simpson's method [6]. Wall motion score index (WMSI) was obtained in all patients; normal, 1) hypokinesia, 2) akinesia, 3) dyskinesia, 4) the total wall motion score (WMS) was obtained by adding the score for each segment. The WMSI was calculated by dividing the total wall motion score by 16 [7]. Strain is defined as the percentage change in the original dimensions of an object. When applied to left ventricle, left ventricular deformation is defined by the three normal strains (longitudinal, circumferential, and radial) [8]. Using speckle-tracking echocardiography was to measure global longitudinal strain. The 2D echocardiography images (transmit/receive 1.9/4.0 MHz) were obtained from several views with frame rates of 30 - 90 frames/s. Digital data were stored and analyzed off-line. LV endocardial surface was traced manually, and the speckle tracking width was modified to cover the whole LV wall thickness so as to obtain curves for the peak longitudinal strain of: the inferior septum and lateral wall in the apical four-chamber view (4C-PLS); the inferior and anterior walls in the apical two-chamber view (2C-PLS); and The inferior lateral and anterior septum in the apical three-chamber view (3C-PLS). LV global longitudinal systolic strain (GLS) was calculated by averaging the peak systolic values of the six LV walls (**Figure 1** and **Figure 2**). All the echocardiographic studies were performed by one echocardiographer. Follow-up of patients was done at day 1 and 3 months later after percutaneous coronary intervention was done by clinical examination and echocardiography as described.

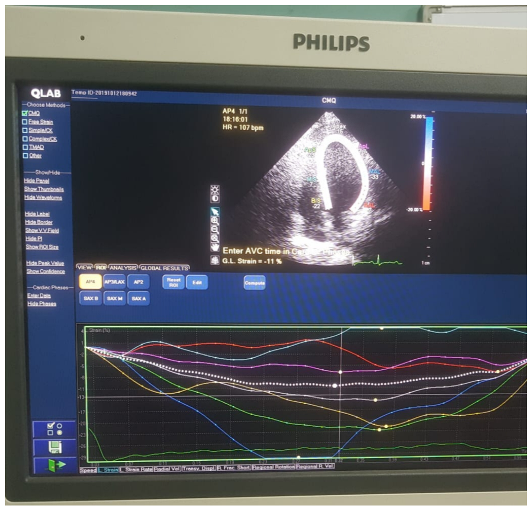

Figure 1. Left ventricular global longitudinal strain pre PCI.

Figure 2. Left ventricular global longitudinal strain 3 months after PCI.

3. Statistical Methods

Data were statistically described in terms of range, mean standard deviation (SD), median, frequencies (number of cases) and percentages when appropriate. Comparison of quantitative variables between the study groups was done using Mann Whitney U test for independent samples. For comparing categorical data, Chi square (χ^2) test was performed. Exact test was used instead when the expected frequency is less than 5. ROC curves were plotted to determine cutoff values. Correlation between various variables was done using Spearman rank correlation equation for non-normal variables. A probability value (p-value) less than 0.05 was considered statistically significant. All statistical calculations were done using computer programs Microsoft Excel 2010 (Microsoft Corporation, NY, USA) and SPSS (Statistical Package for the Social Science, SPSS Inc., Chicago, IL, USA) version 15 for Microsoft Windows.

4. Results

40 patients were included in this study, their ages ranged from 47 to 79 years with a mean 58.55 ± 7.98 years. Males were 33 (82.5%) and females were 7 (17.5%). All patients had at least one risk factor and the most frequent was DM 22 (55%) followed by hypertension 21 (52.5%), and smoking 21 (52.5%) beside other risk factors. Patients who had chest pain with Canadian class score (CCS) ≥ 2 were 24 (60%). Lipid profile of the patients shows that mean levels of cholesterol, HDL, LDL and TG were (184.85 ± 56.50, 54.1 ± 11.66, 132.25 ± 22.17 and 193.07 ± 81.36) mg/dl respectively. Mean creatinine level in the studied patients was 0.90 ± 0.24 mg/dl (**Table 1**). Regarding the angiographic data, two vessel disease lesions were most frequent 42.5%, then multivessels 32.5% and single vessel 25.5%. The CTO was located in the left anterior descending in 15 (37.5%) patients, the right coronary artery in 16 (40%) patients, and the circumflex artery in 9 (22.5%) patients. Mean of J-CTO score was 1.77 ± 1.02 in CTO vessels. Revascularization was done by antegrade approach only through antegrade wire escalation (AWE) in 35 (87.5%) and Antegrade Dissection and Reentry (ADR) in 5 (12.5%). The mean of procedural time was 77.25 ± 18.22 minutes (**Table 2**).

The echocardiographic findings show that mean of pre-procedural LVEDV 104 ± 32.17 and day 1 post-procedural LVEDV 105 ± 38.85 without statistical difference. Mean of pre-procedural LVESV was 61.52 ± 15.14 and day 1 post-procedural LVESV was 58.22 ± 11.65 with statistical difference (p = 0.031).

Mean value of pre-procedural GLS (−14.22 ± 0.91) and day 1 post-procedural GLS was −14.26 ± 0.93) without significant statistical difference. Mean value of pre-procedural WMSI (1.48 ± 0.31) and day 1 post-procedural WMSI was (1.41 ± 0.17) without significant statistical difference. Mean value of pre-procedural EF% for patients was 53.88% ± 14.30% and the mean value of day 1 post-procedural EF was 54.85% ± 7.63% without statistical difference between them (**Table 3**).

Echocardiographic findings show that mean of pre-procedural LVESV was

61.52 ± 15.14 and follow-up LVESV was 50.60 ± 14.07 with statistical difference ($p = 0.047$). Mean value of pre-procedural GLS (−14.22 ± 0.91) and follow-up GLS was (−15.66 ± 0.92) with significant statistical difference ($p < 0.001$). Mean value of pre-procedural WMSI (1.48 ± 0.31) and follow-up WMSI was (1.20 ± 0.13) with significant statistical difference ($p < 0.001$). Mean value of pre-procedural EF% for patients was 53.88% ± 14.30% and the mean value of follow-up EF was 55.54% ± 8.19% without statistical difference between them (Table 4).

Comparison between post-procedural changes in GLS and WMA in LAD and non-LAD CTO-lesions shows that there was significant statistical difference between Non-LAD CTO-lesion and LAD CTO-lesion as regard post-procedural changes in GLS but non-significant in post-procedural WMA score changes and LVEF, % changes (Table 5).

Table 1. Baseline characteristics of study patients.

Baseline Characteristics of Study Patients	n (%)	Mean ± SD
Age (years)		**58.55 ± 7.98**
Body Mass Index (BMI)		**30.09 ± 2.73**
Male	33 (82.5%)	
Female	7 (17.5%)	
Risk factors for CAD		
Smoking	21 (52.5%)	
Dyslipidemia	19 (47.5%)	
DM	22 (55%)	
Hypertension	21 (52.5%)	
family history	9 (22.5%)	
Past history of CAD	10 (25%)	
Canadian Cardiovascular classification score (CCS)		
CCS ≥ 2	24 (60%)	
Laboratory investigation		
Total cholesterol (mg/dl)		**184.85 ± 56.50**
HDL (mg/dl)		**54.1 ± 11.66**
LDL (mg/dl)		**132.25 ± 22.17**
TG (mg/dl)		**193.07 ± 81.36**
Creatinine (mg/dl)		**0.90 ± 0.24**

Table 2. Characteristics of angiographic data.

Characteristics of angiographic data		%
Single vessel	n (%)	**10 (25%)**
2 vessels	n (%)	**17 (42.5%)**
Multivessels		**13 (32.5%)**
CTO vessel		
LAD	n (%)	**15 (37.5%)**
LCX	n (%)	**9 (22.5%)**
RCA	n (%)	**16 (40%)**
J-CTO score	mean ± SD	**1.77 ± 1.02**
Antegrade approach only	n (%)	**40 (100%)**
-Antegrade wire escalation (AWE)	n (%)	**35 (87.5%)**
-Antegrade Dissection and Reentry (ADR)	n (%)	**5 (12.5%)**
Procedure time (minutes) mean ± SD		**77.25 ± 18.22**

Table 3. Comparison between echocardiographic parameters at pre-procedural and day 1 post-procedural follow-up.

Variables	preprocedural	Day 1	p-value
	Mean ± SD	Mean ± SD	
LVEF, %	53.88 ± 14.30	54.85 ± 7.63	0.12
LVEDV, ml	104 ± 32.17	105 ± 38.85	0.46
LVESV, ml	61.52 ± 15.14	58.22 ± 11.65	**0.031***
GLS	−14.22 ± 0.91	−14.26 ± 0.93	0.39
WMSI	1.48 ± 0.31	1.41 ± 0.17	0.11

EDV, end-diastolic volume; e0, early diastolic velocity of mitral annular displacement; GCS, global circumferential strain; GLS, global longitudinal strain; LA, left atrium; LVEF, left ventricular ejection fraction; SV, stroke volume; WMSI, wall motion score index.

Table 4. Comparison between echocardiographic parameters pre-procedural and 3 months follow-up.

Variables	preprocedural	3 month follow-up	p-value
	Mean ± SD	Mean ± SD	
LVEF, %	53.88 ± 14.30	55.54 ± 8.19	0.76
LVEDV, ml	104 ± 32.17	101 ± 45.22	0.18
LVESV, ml	61.52 ± 15.14	50.60 ± 14.07	**0.047**
GLS	−14.22 ± 0.91	−15.66 ± 0.92	**<0.001***
WMSI	1.48 ± 0.31	1.20 ± 0.13	**<0.001***

EDV, end-diastolic volume; e0, early diastolic velocity of mitral annular displacement; GCS, global circumferential strain; GLS, global longitudinal strain; LA, left atrium; LVEF, left ventricular ejection fraction; SV, stroke volume; WMSI, wall motion score index.

Table 5. Comparison between post-procedural changes in GLS, WMA in LAD, and non-LAD CTO-lesions.

Variable	Non-LAD CTO-lesion	LAD CTO-lesion	p-value
	Mean ± SD	Mean ± SD	
GLS changes post-procedural	1.36 ± 0.22	1.70 ± 0.48	**0.005***
WMA score changes post-procedural	0.27 ± 0.16	0.29 ± 0.10	0.67
LVEF, % changes differences post-procedural	4.36 ± 1.49	5.06 ± 1.38	0.14

Lad: Left Anterior Descending; CTO: chronic total occlusion; GLS: global longitudinal strain; WMA: wall motion abnormality; LVEF: left ventricular ejection fraction.

GLS and WMAI difference at baseline and 3 months follow-up shows a positive correlation with LVEF changes at baseline and follow-up with significant statistical difference ($p < 0.001$) (Table 6, Figure 3 and Figure 4).

Receiver operator characteristic (ROC) curve (Figure 5 and Figure 6) was calculated for GLS difference as a predictor improved left ventricular EF. The area under the curve (AUC) was 82% and confidence interval CI (0.677 - 0.962). The optimal cut off value of GLS change to predict improved left ventricular EF was 1.025 with a sensitivity of 95% and specificity of 40.7% and ($p = 0.001$). ROC curve was calculated for WMSI score difference as a predictor improved left ventricular EF (Table 7). The area under the curve (AUC) was 79% and confidence interval CI (0.638 - 0.941).

Periprocedural complications were contrast induced nephropathy in 2 (5%), Cardiac tamponade 1 (2.5%) and Emergency re-PCI 1 (2.5%) (Table 8).

Clinical follow-up of patients 3 months post-procedural shows that 2 (10%) patients were readmitted because of chest pain without any new angiographic lesions and received medical treatment. 2 patients (5%) had paroxysmal AF and one patient developed signs of heart failure. There was no MI, stroke or mortality in the studied patients (Table 9).

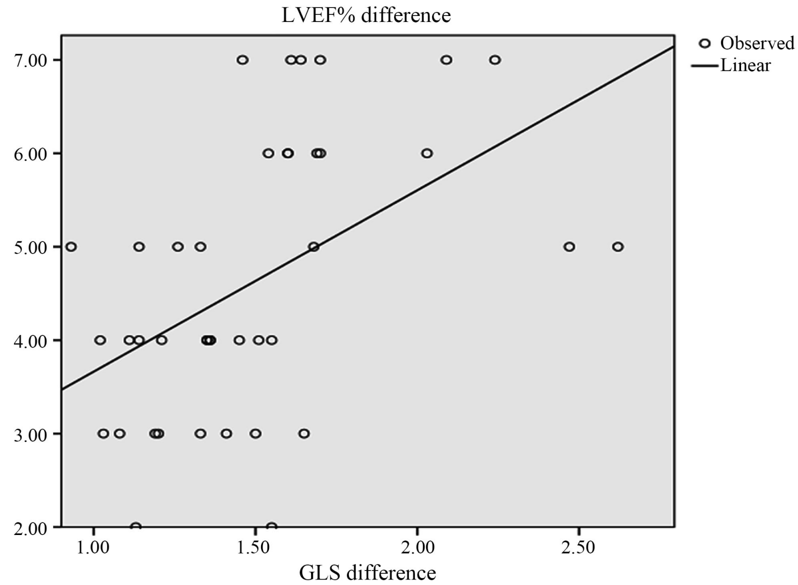

Figure 3. Correlations between changes in LVEF by echocardiographic parameters and changes in GLS.

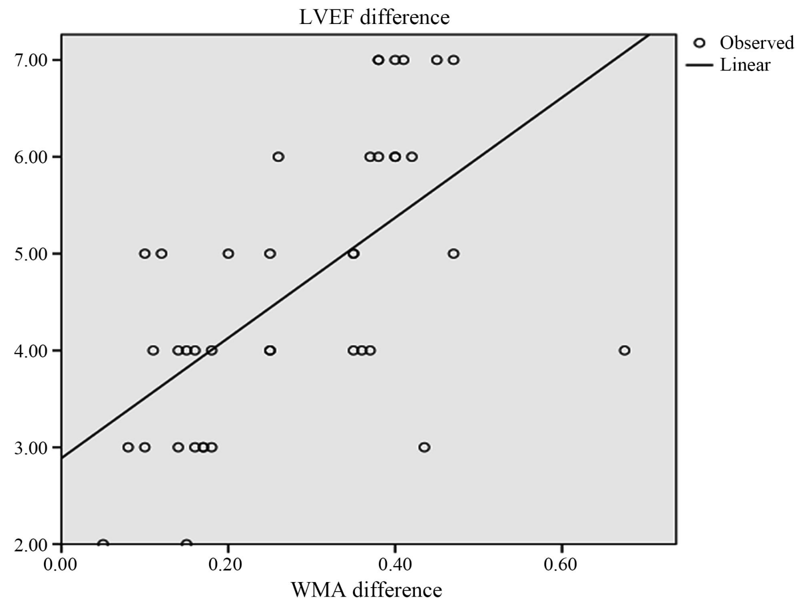

Figure 4. Correlations between changes in LVEF by echocardiographic parameters and changes in WMSI.

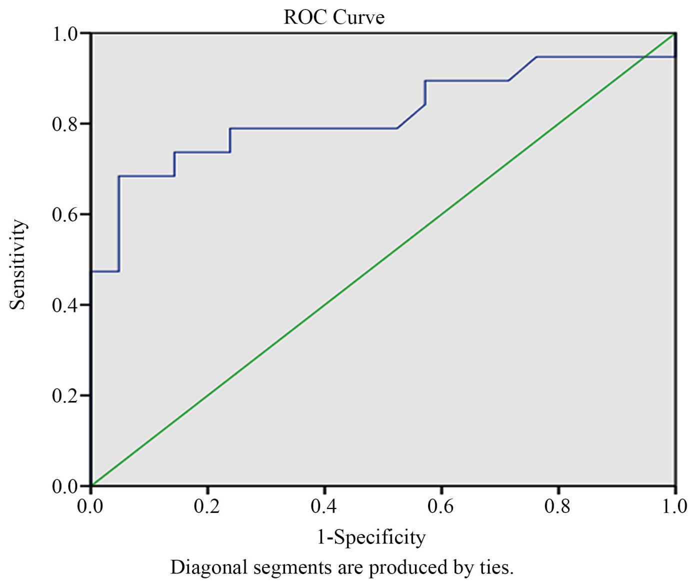

Figure 5. Roc curve for GLS difference to predict improved left ventricular EF.

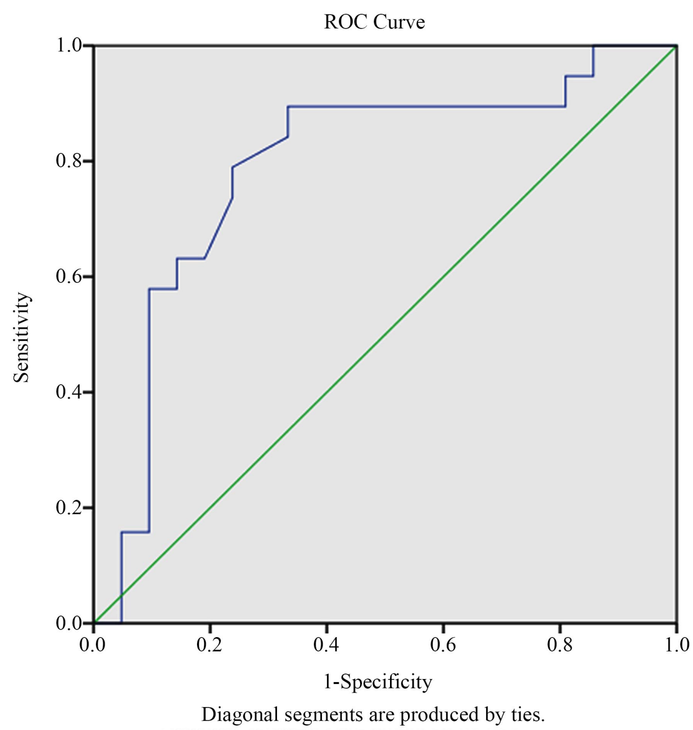

Figure 6. Roc curve for WMSI difference to predict improved left ventricular EF.

Table 6. Correlations between changes in LVEF by echocardiographic parameters and changes in GLS and WMA.

Variable	r	p-value
Difference GLS	0.496	**0.001***
WMSI difference	0.599	**<0.001***

GLS: Global longitudinal strain; WMSI: Wall motion scoring index.

Table 7. Roc curve for GLS and WMSI difference to predict improved left ventricular EF.

Variable	AUC	CI 95%	Cut-off	Sensitivity	Specificity	p-value
GLS	0.82	0.677 - 0.962	1.025	95%	40.7%	**0.001***
WMSI	0.79	0.638 - 0.941	0.10	100%	55%	**0.002***

GLS: Global longitudinal strain; WMSI: Wall motion scoring index; GLS: Global longitudinal strain; WMSI: Wall motion scoring index.

Table 8. Peri-procedural Complications.

Peri-procedural Complications		%
-adiac tamponade	n (%)	**1 (2.5%)**
-mergency re-PCI	n (%)	**1 (2.5%)**
-Contrast induced nephropathy	n (%)	**2 (5%)**

Table 9. Clinical follow-up after 3-month follow-up across groups.

3 months clinical follow-up	n = 40	%
Readmission for ACS	4	10%
Arrythmias	2	5%
Heart failure	1	2.5%
Stroke/TIA	0	0
New Myocardial Infarction	0	0
Cardiac mortality	0	0

5. Discussion

Ischemia produces a cascade of events beginning with metabolic and biochemical alternations that lead to impaired ventricular relaxation and diastolic dysfunction followed by impaired systolic function. Despite the presence of coronary collaterals, the majority of patients with a CTO show various degrees of LV dysfunction. The possibility of a functional recovery and its beneficial effect on survival are the rationale for the often technically demanding attempt to recanalize a CTO [9]. In CTO patients, as a hypothesis, the distal arterioles of the CTO area would dilate to the maximum to increase myocardial perfusion from the donor artery. In order to provide enough perfusion for the CTO area, the precapillary arterioles and arteriolar capillary vessels in the donor area must constrict to maintain the perfusion pressure [10]. Also, subendocardium is the most vulnerable part to ischemia. The longitudinal component of cardiac deformation predominates in this part of myocardium. Longitudinal strain analysis by 2D-STE is a sensitive and convenient method to evaluate this component of cardiac motion [11]. Recanalization of CTO lesions by PCI reportedly produces beneficial effects on symptoms, long-term survival, and incidence of coronary artery bypass grafting (CABG). However, mechanism of the beneficial effects of recanalization of CTO still remains unclear [5]. Improvement of LV function in previous reports describing improvement in LV function following CTO revascularization, LV function was most commonly assessed by the LV ejection fraction using ventriculography [12] or 2D echocardiography [13]. Recently, the use of more accurate non-invasive methods for quantifying LV function, such as cardiac MRI [14] and 2D STE [15], also confirmed the improvement in LV function after CTO PCI. In this study, we aimed to evaluate the role of 2D speckle tracking in evaluation of the LV systolic function in CTO patients before and at 1 day as well as 3 months after percutaneous coronary intervention. To achieve our aim, this prospective observational study was conducted on 40 patients who have ischemic heart disease and diagnosed with coronary angiography to have a chronic total occlusion. Patients were assessed by 2D echocardiography and speckle tracking and were followed-up for recovery of left ventricular function in 3 months after percutaneous coronary revascularization for chronic total occlusion.In this study, comparison of mean value of baseline GLS (-14.26 ± 0.93) and 3 moths follow-up GLS were (-15.66 ± 0.92) with significant statistical difference ($p < 0.001$). Comparison of mean value of baseline WMSI (1.41 ± 0.17) and 3 months follow-up WMSI were (1.20 ± 0.13) with significant statistical difference ($p < 0.001$). The more significant improvement of GLS and WMSI reflect improvement in the myocardial contractile function based on strain analysis. In accordance with several studies as follows; Choi *et al.*, 2009 reported that longitudinal strain analysis by 2D-STE is a quite sensitive and suitable method to evaluate this component of cardiac motion. Multiple retrospective studies have shown the potential benefit of PCI in patients with CTO [11]. Successful treatment improves anginal symptoms, exercise tolerance, and LV function. The prospective Total Occlusion Angioplasty Study (TOAST-GISE) showed that revascularization of a CTO is associated with relieved angina and reduces the 12-month incidence of cardiac death or MI and the need for CABG [9]. This study found that the LVEF tended to improve at 3 months after percutaneous revascularization in patients with CTO. These findings were in agreement with Wang *et al.* in 2019 that using 2D-STE, GLS was observed to be restored as early as 1 day after CTO-PCI and improvement of LVEF was observed for up to 3 and 6 months. Their results demonstrate that 2D-STE is a reliable way to monitor early subclinical LV changes [16]. Also, Erdogan *et al.* in 2013 showed that restoring the coronary blood flow in chronic total occlusion patients reduces the left ventricular volumes and improves the left ventricular ejection fraction and the global longitudinal strain of hibernating myocardium. These findings were assessed by two-dimensional speckle tracking echocardiography immediately afer and one month after the procedure [15]. Nakachi *et al.* in 2017 assessed functional recovery after PCI to CTO vessels. They reported that the change in longitudinal strain (LS) was more sensitive for removal of ischemia by CTO PCI, indicating the utility of LS to monitor the therapeutic effects of CTO recanalization [17].

Rifqi *et al.* in 2017 have compared the LV function measured by ejection fraction (EF) and global longitudinal strain in patients with CAD underwent PCI, and to identify factors affecting the change of LV function [18]. The results of their study showed that the recovery of left ventricular function could be detected early post-revascularization of coronary artery disease by either ejection fraction or global longitudinal strain measurements; however the latter is more accurate. Improvement of GLPS is correlated moderately with target vessel revascularization involving non-left anterior descending artery. González *et al.*, in 2016 concluded that Successful revascularization of CTO improves regional systolic function determined by WMSI and decreases angina. LS of treated segments tend to decrease after the procedure, with no change in global measures of cardiac function. In the current study, GLS and WMAI difference at baseline and follow-up shows a positive correlation with LVEF changes at baseline and follow-up with significant statistical difference ($p < 0.001$). This was in line with Staron *et al.* in 2013 who reported that GLS correlates well with EF measured by echocardiography, and GLS is a superior predictor of outcome compared with LVEF [19]. This could be explained by probable initial appearance of systolic dysfunction in the longitudinal direction, as the longitudinally oriented subendocardial fibers are more vulnerable to myocardial ischemia and fibrosis. GLS improvement can predict improved left ventricular EF and could be used as a prognstic factor with high sensitivity 95% ($p = 0.002$). Biopsies of hibernating myocardium always show defects in nearly all cells [20]. The pathological changes include loss of sarcomeres and myofibrils in the center of the cells, absence of contractile material in the perinuclear areas, and presence of cellular debris in the enlarged extracellular space [21]. The dysfunctional heart tissue in CTO patients can be improved after revascularization [22]. Steg and colleagues found that the recovery time of dysfunctional myocardium is dependent on the extent of damage at the cellular level, which is affected by different factors such as the duration and severity of ischemia [23]. The current results were not in agreement with several investigators; Henriques *et al.* in 2016 reported that they did not find an overall benefit for CTO-PCI in terms of LVEF or LVEDV [24]. Mashayekhi *et al.* in 2018 reported that no benefit was seen for CTO-PCI in terms of the segmental wall thickening, LVEF and LVEDV [25]. Also, in the study by Chimura *et al.* in 2019, LVEF and LVEDV also showed no significant changes both successful and failed PCI groups during the 9 month follow-up, respectively [26]. However, since there was report that reduced major adverse coronary event rates at 12 months in CTO-PCI compared with optimal medical therapy. These differences can be explained by small sample size or difference in some end points of the studies. However, longer duration of follow-up in these studies differ from follow-up period in the current study.

In this study, Periprocedural complications were contrast induced nephropathy 2 (5%), Cardiac tamponade 1 (2.5%) and, emergency re-PCI 1 (2.5%). The findings were nearly similar to several studies. Patel *et al.* in 2013 reported that contrast nephropathy was (3.8%) and cardiac tamponade in 0.3% [27]. El Sabbagh *et al.*, in 2014 found that tamponade was (1.4%) and was noted amongst 3482 patients undergoing retrograde CTO PCI procedures. The risk of tamponade is low (approximately 0.5%) [28]. The risk factors predictive of perforation include the use of oversized compliant balloons (balloon-to-artery ratio > 1.2) coupled with relatively high inflation pressure and hydrophilic and stiffer wires, particularly in calcified and tortuous arteries [29].

6. Limitations

The limitations in the current study were small sample size and short duration follow-up and observational not comparative. Also, we didn't correlate LV functions improvement to related CTO vessel, as longitudinal shortening mechanics were correlated with the target vessel revascularization. Since the vascular coverage of LAD in myocardium is wider than that of right coronary artery as well as left circumflex artery, the remodeling area of LAD covered myocardial cells is wider when LAD gets ischemia or infarct, this must be considered.

7. Conclusion

CTO-PCI can effectively improve LV function. The results of this study provide evidence to support the clinical use of 2D-STE to monitor the early changes of LV function. In patients undergoing CTO revascularization, change in LS and GLS was more sensitive predictors for LV function improvement at 3-month follow-up.

Disclosure Statement

Data are available at Faculty of Medicine, Menoufia University and Al Agouza Charity Hospital through the authors only as at those places there is no recording system for the data of all cases. Only researcher keeps his data.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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