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Evaluation of Successful Percutaneous Coronary Intervention for Right Coronary Artery Chronic Total Occlusion on Improvement of Right Ventricular Systolic Function and Reverse Remodeling

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Abstract

Background: Lesions with TIMI grade 0 flow for over three months are chronic total occlusions. Chronic coronary occlusions cause ventricular arrhythmias and poor outcomes. CTO difficulties and failure rates increased even among seasoned PCI operators. 38–50% of CTO patients had RCAs. Right ventricular echocardiography was disregarded in the past. After depending largely on qualitative assessment in past, the American Society of Echocardiography and the European Association of cardiovascular imaging now offer many quantitative methods for assessing the RV.

Aim: To correlate the relationship between Successful percutaneous coronary intervention for right coronary artery chronic total occlusion and improvement of Right ventricular functions.

Subjects and techniques: The research contained 60 studied cases who had undergone coronary angiography at National Heart Institute, Giza, Egypt.

Results: Hypertension was the most frequent risk factor found in most patients. The stress test revealed that all studied cases had viable RCA territory. The left main coronary artery was free in all cases and the proximal segment of the left anterior descending artery had lesions in some cases. Successful PCI was achieved in most studied cases. There was a significant elevation in S' and TAPSE after the intervention compared to results before the intervention.

Conclusion: RV function improves after percutaneous coronary intervention of a chronically and totally occluded artery. Successful CTO PCI improves RV and LV ejection fraction and decreases LV end-systolic volume, suggesting a favourable influence on LV and RV systolic function and remodeling.

Keywords: Coronary chronic total occlusions, Chronic total occlusions, Right ventricular systolic function

1. Introduction

Euro CTO Club defines chronic total occlusions (CTO) as lesions with TIMI grade 0 flow for more than three months. In the lack of earlier coronary artery bypass surgery, CTO lesions are found in 18.4% of studied cases undergoing elective percutaneous coronary intervention.¹ Chronic total occlusions of the coronary arteries are common and have been linked to raised risk of ventricular arrhythmias and poor clinical results. The advantages of PCI for CTO are debatable. The process may take

many hours and expose the patient to significant radiation and contrast doses. Moreover, in experienced dedicated PCI operators, greater problem rates of CTO procedures and greater failure rates of CTO PCI were observed. As a result, it is critical to select studied cases that are candidates for PCI CTO and to evaluate the effects of CTO revascularization using conventional methods.

Numerous research, the majority of which were retrospective, have looked into whether CTO revascularization enhances symptoms, and majority have found it to be beneficial. Right coronary artery

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CTO has been reported from 38 to 50% of the entire CTO population.² Studied cases with RCA-CTO are less likely to be treated with revascularization via percutaneous coronary intervention than studied cases with LAD CTO.³ We hypothesized that the cause of this disparity was due in part to RCA's smaller territory than LAD's, and in part to competing views on whether successful reperfusion of RCA-CTO offers studied cases clinical advantages. Safley DM *et al.*,⁴ enrolled the entire CTO population and described that successful RCA-CTO PCI did not advance studied case survival. This claim was doubted by Mitomo S *et al.*,⁵ who discovered that successful RCA-CTO PCI was associated with lower cardiac mortality than failed CTO PCI. So, the Goal of research is to correlate the relationship between Successful percutaneous coronary intervention for right coronary artery chronic total occlusion and improvement of Right ventricular functions.

2. Studied cases and techniques

This research was conducted in Cardiology Department, Al-Azhar University, Cairo and National Heart Institute, Giza, Egypt. The study included 60 patients who had undergone coronary angiography at National Heart Institute, Giza, Egypt.

Inclusion criteria: studied cases with suspected or documented CAD who had underwent coronary angiography and had CTO-RCA lesion and patients with viable myocardium by positive stress test for RCA territory.

Exclusion criteria: Patients with scar tissue or without viable myocardium, studied cases who had previous coronary artery bypass graft and studied cases with severe Valvular diseases.

Upon admission, next information was collected from every studied case: **Initial assessment:** Complete full history: Age, Sex, HTN, DM, Smoking, history of ischemic heart disease (IHD) and **Clinical examination focusing on:** General examination in form of Vital signs and Signs of (Pallor, Cyanosis).

2.1. Investigations

2.1.1. 12 Leads surface ECG

Laboratory study: Complete blood picture, cardiac markers, lipid profile, and renal function tests.

Standard resting transthoracic echocardiography (TTE): All patients were subjected to clinically indicate transthoracic echocardiogram before and after PCI to assess RV systolic function by tricuspid annular plane systolic excursion, and Tissue

Doppler. All measurements were taken in accordance with the American Society of Echocardiography's guidelines.

2.2. Positive stress test before the procedure

Dobutamine Stress echo was done to fifty-four patients and was positive in all cases.

Stress ECG test (treadmill test) was done to one case and was positive.

Stress thalium (MPI) was done to 5 cases and was positive for ischemia.

Administrative and Ethical Design: Official permission was got from Cardiology Department, Al-Azhar University, Cairo and National Heart Institute, Giza, Egypt, approval from ethical committee in faculty of medicine.

2.3. Statistical analysis

Statistical analysis was completed by SPSS v26. Quantitative variables were accessible as mean and standard deviation and Wilcoxon Rank test was used to compare two related samples, matched samples, and to conduct paired variance test of repeated measurements on single sample to evaluate if their populations mean ranks vary. Qualitative variables were accessible as frequency and percentage and were utilizing χ^2 test A two-tailed P value less than 0.05 was measured important.

3. Results

This research was carried out on 60 studied cases who had undergone coronary angiography that performed at Cardiology Department, Al-Azhar University, Cairo and National Heart Institute.

Years old of included studied cases ranged from 33 to 70 with mean of 54.27 ± 8.22 . The group age ≤ 60 years was the most frequent representing 76.7% cases. There was male prevalence in our study (90%) compared to females that represent only 10% with male to female ratio was 2.23: 1. [Table 1](#).

Regarding risk factors, hypertension was the most frequent risk factor found in 54 (90%) patients followed by dyslipidemia in 83.3% of cases then smoking that found in 66.7% of cases. 33 (55%) patients had a history of DM, and 17 (28.3%) had history of ischemic heart disease. [Fig. 1](#).

Stress examination revealed that all studied cases had viable RCA territory.

[Table 2](#).

The studied patients underwent coronary angiography upon admission. The results revealed that:

Table 1. Distribution of patients as regard demographic characteristics.

	Studied patients (N = 60) N (%)
Sex	
Men	54 (90.0%)
Women	6 (10.0%)
Age groups	
≤60 years	46 (76.7%)
>60 years	14 (23.3%)
Years old	
Mean ± SD	54.27 ± 8.22
Median	56.0
Range	33.0–70.0

SD, standard deviation.

Left main coronary artery was free in all cases. Proximal segment of left anterior descending artery had significant lesion in 15% cases, 5% had significant lesion in mid segment. 11.7% had patent stent. Proximal segment of left circumflex artery (LCX) had proximal CTO in 15% cases, 3.3% had significant lesion in mid segment. 11.7% had patent stent. The proximal right coronary artery had CTO in most cases (65%), and distal CTO in one case, mid segment in 20% cases. DES was the type of stent that used in all cases with TIMI flow grade III. Mean number of stents used was 2.33 ± 0.71 and ranged from one to four stents. Table 3.

Successful PCI was achieved in the majority of studied cases (95%) while the procedure was failed in three (5%) patients, two of them due to heavy calcification (Fig. 2).

The mean ejection fraction was $53.42 \pm 9.82\%$ and ranged from 30% to 75%. Fig. 3.

The mean S' before intervention was 9.46 ± 1.76 and ranged from 7.7 to 14.92 while the mean S' after intervention was 13.94 ± 1.71 and ranged from 11.2 to 16.8. There was significant elevation in S' after

Table 2. Distribution of studied cases as regard stress Echo, MPI, Stress ECG.

	Studied patients (N = 60) N (%)
Viability	
Viable RCA territory	60 (100.0%)

IQR, Inter-quartile range; SD, standard deviation.

intervention compared to results before intervention ($P < 0.001$). Table 4.

The mean TAPSE before intervention was 15.07 ± 2.67 and ranged from 11 to 19 while the mean TAPSE after intervention was 24.58 ± 3.67 and ranged from 18.68 to 31. There was significant elevation in TAPSE after intervention compared to results before intervention ($P < 0.001$). Fig. 4.

4. Discussion

Both the American Society of Echocardiography and the European Association of Cardiovascular Imaging now advocate a number of quantitative approaches for assessing the RV after formerly relying primarily on qualitative assessment.⁶

Therefore, to investigate impacts of a successful CTO-RCA PCI on the expansion of RV size and RV functions, we conducted systematic review and meta-analysis.

RV function has been found to be significant forecaster of findings in studied cases with heart failure, myocardial infarction, and pulmonary embolism. Because RV dysfunction is linked to great in-hospital morbidity and mortality, primary detection of RV dysfunction is recommended.⁷

Multiple imaging modalities can be used for assessment of RV performance, including myocardial perfusion imaging and cardiac magnetic

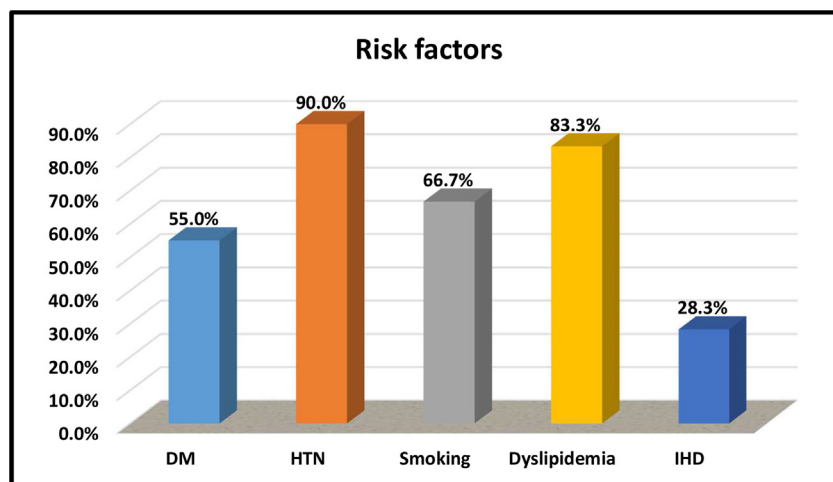


Fig. 1. Distribution of studied patients regarding clinical history and risk factors.

Table 3. Distribution of patients as regard coronary angiography.

	Studied patients (N = 60) N (%)
LM	
Free	60 (100.0%)
LAD	
Free	26 (43.3%)
NSL	9 (15.0%)
Proximal significant lesion	9 (15.0%)
Mid SL	3 (5.0%)
Osteal	5 (8.3%)
Mixed	1 (1.7%)
Patent stent	7 (11.7%)
LCX	
Free	35 (58.3%)
NSL	2 (3.3%)
Proximal CTO	10 (15.0%)
Mid CTO	2 (3.3%)
Osteal critical lesion	3 (5.0%)
Paraosteal CTO	1 (1.7%)
Patent stent	7 (11.7%)
RCA	
Free	4 (6.7%)
Proximal CTO	39 (65.0%)
Mid CTO	12 (20.0%)
Distal CTO	1 (1.7%)
Osteal CTO	2 (3.3%)
Paraosteal CTO	2 (3.3%)
Type of stent	
DES	60 (100.0%)
BMS	0 (0.0%)
TIMI flow	
III	60 (100.0%)
Less than III	0 (0.0%)
Number of stents	
Mean \pm SD	2.33 \pm 0.71
Median	2.0
Range	1.0–4.0

LAD, left anterior descending; LCX, left circumflex artery; LM, Left main coronary artery; RCA, right coronary artery.

resonance which is gold standard for imaging * evaluating the RV functions. Even so, these imaging modalities may have drawbacks that make them unsuitable for several studied cases and unfeasible in several centers due to cost, radiation exposure,

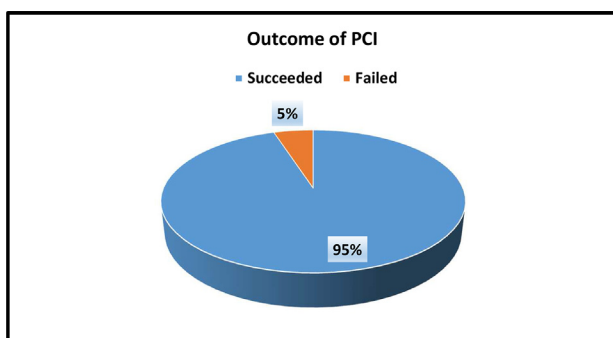


Fig. 2. Distribution of studied patients regarding outcome of PCI.

and contraindications to performing in studied cases with cardiac devices. With its traditional and new modalities, echo-Doppler imaging is safe and feasible evaluation tool that can be repeated numerous times at low cost.⁸

The aim of this study was to correlate the relationship between Successful percutaneous coronary intervention for right coronary artery chronic total occlusion and improvement of Right ventricular functions.

Age of included studied cases ranged from 33 to 70 with mean of 54.27 ± 8.22 years. The group age ≤ 60 years was the most frequent representing 76.7% cases. There was male prevalence in our study (90%) compared to females that represent only 10% with male to female ratio was 2.23: 1. Regarding risk factors, hypertension was the most frequent risk factor found in 54 (90%) patients followed by dyslipidemia in 83.3% of cases then smoking that found in 66.7% of cases. 33 (55%) patients had a history of DM, and 17 (28.3%) had history of ischemic heart disease.

In the study conducted by Mahgoub *et al.*,⁹ as regard hypertension, there were 38 hypertensive studied cases (63.33%) and 22 non-hypertensive studied cases (36.67%). The study included 32 patients with diabetes (53.33%) and 28 patients were nondiabetics (46.67%). 38 patients of our study population were smokers (63.33%) and 22 patients were non-smokers (36.67%)

In a study performed by Schumacher *et al.*¹⁰ showed that time among baseline CMR and CTO PCI and among CTO PCI and follow-up CMR was 38 (IQR 22–59) days and 102 (IQR 94–118) days.

DES was the type of stent that used in all cases with TIMI flow grade III. Mean number of stents used was 2.33 ± 0.71 and ranged from one to four stents.

Successful PCI was achieved in the majority of studied cases (95%) while procedure was failed in three (5%) patients, two of them due to heavy calcification.

The mean S' before intervention was 9.46 ± 1.76 and ranged from 7.7 to 14.92 while the mean S' after the intervention was 13.94 ± 1.71 and ranged from 11.2 to 16.8. There was a significant elevation in S' after intervention compared to results before intervention ($P < 0.001$). The mean TAPSE before intervention was 15.07 ± 2.67 and ranged from 11 to 19 while the mean TAPSE after intervention was 24.58 ± 3.67 and ranged from 18.68 to 31. There was significant elevation in TAPSE after intervention compared to results before intervention ($P < 0.001$).

The presence of right ventricular dysfunction in our patients who had LAD lesions prior to PCI

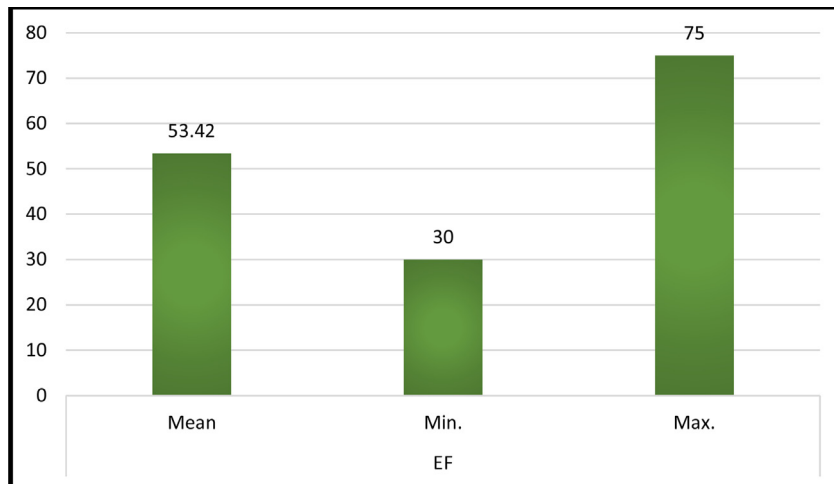


Fig. 3. Mean and range of EF in the studied patients.

Table 4. S' measurements before and after intervention.

	Before intervention	After intervention	Wilcoxon signed Ranks test	
			Test value	P value
S'				
Mean ± SD	9.46 ± 1.76	13.94 ± 1.71		
Median	8.70	13.80	14.980	<0.001
Range	7.7 ± 14.92	11.2 ± 16.8		

P value < 0.05 is significant, P value < 0.01 is greatly significant, SD: Standard deviation.

might be explained by the presence of systolic and diastolic ventricular interaction, annular interaction, and pericardial interaction effect of the tethered LV myocardium. This could also be explained by the presence of pericardial interaction.

In agreement with our results, El-Adawy *et al.*,¹¹ who assessed Right Ventricular Functions in studied cases with Ischemic Heart Disease before and after

Percutaneous Coronary Intervention using Colored Tissue Doppler Imaging and showed that TAPSE enhanced following PCI ($P = 0.001$). The majority of myocardial function enhanced significantly after PCI using TDI, with $P = 0.003$ and $P = 0.008$, for E' and A' diastolic wave velocities, RMPI ($P = 0.008$), and S/RIMP ratio ($P = 0.04$). Some myocardial functions improved significantly after PCI using color-coded tissue Doppler, including E' ($P = 0.02$), RMPI ($P = 0.01$), and S/RIMP ratio ($P = 0.07$). They concluded that a significant advancement in RV function was discovered after PCI that was not limited to right coronary artery revascularization moreover extended to studied cases with non-RCA lesions.

In the line with our results, Zaki *et al.*,¹² enrolled twenty five studied cases with chronic total occlusion who underwent PCI and discovered significant rise in RV-FAC, tricuspid Sa and Ea, and RV-

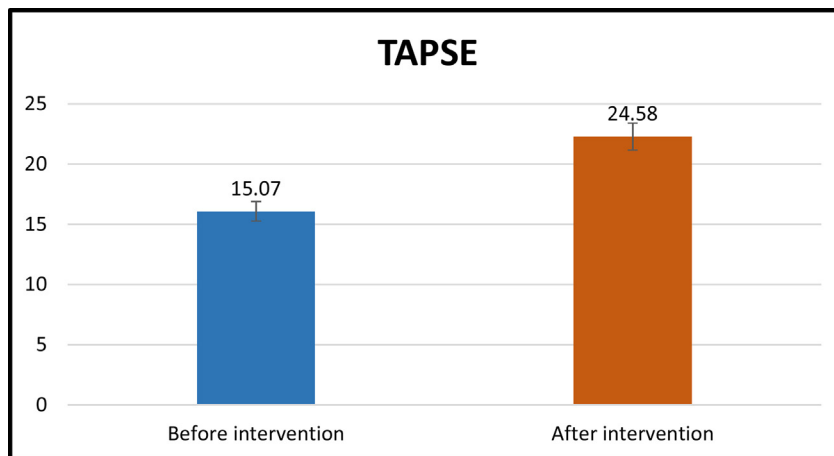


Fig. 4. TAPSE measurements before and after intervention.

GLS ($P < 0.05$). E/A ratio of tricuspid flow and tricuspid annular plane systolic excursion did not differ significantly between pre- and 48-h or one-month PCI values. They concluded that RV performance increases after successful PCI of chronic totally occluded vessels.

Earlier researches showed by Ozkan *et al.*⁷ and Acar *et al.*,¹³ evaluated RV function using conventional and new echo-Doppler modalities like TDI and STE in studied cases with CTO PCI. RV-GLS that discovered enhancement of RV systolic function, TAPSE in researches could not recognize impact of PCI on RV function.

In disagreement with our results, Ozkan *et al.*⁷ reported that after successful percutaneous recanalization of RCTOs, TDI-derived isovolumic acceleration and 2DSTE-derived global longitudinal strain and systolic strain rate values found enhancement in RV functions, indicating RV viability in chronic ischemia. They showed that no significant difference between before and after PCI; thus, it could not demonstrate improvement of RV systolic function like the RV-GLS.

Our findings may differ from Ozkan and colleagues' due to collateral status and RV performance. However, the mismatch between tissue Doppler velocities and RV-GLS in their investigation supports the advantage of STE-derived strain over TDI in detecting early or mild ventricular performance improvement.

In line with our results Diller *et al.*,¹⁴ who evaluated present research found that, while advancements in right ventricular longitudinal function were marked in studied cases undergoing PCI of RCA, right ventricular function enhanced in studied cases who did not have revascularization within RCA territory. Numerous factors could be to blame for advancement in RV function following intervention. Enhanced blood supply to RV as consequence of successful PCI to RCA territory.

Gaber *et al.*¹⁵ results support our finding. They investigated 60 RV participation in studied cases with myocardial infarction and single LAD lesion after PCI and recanalization of LAD. They found that studied case group's right ventricular tissue Doppler parameters were lower than controls. Furthermore, modifications in right ventricular mean strain and strain rate values were minor in studied case group than in control group. Findings contradict Gaber's, because we discovered advancement in RV function after successful PCI to completely occluded vessels, despite fact that majority of cases had CTO of LAD coronary artery. Variations among results and those of Gaber could be related to different types of studied cases in two

researches, because all of Gaber's research studied cases had MI, whereas not all of cases had MI, owing to existence of collaterals.

Mahgoub *et al.*,⁹ showed that in pre procedure, LVEF by Simpson's method ranged from 41% to 75% with a mean of 57.0 ± 8.7 SD (%). In post-procedure, ranging from 44% to 76% with a mean of 58.5 ± 8.1 SD (%). There was significant increase in the mean LVEF % measured by 2DE (Simpson's method) postprocedure.

In the study conducted by Nakamura *et al.*,¹⁶ ejection fraction outcomes of five-center Asian registry, in which 88 studied cases with recanalized CTOs were treated with DES, was enhanced in these studied cases on follow-up.

In the study performed by Megaly *et al.*,¹⁷ achieved systematic review and meta-analysis of researches on impact of successful CTO PCI on LV function published among January 1980 and November 2017. The average age of studied cases was 61 ± 10 years, and 80.6% were men.

In another study performed by Mahgoub *et al.*,⁹ aimed to determine influence of revascularization for chronic total occlusion coronary artery disease on left ventricular function using 3D and three-dimensional speckle tracking echocardiography. Age of studied cases ranged from 48 to 72 years with mean of 60.8 ± 6.2 SD years [39 males (65%) and 21 females (35%)].

El Shafey *et al.*,¹⁸ study showed improvement in regional and global LV function measured by PW-TDI in patients with CTO vessel after successful recanalization by PCI.

The mean ejection fraction was $53.42 \pm 9.82\%$ and ranged from 30% to 75%.

In the study performed by Mahgoub *et al.*,⁹ described that there was very high statistically significant comparison among LVEF (%) by 3DE pre and postprocedure with a P value < 0.001 . In pre procedure, LVEDV (ml) by 3DE varied from 85 ml to 155 ml with mean of 102.5 ± 12.8 SD (ml). In post-procedure, LVEDV (ml) by 3DE ranged from 81 ml to 132 ml with mean of 96.4 ± 10.5 SD (ml). There was significant decrease in the mean LVEDV (ml) by 3DE postprocedure. There was very high statistically significant comparison between LVEDV (ml) by 3DE pre and postprocedure with a P value < 0.001 .

In the study conducted by Megaly *et al.*,¹⁷ showed that follow-up of 7.9 months, effective CTO PCI was related to significant rise in LVEF (mean variance 3.8%, 95% CI 3.0–4.6, P 0.0001, $I^2 = 45\%$), whereas failed CTO PCI was not related to modification in LVEF (4 cases, 70 studied cases) 18,33,40,41 (mean difference 2.2%, 95% CI –1.4, 5.8, $P = 0.24$).

Another study conducted by Megaly *et al.*¹⁷ showed that in sensitivity analysis that included only researches with recognized CTO time of at least three months and follow-up time of at least three months after CTO PCI (15 cases, 1248 studied cases), successful CTO PCI stayed related to advancement in LVEF (4.3%, 95% CI 3.0–5.5, $P < 0.00001$).

4.1. Conclusion

RV function increases after successful percutaneous coronary intervention of chronically and completely blocked artery, regardless of where the obstruction is located. Successful CTO PCI is linked to enhancement in RV and LV ejection fraction and reduce in LV end-systolic volume, suggesting beneficial impact of CTO recanalization on LV and RV systolic function and remodeling. Extended follow-up time might be essential to detect further enhancement in systolic function after successful CTO recanalization. Clinical associations of these results warrant further investigation. The more recent echo-Doppler modalities tend to be superior instruments for evaluating the performance of RVs.

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Conflicts of interest

The authors declared that there were NO conflicts of Interest.

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