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Assessment of the Impact of Percutaneous Coronary Intervention to Chronic Total Occlusion on the Ventricular Performance Using Different Echo-Doppler Modalities

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ABSTRACT

Background: Chronic total occlusion (CTO) of coronary arteries represents one of the most challenging targets of lesion recanalization with percutaneous coronary intervention (PCI). The rationale for recanalization of CTO is the possible improvement of ventricular function. Different echo-Doppler modalities can be used for the assessment of ventricular performance with reported superiority of the newer modalities.

Aim: To assess the impact of successful percutaneous coronary intervention for chronic totally occluded vessel on the ventricular performance using different echo-Doppler modalities.

Methods: This study enrolled 30 patients with CTO for whom PCI was performed. Patients were subjected to thorough clinical assessment, Echo-Doppler evaluation of LV and RV functions before, within 48-hrs after successful PCI and one-month later, Echo-Doppler parameters included LV dimension, LV volumes, biplane and 3D-LV ejection fraction (LVEF), mitral Doppler-flow velocities (E, A & E/A), mitral valve early deceleration time (MV-EDT), mitral tissue Doppler systolic & diastolic annular velocities (Sa, Ea and Aa), LV global longitudinal strain (GLS).

Results: There was no significant improvement of parameters reflecting LV function comparing the pre and 48-hrs post PCI. On the other hand, significant improvement was detected comparing the echo-Doppler measures of either the pre or 48-hours after PCI with those of one-month later. There was significant increase of biplane-LVEF ($p<0.0001$), MV-EDT ($p<.005$), mitral Sa & Ea, 3D-LVEF and LV-GLS ($p<0.0001$)

Conclusion: Ventricular performance improves after successful PCI of chronic totally occluded vessels. Newer echo-Doppler modalities appear to be better tools for assessment of ventricular performance, especially the diastolic function.

Keywords: Chronic total occlusion; percutaneous coronary intervention; tissue Doppler imaging; global longitudinal strain; ventricular performance.

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INTRODUCTION

Echocardiography remains the most commonly used comprehensive cardiac imaging modality and is often the first test of choice for assessing cardiac structure and function, it offers several methods for assessment of systolic and diastolic function. The assessment of ventricular function provides important information for diagnosis, treatment strategy, and prognosis in cardiovascular disease [1]

Coronary artery disease (CAD) is a major cause of mortality and disability in developed countries and causes a negative impact on the physical, psychological, social, and occupational functioning of patients. [2]

Coronary artery chronic total occlusion (CTO) is one of most challenging obstacles faced by interventional cardiologists [3]. CTOs represent a frequent lesions' subset observed in everyday catheterization laboratory practice. Previously considered to be an indication for surgical myocardial revascularization, the interest of interventional community in CTOs has exponentially grown during the last decade, particularly thanks to an important development in dedicated equipment and techniques and has led to the achievement of high rates of success and low rates of complications by expert operators [4].

Previous investigators [5] studied left ventricular performance for assessment of acute outcomes in patients with coronary artery disease after successful PCI to coronary lesions in general and not for PCI to chronic total occlusions only. ***Sun et al, in 2012*** [6] studied highly selected patients with totally occluded left anterior descending artery, but they didn't include chronic total occlusions of other coronary vessels.

Erdogan et al, in 2013 [7] assessed the impact of successful PCI to CTOs on systolic left ventricular function by novel echo-Doppler modalities late post intervention; however, they didn't evaluate it early post procedure or evaluate its impact on diastolic function.

Aim of the study

We aimed to assess the impact of successful percutaneous coronary intervention for chronic totally occluded vessel on the ventricular performance using conventional and new echo-Doppler modalities.

PATIENTS AND METHODS

This observational prospective study was conducted during the period from May 2016 till October 2020 and enrolled 30 patients with CTO who were candidates for PCI which was performed in the cath lab of Nasr City Health Insurance Hospital. Echo-Doppler assessment of ventricular performance was done for all cases within 48 hours before PCI. However, 5 patients didn't fulfill the criteria of successful PCI, thus were excluded from completion of the study, and only 25 cases were included. The study protocol was approved by the Medical Ethics Committee of the Faculty of Medicine for Girls, Al-Azhar University and a verbal informed consent was obtained from all participants before enrollment into the study.

Patients with cardiomyopathies, significant organic valvular heart disease, cardiogenic shock or post cardiac

arrest, uncontrolled serious arrhythmia and patients with implanted pacemaker or cardiac resynchronization device were excluded from the study.

All patients were subjected to:

- **Thorough medical history analysis and clinical evaluation** with special emphasis on risk factors for ischemic heart disease (hypertension, diabetes, smoking & family history of IHD), chest pain according to Canadian Cardiovascular Society angina (CCSa) classification [8] and New York Heart Association (NYHA) classification [9].
- **12-Leads surface ECG:** for documenting ST changes, Q waves and arrhythmias if present.
- **Echo-Doppler evaluation for LV** was performed within 48 hours before PCI and repeated 48 hours after PCI and one month later.
- **Percutaneous coronary interventions to CTO** lesions were performed in the standard manner with either ante- or retro-grade technique. Procedural success was defined as successful dilatation and recanalization of at least one chronic total occlusion per patient with or without stent implantation and with residual stenosis less than or equal to 50%, and TIMI flow equal or more than 2.

Echo-Doppler examinations were performed in Al Zahra University Hospital using Vivid-E9 GE, ultrasound system, Horten Norway with tissue Doppler, speckle tracking imaging and three-dimensional imaging (3-D) capabilities. Standard views were obtained from all available windows, using multi-frequency (1.5-4.6 MHz) matrix probe M5S and 4V probe for 3-D acquisition. The images and cine-loops were digitally stored for later offline analysis through an echo-pack workstation version 201.

Ventricular performance was evaluated with parameters obtained from conventional echo-Doppler, tissue Doppler imaging (TDI), 2D speckle tracking echo (STE) and 3D-echo, for assessment of LV.

LV parameters included:

- **M-mode measures:** LV end-diastolic and end systolic dimensions (**LVEDD** & **LVESD** respectively), LV percent fractional shortening (**PFS**).
- **2DE measures** left ventricular end-systolic and end-diastolic volumes obtained from both 4-chamber and 2-chamber views (**LVEDV** & **LVESV** respectively) and LV ejection fraction measured by 2D echo biplane area length method (**Biplane-LVEF**)
- **Doppler flow measures:** transmitral Doppler flow was obtained by putting the pulsed Doppler cursor midway between the level of mitral anuulus and tips of opened mitral leaflets in the 4-chamber view with measurement of early & late flow velocities and their ratio (**MV-E, MV-A, MV-E/A** respectively), and mitral valve early deceleration time (**MV-EDT**)
- **TDI measures:** tissue Doppler systolic, early and late diastolic velocities were obtained from 4 mitral annular sites (septal, lateral, anterior and inferior) and values were averaged (**Av-Sa, Av-Ea, Av-Aa** respectively)
- **2D- STE:** LV global longitudinal strain (**LV-GLS**) was calculated automatically by the bull's eye method of the machine software after tracing the endocardium in 3 apical views (4-chamber, 2-chamber and apical long axis view).
- **3D echo measures:** LV end systolic and end diastolic volumes (**3D-LVEDV & 3D-LVESV** respectively) and **3D-LVEF** were calculated using 4D auto quantification software.

Statistical analysis: Recorded data were analyzed using the statistical package for social sciences, version 23.0 (SPSS Inc., Chicago, Illinois, USA). Quantitative data were expressed as mean± standard deviation (SD). Qualitative data were expressed as numbers and percentages. Paired t-tests were used to compare values of echo parameters between each two of the 3 settings (before PCI, 48-hrs after PCI and one-month later). *P* value less than 0.05 was considered statistically significant.

RESULTS

The current study patients (pts) included 17 males (68%) and 8 females (32%). The mean value (± SD) of age was 56.6±8.7 years, heart rate 75.9±7.9 bpm, systolic blood pressure 134±15.5 mmHg and diastolic blood pressure 83.8±10.9 mmHg. Risk factors for IHD in the study cases were diabetes 15 pts (60%), hypertension 21 pts (84%), smoking 17 pts (68%) and family history of IHD 6 pts (24%). Chest pain classification according to CCSa was class II in 17 pts (68%) and Class III in 8 pts (32%). NYHA class I was found in 13 pts (52%), class II in 9 pts (36%) and class III in 3 pts (12%). ECGs showed Q waves in anteroseptal leads in 7 pts, anterior leads in 7 pts, inferior leads in 3 pts and lateral leads in one patient. The CTO vessel was LAD in 16 pts (64%), LCX in 5 pts (20%) and RCA in 4 pts (16%).

Comparison between parameters of LV function before PCI and 48 hrs after PCI showed no significant differences in nearly all systolic and diastolic measures, whether measured by conventional echo-Doppler or by the newer modalities. Exceptions were significant increase in the values of averaged mitral annular late diastolic velocity (Av-Aa) & 3D-LVESV; and decrease of LV-GLS in the values of 48 hrs after PCI compared to the corresponding pre-PCI measures; changes that are not in-favor of an improvement of LV performance in the early post PCI assessment.

On the other hand, LV diameters and volumes showed a significant reduction in values one month after PCI compared to the corresponding values in both the pre PCI and early 48 hrs after PCI measures. The values of PFS, biplane-LVEF, MV-E velocity and MV-EDT significantly increased in the one-month post PCI compared to either before or 48 hrs after PCI (**Table-1**).

Table-1: Conventional echo-Doppler LV parameters (M-mode, 2D & Doppler flow)

Parameter	before PCI	48 hrs after PCI	one month after PCI	*P value*	
				Before vs one month	48-hrs vs one month
LVEDD	60.6±8.5	60.2±9.5	51.7±9.1	0.000	0.000
LVESD	43.5±12.0	43.9±12.8	34.7±10.2	0.000	0.000

PFS	29.0±10.9	28.7±9.9	34.1±7.8	0.018	0.006
4CH-LVEDV	153.2±43.8	153.2±46.4	117.2±38.7	0.000	0.000
4CH-LVESV	79.6±38.7	81.7±39.2	50.8±35.2	0.000	0.000
2CH-LVEDV	108.0±34.8	108.7±32.7	78.8±27.7	0.001	0.000
2CH-LVESV	57.3±27.4	57.3±29.5	32.8±25.3	0.000	0.000
Biplane-LVEF	49.0±11.1	48.6±12.8	60.7±11.6	0.000	0.000
MV-E	0.61±0.12	0.61±0.14	0.71±0.12	0.002	0.001
MV-A	0.73±0.14	0.98±1.16	0.81±0.11	0.022	NS
MV-E/A	0.83±0.19	0.82±0.18	0.88±0.13	NS	NS
MV-EDT	148.2±52.6	147.2±47.5	181.9±40.4	0.001	0.003

Table-2 demonstrates parameters of the LV systolic and diastolic performance as measured by the newer modalities (TDI, 3D & 2D-TE).

Table-2: LV parameters as measured by the new modalities (TDI, 3D & GLS)

Parameter	before PCI	48 hrs after PCI	one month after PCI	*P value*	
				Before vs one month	48-hrs vs one month
Av-Sa	6.50±0.97	6.71±0.98	8.24±1.13	0.000	0.000
Av-Ea	7.76±1.25	7.80±1.29	9.92±1.52	0.000	0.000
Av-Aa	7.17±0.81	7.45±0.82	8.53±0.89	0.000	0.000
3D-LVEDV	74.7±10.0	77.3±14.8	57.4±10.3	0.000	0.000
3D-LVESV	41.3±10.5	43.8±13.5	25.5±11.5	0.000	0.000
3D-LVEF	45.0±8.3	44.1±8.4	56.8±9.8	0.000	0.000
LV-GLS	14.4±2.1	13.7±2.5	20.9±4.0	0.000	0.000

Values of mitral annular velocities, 3D-LVEF and LV-GLS showed significant increase in the one-month post PCI compared to either before or 48 hrs after PCI (**Fig. 1**). The values of 3D-LV volumes decreased significantly in the one-month post PCI compared to either before or 48 hrs after PCI.

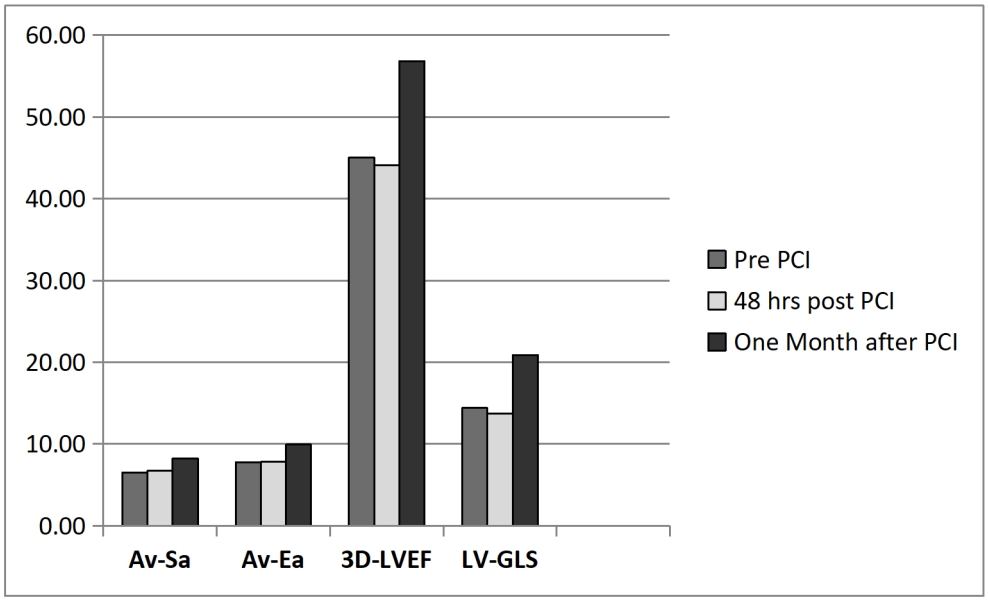

Fig. 1: *Improvement of LV functions more prominent one month after PCI to CTO. The Av-Sa, Av-Ea, 3D-LVEF & LV-GLS showed significant increase (p<0.001) comparing Pre PCI Vs one month after PCI and 48 hrs post PCI Vs one month after PCI, with no significant improvement between Pre PCI and 48 hrs post PCI*

DISCUSSION

Over the past years, chronic total occlusions (CTO) recanalization has received much attention as one of the major frontiers of interventional cardiology. Coronary CTO are commonly encountered complex lesions and were reported to be identified in 15% to 30% of patients referred for coronary angiography [10].

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 [6].

The rationale for the recanalization of a chronic total coronary occlusion is the possible improvement of left ventricular function through the recovery of a hibernating myocardium [11]. Recanalization of CTO lesions by percutaneous coronary intervention (PCI) reportedly produces beneficial effects on patients' symptoms, long-term survival, and need for later coronary artery bypass grafting (CABG). However, mechanism of the beneficial effects of recanalization of CTO still remains unclear [12].

Khanra D et al. in 2020 [13], conducted meta-analysis published data and reported that PCI of CTO is rewarded with better long term outcome, in terms of Major Adverse Cardiovascular Events (MACE), all-cause mortality and cardiac death. They concluded that PCI provided better long-term results than optimal medical therapy alone in patients with chronic total occlusion.

Multiple imaging modalities can be reliably used for evaluation of ventricular performance. Among these modalities are, myocardial perfusion imaging (SPECT) and cardiac magnetic resonance (CMR). However, these imaging modalities might have limitations that make them not feasible in all centers and not fit in many patients either because of cost, radiation exposure or contraindication to perform in some patients with cardiac devices. Echo-Doppler imaging with its conventional and new modalities represents a safe and feasible assessment tool that can be repeated many times with acceptable cost.

The current study aimed to assess the impact of successful percutaneous coronary intervention for chronic totally occluded vessel on the ventricular performance using conventional and new echo-Doppler modalities. Ventricular performance was evaluated by conventional echo-Doppler, TDI, 3D-echo and STE in 25 patients with CTO before PCI, 48 hrs after PCI and one month later.

The present study revealed improvement of parameters reflecting LV systolic function including LV dimensions and volumes, LVEF (biplane or 3D), systolic tissue Doppler mitral annular velocity and LV-GLS in the one month after PCI compared to pre PCI or 48 hrs post PCI examination. These findings regarding the late one-month effect are concordant with many previous studies that reported improvement of left ventricular systolic function late after PCI whether assessed by echo modalities [7, 14], SPECT/CTCA fusion imaging [6] or cardiac magnetic resonance (CMR) [15, 16]. On the other hand, our study didn't show significant improvement in the early 48 hrs post PCI compared to the pre-PCI parameters.

Our results are partially discordant with some previous studies in respect to improved LVEF & LV volumes after CTO-PCI contrary to the improved LV-GLS. Chimura et al. in 2019 [17] found that LVEF, LVEDV and LVESV did not change significantly during follow-up in both successful and failed CTO-PCI groups. On the other hand, they reported improved LV function in patients with successful PCI to CTO when assessed by LV-GLS indicating the superiority of STE over the conventional echo measures in detecting early subclinical improvement of LV function. The difference between our results and those of ***Chimura et al*** can be explained by the difference of patients' subsets in the 2 studies. They studied patients with preserved ejection fraction before PCI while our study was conducted on patients with some impairment of LVEF (mean value of biplane-LVEF before PCI was 49.0±11.1 and the 3D-LVEF was 45.0±8.3). It was reported that the effect of CTO PCI on LV systolic function seems to be more pronounced in patients with depressed LVEF [18]

Wang et al. in 2018 [14] reported improvement of LV-GLS as early as one day after CTO-PCI whereas LVEF showed significant improvement only after 3 or 6 months. Our results are partially concordant with those of Wang et al. Both LVEF and LV-GLS increased 3 months after CTO-PCI but didn't show improvement early 48-hrs after PCI. The difference between our results and those of Wang et al. in respect to the LV-GLS can be explained by a different extent of pathology in the studied patients related to either collaterals or size of segments affected by the CTO lesions.

Changes in diastolic function (DF) after PCI would be of great prognostic importance on long-term clinical outcomes because many patients undergoing PCI have preserved LV systolic function and impaired DF. Thus, the effects of revascularization cannot be fully determined, based on changes in LV systolic function alone. ***Kim et al. in 2019*** [19] reported that no study to date has looked into how DF changes after revascularization in a sufficiently large population that includes patients with preserved LV systolic function. Diastolic function might be considered as a more sensitive measure of the effects of revascularization compared with systolic function, because myocardial ischemia causes diastolic dysfunction earlier than systolic dysfunction [19].

In the current study, the trans-mitral E/A ratio which is a conventional Doppler flow parameter couldn't indicate changes in LV diastolic function after successful PCI. On the other hand, the tissue Doppler mitral annular velocity showed significant increase in one month after PCI compared to values in the pre or early post PCI, indicating a good impact of CTO-PCI on LV diastolic performance, and the superiority of TDI over conventional Doppler in assessment of diastolic function.

The findings of the current study demonstrated improvement of ventricular performance after successful PCI to totally occluded vessels and support the superiority of the newer STE modality over conventional parameters.

We recommend further studies with a large number of patients and longer follow-up periods to evaluate the impact of successful PCI on ventricular performance and long-term clinical outcomes.

CONCLUSION

Ventricular performance improves after successful PCI of chronic totally occluded vessels. Newer echo-Doppler modalities appear to be better tools for assessment of ventricular performance, especially the diastolic and RV function.

LIMITATION

There are some limitations in this study that might affect the accurate interpretation of data regarding the impact of PCI to CTO on ventricular performance. One of these limitations is the absence of complete data about treatment options in the study cases post PCI including drug treatment, lifestyle and control of risk factors. Other limitations include the number of patients in each site of

CTO lesion; most of the study patients had their CTO in the LAD coronary artery. Better results would be obtained if the number of patients in each site allows comparison of the impact of recanalization of a specific CTO artery on the function of a specific chamber (LV), or myocardial wall. Also, comparison of data in patients with successful PCI versus failed PCI would exclude other factors affecting ventricular performance in the post PCI time. Sample size and timing of follow-up echo evaluation might represent other limitations; larger sample size and repeated evaluation at several months after PCI would elucidate more the effect of successful PCI on ventricular performance.

Conflict of Interest: None declared.

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