The Egyptian Journal of Hospital Medicine (July 2024) Vol. 96, Page 3237-3243

Immediate Changes of Left Ventricular Function after Total Occlusion Opening of Artery Rich in Collaterals Versus in Artery without Collaterals

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ABSTRACT

Background: For ischemic patients, left ventricular function is essential to their quality of life, and the major goal of coronary interventions is to keep the myocardium's blood supply productive. Thus, the complete cessation of blood flow to the myocardium for a prolonged duration is the obstacle to chronic total occlusion (CTO). Effective CTO coronary interventions improve the quality of life for the patient by improving LV systolic function, reducing angina, and increasing exercise capacity. **Aim:** This study aimed to compare the immediate changes that occur in the left ventricular systolic function in patients with CTO after successful revascularization in presence or absence of collateral circulation.

Subjects and methods: This was an analytical cross-sectional study that was conducted at the Military Hospitals (Air Force, Maadi and Kobri El Koba Hospitals). Patients were recruited from the Cardiology Department from January 2023 to December 2023. Two groups were included: Group 1 included forty patients with CTO in any coronary artery more than 2.5 mm in its diameter with presence of ipsilateral or contralateral collateral circulation based on coronary angiography. Group 2 included other forty patients with CTO in any coronary artery more than 2.5 mm in its diameter with no collateral circulation based on the coronary angiography. Trans- thoracic echocardiography was done for all patients including both conventional (M-mode and 2D) and tissue Doppler strain rate studies 24 hours before PCI and two weeks after successful CTO PCI with final TIMI III flow. **Results:** Strain rate statistically significantly improved in group 1 compared to group 2 in terms of the septal and inferior wall segments 2 weeks after CTO opening.

Conclusion: In CTO interventions, the presence of collateral circulation predicts immediate improvement in left ventricular systolic function as assessed by tissue Doppler intervention (TDI) using strain rate technique despite the lack of significant effect on conventional left ventricular systolic parameters as wall motion score index measurements.

Keywords: Left ventricular function, Collaterals, Occlusion opening.

INTRODUCTION

An occluded coronary segment with thrombolysis in myocardial infarction (TIMI) flow (0) for more than three months is referred to as a coronary chronic complete occlusion (CTO). First of all, in patients with significant coronary disease, approximately 18–33% have at least one CTO [1, 2]. It has been shown that effective percutaneous coronary interventions (PCIs) of CTOs improve left ventricular systolic function, reduce angina, increase exercise tolerance, and reduce the need for bypass surgery [3]. In patients with ischemic heart disease, the left ventricular ejection fraction (LVEF) is widely acknowledged as an independent predictor of the prognosis for their cardiovascular system [4]. The development of technologies for measuring regional cardiac velocities using tissue. Doppler and software have provided researchers with a potential new method for noninvasive evaluation of heart function. The early recovery of left ventricular function after successful CTO PCI in the context of collateral circulation is not well documented [5]. The advantages of percutaneous coronary intervention (PCI) and revascularization for patients with CTO have been highlighted in numerous studies [6–8]. Thanks to advancements in technology, such as drug-eluting stents, specialized guidewires, and microcatheters, the success rate of PCI in patients with CTO has increased [9-10]. Nonetheless, patients with CTO continue to experience higher PCI failure rates and perioperative death associated with revascularization. As a result, some medical professionals are more inclined to use medication alone to treat patients with CTO and extensive distal collateral flow [11].

As far as we are aware, no research has evaluated the early changes in left ventricular performance after revascularization in individuals with CTO and well-developed collateral circulation. Thus, the purpose of this study was to evaluate the differences between patients with at least one CTO and well-developed collateral circulation versus those without collateral circulation in terms of the rapid alterations in left ventricle systolic function brought on by revascularization.

PATIENTS AND METHODS

This was an analytical cross-sectional study that was conducted at the in Military Hospitals (Air Force, Maadi and Kobri El Koba Hospitals). Patients were recruited from the Cardiology Department from January 2023 to December 2023. Two groups were included: Group 1 included forty patients with CTO in any coronary artery more than 2.5 mm in its diameter with presence of ipsilateral or contralateral collateral circulation based on coronary angiography. Group 2 included other forty

Received: 04/04/2024
Accepted: 12/06/2024

patients with CTO in any coronary artery more than 2.5 mm in its diameter with no collateral circulation based on the coronary angiography.

A) Data collection tools:

- Questionnaire contained some information as name, age, sex and history of present illness and drugs.
- Cardiac examination included inspection, palpation, percussion and auscultation of the precordial area.

B) Procedures:

- Trans Thoracic Echocardiography was done for all patients including both conventional (M-mode and 2D) and tissue Doppler strain rate studies 24 hours before PCI and 3 months after successful CTO PCI with final TIMI III flow.
  The following echocardiographic variables were measured:
- The modified Simpson biplane method was used to compute the left ventricular ejection fraction. After measuring the regional LV wall motion score (LVWMS), each wall segment was given a numerical score based on the visual assessment of its contractile function: 1 denotes normalcy (thickness with systole > 40%), 2 hypokinesis (10% to 40% thickening), 3 severe hypokinesis to akinesis (thickness <10%), 4 dyskinesis, and 5 aneurysm.
- TDI Strain Rate: Strain rate (SRs) was obtained by placing a tissue Doppler sample volume at anterior, lateral and septal left ventricular walls, in basal , mid and apical levels in different apical views and was compared before, early after successful CTO revascularization and 2 weeks later [12].
- Resting Electrocardiogram.
- Coronary angiography: The coronary vessels were viewed in different projections for better quantification and assessment.
- **The left coronary system:** 20º view for the right anterior oblique (RAO) with 20º caudal to display the entire left coronary system. A 30º RAO 25º cranial view can be used than to separate the diagonals from the left anterior descending artery (LAD). A posterior-anterior view (PA) with 40º cranial angulation viewing the mid and distal portions of the LAD. The 45º left anterior oblique (LAO) 30º cranial view was used for separating the LAD from its diagonal branches. The 45º LAO and 30º caudal (spider view) was employed to examine the left circumflex origin and left major coronary artery (LCX) [13].
- **The right coronary system:** The right coronary artery (RCA) was viewed in the LAO and RAO views. The 30º RAO provided a view for the proximal and mid-RCA. The 45º LAO with cranial angulation was for viewing the posterolateral arteries. The lateral view was for viewing the mid-RCA [13].
- According to the findings, if the decision is taken for CTO intervention, the procedure was done with the feasible technique according to the operator choice.
- PCI techniques: General Electric (GE), Siemens and Philips catheterization systems were used and all possible intervention tools and techniques were used including:
- Antegrade, retrograde or hybrid approach according to feasible techniques and evident collateral branches [14, 15].
- Special types of guidewire specified to CTO interventions (Like Fielder XT, Asahi Sion black, Asahi Gaia I, II, III, etc.).
- Using either microcatheter or over the wire balloon (OTW) [16]: The most used microcatheters were Caraval and Crosair.
- Simultaneous contralateral injection to assess contralateral collaterals [17]: We used all available curves of guiding and diagnostic catheters according to coronary anatomy.
- In terms of the vascular access site, 25% of patients had a right radial and a right femoral access, 20% of patients had a right femoral access alone, and 55% had a bilateral femoral access. Technically, every patient was treated successfully using an antegrade approach in 85% of cases and a retrograde technique in 15% of cases. The study revealed that the underutilization of IVUS (6.25% of procedures) to guide the procedure was caused by cost constraints that restricted its availability and hindered its routine use in our circumstances. Using Rentrop classification [18], evaluate collateral circulation:
  - Grade 0: No collateral channel filling was visible.
  - Grade 1 filling of the CTO artery's lateral branches.
  - Grade 2: Partial filling of the CTO artery's epicardial vessel.
  Level 3: Final filling of the epicardial CTO vessel with collateral.

Statistical analysis

Collected Data were coded, entered, and analyzed using Microsoft excel program software. Data analysis was done by statistical package for social science (SPSS) version 26. **Descriptive statistics:** After doing the Shapiro-Wilk test, we discovered that the numerical data we had was normally distributed, thus we reported it as mean ± SD. Proportions were used to express categorical data. **Analytic statistics:** The used tests were: The Chi-square test was applied to compare different qualitative data sets. The T test for independent samples was employed to compare continuous quantitative data. An analysis of variance (ANOVA) in one direction is used when comparing more than two groups. At $p \leq 0.05$, it was deemed statistically significant.

RESULTS

In group 1 of our study, 87.5% were males and 12.5% were females, while group 2 was composed of 75% males, and 25% females. The mean age of our study patients in group 1 was 57.3 ± 8.6 years, while the mean age of those in group 2 was 57.4 ± 9.6 years. Both our study groups contained obese participants (31.8 kg/m² in group 1 and 31.7 kg/m² in group 2). Additionally, the majority of the patients in both groups were smokers, had hypertension, and suffered from DM. These characteristics did not vary significantly between both groups (Table 1).

Table (1): Comparison of all studied groups as regards demographic data

		Collaterals				P-value
		Group 1 (n = 40)		Group 2 (n = 40)		
Gender	Male	35	87.5%	30	75%	0.15 NS
	Female	5	12.5%	10	25%	
Age (Years)	Mean	57.3		57.4		0.95 NS
	SD	± 8.6		± 9.6		
BMI (kg/m²)	Mean	31.8		31.7		0.95 NS
	SD	± 3.3		± 3.6		
Smoking	Positive	25	62.5%	27	67.5%	0.64 NS
HTN	Positive	32	80%	32	80%	1 NS
DM	Positive	33	82.5%	32	80%	0.78 NS

T: value of independent sample T test. NS: p-value > 0.05 is considered non-significant, X^2: Chi-square test.

Regarding the distribution of the guilty vessel in this investigation, LAD CTO was more common across the board in the population (45%), the majority of our patients in group 1 suffered from coronary chronic total occlusions in the right coronary artery (RCA) (47.5%), followed by the left anterior descending artery (LAD) (42.5%), then the posterior descending artery (5%). Regarding group 2, the major occlusion were in the LAD, followed by the RCA, and the PDA (47.5%, 12.5% and 5% respectively). Between the two groups, there was a statistically significant difference (p value= 0.004) (Table 2).

Table (2): Comparison of all studied groups as regards CTO artery

		Collaterals				P-value
		Group 1 (n = 40)		Group 2 (n = 40)		
CTO	LAD	17	42.5%	19	47.5%	0.004 S
	RCA	19	47.5%	5	12.5%	
	PDA	2	5%	2	5%	
	CXA	2	5%	11	27.5%	
	D1	0	0%	2	5%	
	OMB1	0	0%	1	2.5%	

NS: p-value > 0.05 is considered non-significant. X^2: Chi-square test S: p-value < 0.05 is considered significant

Upon investigating the difference in the anterior wall strain rate between baseline assessment, and 2 weeks after revascularization between both our study groups, we found that no statistically significant difference was observed in all the view levels; basal, mid and apical (Table 3).

Table (3): Comparison of all studied groups as regards anterior wall strain rate (before, and 2 weeks after revascularization)

Anterior Wall			Collaterals Group 1 (n = 40)	Collaterals Group 2 (n = 40)	P-value
Before	SRs AB	Mean	0.98	0.93	0.43 NS
		SD	± 0.27	± 0.26	
	SRs AM	Mean	0.98	0.94	0.39 NS
		SD	± 0.25	± 0.24	
	SRs AA	Mean	1	0.93	0.16 NS
		SD	± 0.22	± 0.23	
After 2 weeks	SRs AB	Mean	0.99	0.94	0.33 NS
		SD	± 0.26	± 0.26	
	SRs AM	Mean	1.01	0.94	0.19 NS
		SD	± 0.24	± 0.24	
	SRs AA	Mean	1.03	0.94	0.07 NS
		SD	± 0.21	± 0.22	

T: value of independent sample T test. NS: p-value > 0.05 is considered non-significant. S: p-value < 0.05 is considered significant.

Comparing the lateral wall strain rate before and after the intervention revealed no statistically significant difference (Table 4).

Table (4): Comparison of all studied groups as regards lateral wall strain rate (before, and 2 weeks after revascularization)

Lateral Wall			Collaterals Group 1 (n = 40)	Collaterals Group 2 (n = 40)	P-value
Before	SRs LB	Mean	1.03	1	0.4 NS
		SD	± 0.19	± 0.19	
	SRs LM	Mean	1.05	0.98	0.12 NS
		SD	± 0.19	± 0.17	
	SRs LA	Mean	1.06	1.02	0.25 NS
		SD	± 0.15	± 0.12	
After 2 weeks	SRs LB	Mean	1.07	1	0.06 NS
		SD	± 0.17	± 0.19	
	SRs LM	Mean	1.06	1	0.1 NS
		SD	± 0.18	± 0.14	
	SRs LA	Mean	1.07	1.02	0.15 NS
		SD	± 0.16	± 0.12	

T: value of independent sample T test. NS: p-value > 0.05 is considered non-significant, S: p-value < 0.05 is considered significant.

On the other hand, the septal wall strain rate improved significantly in the collateral group as observed in the apical and mid views starting from the 2-weeks follow-up when compared to the non-collateral group (Table 5).

Table (5): Comparison of all studied groups as regards septal wall strain rate (before, and 2 weeks after revascularization)

Septal Wall			Collaterals Group 1 (n = 40)	Collaterals Group 2 (n = 40)	P-value
Before	SRs SB	Mean	1.07	1.09	0.54 NS
		SD	± 0.14	± 0.12	
	SRs SM	Mean	1.07	1.04	0.21 NS
		SD	± 0.09	± 0.1	
	SRs SA	Mean	1.06	1.03	0.07 NS
		SD	± 0.06	± 0.08	
After 2 weeks	SRs SB	Mean	1.1	1.09	0.72 NS
		SD	± 0.13	± 0.12	
	SRs SM	Mean	1.1	1.04	0.01 S
		SD	± 0.1	± 0.1	
	SRs SA	Mean	1.08	1.03	0.01 S
		SD	± 0.07	± 0.08	

T: value of independent sample T test. NS: p-value > 0.05 is considered non-significant.
S: p-value < 0.05 is considered significant.

The same observation was found in terms of the inferior wall strain rate where the strain rate improved significantly after 2 weeks post. Moreover, revascularization was considerably greater in the collateral group compared to the non-collateral group (Table 6).

Table (6): Comparison of all studied groups as regards inferior wall strain rate (before, 2 weeks after and 3 months after revascularization)

Inferior Wall			Collaterals Group 1 (n = 40)	Collaterals Group 2 (n = 40)	P-value
Before	SRs IB	Mean	0.92	1.06	0.002 S
		SD	0.22	0.14	
	SRs IM	Mean	0.92	1.04	0.003 S
		SD	0.21	0.12	
	SRs IA	Mean	0.97	1.01	0.21 NS
		SD	0.18	0.12	
After 2 weeks	SRs IB	Mean	0.95	1.05	0.01 S
		SD	0.21	0.14	
	SRs IM	Mean	0.96	1.03	0.04 S
		SD	0.18	0.12	
	SRs IA	Mean	0.99	1.01	0.58 NS
		SD	0.16	0.12	

T: value of independent sample T test. NS: p-value > 0.05 is considered non-significant.
S: p-value < 0.05 is considered significant.

DISCUSSION

Evidence has been mounting over the past thirty years, showing that the presence of pre-existing, well-developed coronary collateral circulation (CCC) at the time of acute myocardial infarction is critical for survival, preservation of left ventricular function, infarct size reduction, and prevention of left ventricular aneurysm formation. However, the question of whether the amount of collaterals directly affects survivability and functional recovery is still up for debate [19]**.** Furthermore, to the best of our knowledge, there are no studies that investigated the effects of revascularization after chronic coronary occlusion by investigating the change in the three views of the TDI separately.

The clinical features of our patients were consistent with **Erdogan *et al.*** [20], **Wang *et al.*** [21] and **Keulards *et al.*** [22]**.** This is explained by the fact that advancing age, dyslipidemia, obesity, DM, and HTN increase the incidence of IHD in concomitant with smoking. Additionally, the distribution of the culprit vessels among our patients is consistent with Loscalzo [13] who reported in their study that 68% of the patients had affection of the LAD. They demonstrated that among the coronary arteries, the LAD artery was the most frequently occluded (42.4%), followed by the right coronary artery (26.8%) and the left circumflex artery (19.1%). On the other hand, **Keulards *et al.*** [22] found that 65.4% of their patients had affection of the RCA, and this may be due to selection of patients and the difference of epidemiology among the study groups.

There is a different research point in our study than previous studies represented in the lack of previous studies investigating the wall strain in each segment alone and each view in details as our study investigated. As well as the lack of studies investigating the wall motion score index and the wall motion of each segment, then comparing the findings in terms of the presence versus absence of collaterals.

Our study found a discrepancy in the inferior wall strain rate at baseline, and this could be attributed to the difference in the culprit vessel between both groups, where in the collaterals group the main culprit vessel that was majorly affected was the RCA, opposite to the non-collaterals group, which showed a distribution of the occlusion across all the coronary vessels. Furthermore, it is known that the main coronary supply of the inferior wall is mainly through the RCA. **Hasanović** [23] found in the investigation done to assess how the collaterals that were identified angiographically affected the regional myocardial perfusion in patients with a chronic complete occlusion as determined by thallium scintigraphy. According to that study, the left anterior descending artery was linked to flaws in the anterior wall and septal region, the left circumflex coronary artery was linked to defects in the lateral wall, and the right coronary artery was linked to defects in the inferior wall. This explains, in turn, why the non-collaterals group's inferior wall strain rate in our study was higher at baseline.

The cardiac wall motion did not vary significantly between both groups and did not vary significantly when compared across the follow-up periods regarding all cardiac walls except the inferior wall, where the inferior wall motion of the non-collateral group was significantly better than the collateral group. This difference is also explained based on the previous elaborated explanation of **Hasanović** [23], where the wall motion was affected by the occlusion of the RCA in the collaterals group. Furthermore, there is a slight positive impact of CTO PCI on wall motion, according to the results of the REVASC study carried out by **Mashayekhi *et al.*** [24]. Also, they proposed that in individuals with more advanced coronary heart disease, the overall benefit of enhanced myocardial flow resulting from PCI of other lesions can obscure the favorable effect.

However, the difference in our findings regarding the significant difference in the strain rate versus the wall motion agrees with **Brady *et al.*** [25] study that compared the strain rate analysis to the wall motion scoring after revascularization and stated that the strain rate values are more sensitive and vary early after revascularization compared to the values of wall motion, which are more subjective and are less accurate compared to TDI strain rate assessment.

Nevertheless, some limitations existed in our study, where larger sample size can yield more clinically significant outcomes. Also, a longer follow-up period should be taken in consideration to assess any difference in the prognosis of patients post-intervention.

CONCLUSION

In CTO interventions, the presence of collateral circulation predicts immediate improvement in left ventricular systolic function as assessed by TDI using strain rate technique despite the lack of significant effect on conventional left ventricular systolic parameters as ejection fraction and wall motion score index measurements.

Conflict of interest: None.

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