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Comparison of outcome of percutaneous coronary intervention in chronic total occlusion in patients with and without previous coronary artery bypass graft surgery

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Abstract

Background: Coronary artery disease (CAD) is defined by the progressive accumulation of atheromatous lesions within the intima of the coronary arteries. These lesions can induce luminal stenosis, resulting in myocardial ischemia secondary to reduced coronary blood flow. At the other hand, acute myocardial infarction (AMI) can occur when the thrombogenic subendothelial matrix is exposed due to plaque rupture or erosion. This triggers platelet aggregation and thrombus formation. Coronary chronic total occlusions (CTOs) were established by angiographical criteria, which included a Thrombolysis in Myocardial Infarction (TIMI) flow grade of 0, indicating full occlusion, and the presence of coronary artery lesions for a minimum of three months.

Coronary angiography will reveal three or more CTOs in approximately half of all patients who have had a previous CABG procedure. Interventions on the native coronary vasculature are often technically challenging, and patients in this demographic are at increased risk of procedural complications during percutaneous coronary intervention (PCI). The primary objective of this study was to compare the initial procedural success of PCI in treating CTOs of native coronary arteries in patients with and without a history of CABG. A secondary objective was to assess clinical outcomes in both groups at 6-month follow-up.

Methods: This prospective study was carried out on 100 patients who undeerwent PCI for CTO lesions at National Heart Institute & Benha university hospital. There were two equal groups of patients: those who had undergone previous CABG (nCABG group) and those who had not (pCABG group).

Results: The pCABG group had a somewhat higher rate of six-month mortality at 8% vs 0% (P=0.04) and a significantly higher incidence of six-month myocardial infarction (MI) at 12% vs 2% (P=0.049) against the nCABG group. However there was similar incidience of six-month stroke 2% v. 2% (P= 1.0) between the two groups.

Conclusions: The groups exhibited comparable rates of in-hospital MACE. Nevertheless, the procedural and technical success rates of patients who had undergone a previous CABG were significantly reduced. Furthermore, and perhaps most importantly, they experienced significantly higher rates of MI and mortality at six-month follow-up. Although the immediate procedural issues are similar, the data suggests that a history of CABG is associated with a higher risk of unfavorable clinical outcomes in the months following CTO PCI. This investigation emphasizes the significance of ongoing research and the implementation of enhanced procedures to improve the outcomes of this high-risk population.

Keywords: Chronic total occlusion, percutaneous coronary intervention, previous coronary artery bypass graft surgery

Introduction

Coronary artery disease (CAD) is characterized by the gradual formation of atherosclerotic lesions within the coronary artery walls. These plaques can lead to two major consequences: gradual narrowing of the arterial lumen (Stenosis), resulting in myocardial ischemia due to reduced blood flow; or, more acutely, plaque rupture with subsequent thrombus formation causing abrupt occlusion of the artery and acute myocardial infarction (AMI) [1]. There are several common risk factors for CAD, some of which can be changed and others of which cannot. These factors include treatable conditions like hypertension (HTN), dyslipidemia, and diabetes mellitus (DM), as well as lifestyle choices such as cigarette smoking, diet, and physical activity levels leading to obesity, alongside non-modifiable factors like age, sex, and genetic predisposition (Source) [2].

For cases where the coronary arteries are extremely constricted or blocked, two intrusive procedures known as PCI and coronary artery bypass grafting (CABG) are employed to enhance blood flow to the myocardium that has been compromised due to an insufficient blood supply. Medical management is prioritized, with angina control and atherosclerotic progression mitigation being the primary strategies [3].

Percutaneous coronary intervention (PCI) provides a minimally invasive, non-surgical means of revascularizing the myocardium. This approach involves advancing a catheter-based system to the site of coronary artery stenosis or occlusion, performing balloon angioplasty to dilate the vessel, and subsequently deploying a drug-eluting stent (DES) to maintain luminal patency and prevent restenosis [4].

In spite of the significant progress made in diagnostic and interventional cardiology since its inception over 50 years ago, CABG continues to be the gold standard for revascularization in patients with obstructive CAD, particularly those with multivessel disease or diabetes mellitus [5].

Because of the risk of bypass graft failure and the advancement of native coronary artery disease after CABG, subsequent revascularization procedures are often necessary. Right now, PCI is the gold standard for repeat revascularization after CABG. This is because PCI is less invasive and may treat both graft and native artery disease. This trend underscores the evolving management of CAD after surgical revascularization [6]. Patients who undergo coronary angiography and have undergone CABG have a high prevalence of coronary chronic total occlusions (CTOs)–approximately 50%.However, performing PCI in this group poses challenges, including an increased risk of complications and the frequent need for complex interventions on the native coronary vessels [7].

Coronary lesions that demonstrate a TIMI flow grade of 0, which indicates complete occlusion, and have been present for a minimum of three months were classified as CTOs. The occlusion's duration was derived from the time of initial anginal symptoms, a history of MI in the occluded vessel's distribution, or by comparing the current angiogram with previous imaging studies [8].

Finding out how well percutaneous coronary intervention (PCI) worked initially for CTOs located in native coronary arteries in patients with and without prior coronary artery bypass grafting (CABG) was the primary goal of this study. Comparing the two groups' clinical results after six months was one of the ancillary goals.

Patients and Methods

This prospective study was conducted on 100 patients who underwent PCI for CTO lesions at National Heart Institute & Benha university hospital. The study protocol was approved by the Ethics Committee of the Faculty of Medicine, Benha University (approval code: MD 9-4-2023), and all patients provided informed written consent.

Inclusion criteria We included patients with CTO lesions—defined angiographically as coronary lesions with a TIMI flow grade of 0, indicating complete absence of antegrade flow—and an occlusion duration of at least 3 months [8] and viable myocardium assessed by non-invasive tests.

Exclusion criteria were patients who have contraindication to antiplatelet agents, incomplete data or insufficient imaging data, severe renal or liver disease, refusal or inability to consent for participation in the study, non-viable CTO territory in non-invasive assessment and significant valvular heart disease or other indications for cardiac surgery.

Grouping

Participants were assigned to one of two groups, with equal numbers in each: nCABG group (n=50): patients without history of prior CABG and pCABG group (n=50): patients with history of prior CABG.

Data were obtained from all patients, including demographics (Age and sex) and medical history. Factors that are known to increase the likelihood of cardiovascular disease were highlighted. These include hypertension, diabetes, smoking, and heredity. Notable cardiovascular events, such as the patient's stroke, PCI, and MI, were all documented. Each patient underwent a thorough clinical examination, with specific attention to pulse rate, blood pressure, and auscultation of the lungs for evidence of pulmonary congestion.

Baseline electrocardiography

Twelve lead electrocardiogram (ECG) was done for each patient to detect rhythm, ischmeic changes and chamber enlargement.

Baseline Echocardiography

All patients underwent echocardiographic evaluation to assess left ventricular systolic function and to identify any regional wall motion abnormalities and to exclude any significant valvular disease or any indication for surgery.

Evaluation of myocardial ischemia and viability in the CTO territory

In myocardial segments supplied by the chronic total occlusion (CTO) with normal wall motion, inducible ischemia was assessed to quantify the degree of reversible ischemia. The presence of viable myocardium was determined by conducting viability testing in segments that exhibited akinesia or dyskinesia. The extent of inducible ischemia and myocardial viability were used to inform treatment decisions, guide the revascularization procedure, and predict the potential for left ventricular (LV) remodeling and/or reduced residual ischemia after successful CTO revascularization [9].

Methods were used as a criteria to assess viability and inducible ischemia in CTO territory:

Single-Photon Emission CT (SPECT): Viability: A cutoff of >50% tracer activity [10].

Inducible ischemia: Significant inducible ischemia was defined as a stress-induced defect on SPECT myocardial perfusion imaging with technetium-99m (Tc-99m) encompassing greater than 10% of the global myocardial area [10].

Dobutamine stress ECHO

Viability: The definition of myocardial viability was established as an increase in regional wall motion in more than three of the 17 segments of the left ventricle using low-dose dobutamine or low-load exercise stress echocardiography [11]. During stress echocardiography, inducible ischemia was defined as the presence of novel or worsening regional wall motion abnormalities in more than three of the 17 segments [9].

Cardiac magnetic resonance imaging

Viability: delayed gadolinium enhancement <25-50% transmurally in >4 out of 17 segments [12].

Assessment of initial success and clinical outcome of PCI for CTO

PCI details included: The following items were included in the data that was being collected: 1) The chosen vessel for chronic total occlusion percutaneous coronary intervention (PCI)—Left Anterior Descending (LAD), Right Coronary Artery (RCA), or Left Circumflex (LCX)—(2) The technique to be employed during PCI—antegrade wire escalation or antegrade dissection/re-entry—(3) The overall fluoroscopy time in minutes—(4) The overall procedure time in minutes—(5) The total volume of contrast in milliliters.

Procedural and technical success

Procedural success was assessed by the absence of major in-hospital adverse cardiac events (MACE) and the attainment of technical success [13]. In order to determine technical success, angiographic criteria were used. These criteria included recanalization of the CTO, TIMI grade 3 flow (indicating normal antegrade flow), and less than 50% residual stenosis within the treated segment [13].

In-hospital major adverse cardiac events (MACE): If any of the following occurred before the patient was discharged from the hospital, it was considered an adverse event: (1) death from any cause; (2) MI with an acute Q-wave; (3) revascularization of the treated vessel immediately because symptoms are returning; and (4) cardiac tamponade requiring pericardiocentesis or surgical repair [14].

Six-month clinical outcomes, assessed at 6 months following hospital discharge, included the following adverse events: All-cause mortality, MI, stroke, and target vessel revascularization [15].

Statistical analysis

Beginning with Microsoft Excel, data was entered, coded, and analyzed from patients' medical histories, physical exams, lab tests, and outcome measures. By employing the Statistical Package for the Social Sciences, version 20.0, the dataset was integrated to facilitate further statistical analysis. When representing continuous variables, we use the mean plus or minus the standard deviation (SD), whereas when representing categorical variables, we use percentages and integers. We employed the chi-square test ($\chi 2$) to evaluate the dissimilarities among the category variables. When comparing continuous variables between groups, we utilized the t-test for differentiation. We judged a p-value to be statistically significant when it was less than 0.05 and extremely significant when it was less than 0.001.

Results

Compared to the nCABG group, the pCABG group included patients who were significantly older (p = 0.031). Statistical analysis did not reveal any differences in smoking status, family history of coronary artery disease, or sex between the two groups; men constituted the majority in both. Hypertension (p = 0.03), diabetes mellitus (p = 0.04), and prior stroke (p = 0.04) were more common in the pCABG group than in the nCABG group, and the pCABG group had a comorbidity burden that was significantly higher overall. The prevalence of left ventricular dysfunction, prior PCI, and prior MI did not present any significant intergroup differences. Table 1)

Table 1: Demographic data distribution between studied groups, risk factors and previous medical history between studied groups:

		nCABG (n=50)	pCABG (n=50)	t/ X^2	P
Age		57.16±7.68	64.80±7.02	2.314	**0.031***
Sex	Female	9 (18%)	7 (14%)	0.29	0.58
	Male	41 (82%)	43 (86%)		
Risk factors	Smoking	23 (46%)	24 (48%)	0.04	0.48
	Family history	8 (16%)	7 (14%)	0.078	0.77
	HTN	13 (26%)	23 (46%)	4.31	0.03*
	DM	22 (44%)	32 (64%)	4.02	0.044*
	LV dysfunction EF < 40	10 (20%)	9 (18%)	0.065	0.799
	Prior PCI	19 (38%)	24 (48%)	1.02	0.313
	History of MI	16 (32%)	15 (30%)	0.04	0.082
	History of stroke	4 (8%)	11 (22%)	3.87	0.049*

Data are shown as mean ± SD or frequency (%). DM: Diabetes Mellitus, HTN: hypertension, LV: left ventricle, CABG: coronary artery bypass grafting, PCI: Percutaneous coronary intervention, MI: Myocardial infarction, *: significant as P value ≤ 0.05

pCABG group had significantly longer total fluoroscopy time 64.48±21.69 min vs. 52.04±18.92 min (P=0.014) and total procedure time 152.82±30.66 min vs. 105.50±18.02 min (*p*<0.005) compared to nCABG group, and pCABG group had also significantly higher total contrast volume 316.78±60.38 ml vs 270.88±46.79 ml (*p*<0.005) compared to nCABG group. In both the nCABG and pCABG groups, the right coronary artery was the most common CTO target vessel, although the left anterior descending artery was less common in the prior CABG group (26% versus 18%). However, when comparing the two groups' distributions of CTO target vessels, no statistically significant difference was found. In addition, There was no significant difference or association between both groups regarding PCI approach or prior failed attempt for CTO PCI; Antegrade wire escalation attempt in 94% of pCABG vs 96% in Ncabg. Antegrade dissection reentry attempt in 32% of pCABG group vs 32% in nCABG. Prior failed attempt for CTO PCI in 14% of pCABG vs 18% in nCABG. pCABG group had significantly lower procedural success rate 60% vs. 80% (P=0.02) compared to nCABG group and also had significantly lower technical success rate 52% vs 78% (P=0.03) compared to nCABG group. Table 2

Table 2: Fluroroscopy, total procedure time, total contrast volume distribution, procedure characters distribution and procedural outcome distribution between studied groups

		nCABG	pCABG	t	P
Total fluoroscopy (time/min)		52.04±18.92	64.48±21.69	2.499	0.014*
Total procedure (time/min)		105.50±18.02	152.82±30.66	9.447	<0.005*
Total contrast (volume/ml)		270.88±46.79	316.78±60.38	4.249	<0.005*
Procedure characters distribution					
CTO target vessel	LAD	13 (26%)	9 (18%)	1.74	0.41
	LCX	10 (20%)	15 (30%)		
	RCA	27 (54%)	26 (52%)		
Prior failed attempt for CTO PCI		9 (18%)	7 (14%)	0.29	0.58
Antegrade wire escalation attempt		48 (96%)	47 (94%)	0.21	0.64
Antegrade dissection reentry attempt		16 (32%)	16 (32%	0.0	1.0
Procedural outcome distribution					
Procedural success		40 (80%)	30 (60%)	4.72	0.02*
Technical success		39 (78%)	26 (52%)	4.52	0.03*

Data are shown as mean ± SD or frequency (%). CTO: chronic total occlusion, LAD: Left Anterior Descending, LCX: Left Circumflex, RCA: Right Coronary Artery, CABG: coronary artery bypass grafting, PCI: Percutaneous coronary intervention. *: significant as P value ≤ 0.05.

There was no significant difference in overall in-hospital MACE rates between the two groups; As we only had one case of Q wave MI in nCABG group vs two cases in pCABG group and one case of recurrent angina in nCABG group vs three cases in pCABG group. There was also one case of mortality in pCABG group,and regarding Tamponade requiring pericardiocentesis, there was no significant difference as we had two cases in nCABG and one case in pCABG group. Table 3

Table 3: In-hospital MACE distribution between studied groups

	nCABG (n=50)	pCABG (n=50)	X^2	P
Q wave MI	1 (2%)	2 (4%)	1.04	0.31
Recurrent angina	1 (2%)	3 (6%)	0.29	0.89
Mortality	0 (0%)	1 (2%)	1.01	0.31
Tamponade requiring pericardiocentesis	2 (4%)	1 (2%)	0.34	0.55
Overall MACE	3 (6%)	4 (8%)	0.15	0.69

Data are presented as mean ± SD or frequency (%). MI: Myocardial infarction, CABG: coronary artery bypass grafting, MACE: Major adverse cardiac events *: significant as P value ≤ 0.05.

pCABG group was significantly associated with higher rates of six-month MI 12% vs. 2% (P= 0.049) and higher rates of six-month mortality 8% vs 0% (P=0.04) compared to the nCABG group. However there was similar incidence of six-month stroke 2% v. 2% (P= 1.0) between the two groups. Table 4

Table 4: Six-month outcome distribution between studied

	nCABG (n=50)	pCABG (n=50)	X^2	P
MI	1 (2%)	6 (12%)	4.83	0.049*
Stroke	1 (2%)	1 (2%)	0.0	1.0
Mortality	0 (0%)	4 (8%)	4.16	0.041*

Data are presented as mean ± SD or frequency (%).MI: Myocardial infarction, *: significant as P value ≤ 0.05.

Discussion

CTO PCI represents a significant advancement in the treatment of complex CAD. However, prior CABG surgery introduces unique challenges to CTO PCI. As the presence of prior CABG surgery introduces distinctive challenges to CTO PCI. The post-CABG coronary anatomy is frequently characterized by increased vessel tortuosity, calcification, and the presence of bypass grafts themselves, significantly augmenting procedural complexity [16]. In our Study, regarding patient characteristics and comorbidities, we found a significant difference in age between the two groups, with the pCABG group being significantly older compared to the nCABG group. We also found no significant difference or association regarding sex, family history, or smoking status.

These findings align with Christopoulos *et al.* [17] reported older age and higher prevalence of comorbidities in prior CABG patients undergoing CTO PCI.

In Contrast to our study, Shi *et al.* [18] individuals who had undergone CABG were more likely to be male than those who had no prior CABG. Possible causes for this include differences in the study's duration and the overall number of patients.

Also, when comparing the pCABG and nCABG groups, we discovered that the former had a significantly higher prevalence of hypertension, diabetes, and stroke history. Although there was no notable variation in terms of LV dysfunction.

In similar to our study Shoaib *et al.* [15] reported that pCABG patients have a higher burden of comorbidities, including HTN and DM.

However, Teramoto *et al.* [19] No statistically significant difference in the prevalence of diabetes was observed between the categories. This variation might be explained

by differences total number of patinets and difference between number of patients between each group.
In contrast to our study, Tajti P *et al*. [20] reported that post CABG patients had lower left ventricular ejection fraction.
Regarding procedural characteristics in our study, the pCABG group had significantly longer total fluoroscopy time and total procedure time, as well as significantly higher total contrast volume compared to the nCABG group. This suggests that CTO PCI procedures in patients with prior CABG tend to be more complex and technically challenging, potentially requiring longer procedural time and higher contrast use.
These findings align with Teramoto *et al*. [19], Shi *et al*. [18], and Christopoulos *et al*. [17] who also reported longer total fluoroscopy time and total procedure time, as well as significantly higher total contrast volume in prior CABG patients.
Additionally, it was found that CTOs in both groups mainly targeted the right coronary artery. Due to higher patency rates in the left internal mammary artery (17% versus 28%), the current group is more likely to use the left anterior descending artery as a target vessel than the prior CABG group.The two groups did not exhibit any significant difference in the distribution of CTO target vessels, as indicated by the statistical analysis.
In contrast to our study, Alexandrou *et al*. [21] found that the distribution of CTO target vessels varied significantly between the two sets of participants. A higher overall patient load might account for this.
In contrast to our study also, Teramoto *et al*. [19] and Michael *et al*. [14] found that the two groups' distributions of CTO target vessels were significantly different. Given the large sample sizes of both studies, this discrepancy could be attributable to differences in patient selection criteria or the total number of patients included in the analyses.
In regards to procedural Success and Complications in our study, the nCABG group had significantly higher rates of procedural and technical success compared to the pCABG group, aligning with the finding of lower success rates in prior CABG patients due to lesion complexity.
These findings align with He *et al*. [22] in a meta-analysis reported lower technical and procedural success rates in prior CABG patients.
On the other side, Dautov *et al*. [23] stated that there were no discernible variations in the percentages of technical success between the two categories. The widespread use of retrograde approaches in patients undergoing coronary artery bypass grafting (CABG) and the possible impact of bypass venous graft patency on procedural success may be to blame for this disparity.
There was no statistically significant difference between the two groups with respect to the total incidence of in-hospital MACE in our study.
Similarly, Hernandez-Suarez *et al*. [24] reported similar in-hospital complication rates between the two groups.
These findings are supported also by Tajti *et al*. [20], Michael *et al*. [14], Shoaib *et al*. [sa15] and Teramoto *et al*. [19] who reported similar in-hospital MACE rates between the two groups.
In contrast, Megaly *et al*. [25] who conducted a meta-analysis of studies and reported higher in-hospital MACE rates in prior CABG patients. This difference might be explained by variations in the definition of MACE, follow-up durations, or the specific complications included in the composite endpoint.
In contrast to our study also, Alexandrou *et al*. [21] reported higher in-hospital mortality in previous CABG patients.
Our study showed that the pCABG group was significantly associated with higher rates of six-month MI and six-month mortality compared to the nCABG group. This finding is concerning and suggests that despite similar in-hospital MACE rates, patients with prior CABG may experience worse outcomes in the short-term following CTO PCI. This could be related to the higher complexity of their disease, the lower procedural success rates, or other factors that warrant further investigation.
In similar to our study, Toma *et al*. [26] reported increased risk of MI and mortality on follow up.
In similar to our study also, Alexandrou *et al*. [21] Prior CABG patients were significantly more likely to experience ACS, MACE and PCI at the 2-year follow-up.
In contrast to our study also, Hernandez-Suarez *et al*. [24] reported similar short-term clinical outcomes compared with patients without CABG. This difference could be explained by shorter duration of follow up and frequent use intravascular imaging (IVUS) during PCI.
The research had some restrictions. Findings may not be applied to other populations or clinical contexts due to the study's small sample size and single-center design. In patients who have or have not had prior CABG, the six-month follow-up period only reveals short-term results; however, it does not capture the long-term effects of CTO PCI. The number of centers and the operator's level of expertise determine how well CTO PCI works. Different operators with different experience could affect success rate and results. The study focused solely on CTO PCI in native coronary arteries and did not account for interventions on bypass grafts, the overall revascularization strategy and its impact on outcomes may not be fully captured.

Conclusions
The groups did not differ with regard to in-hospital MACE. The procedural and technical success rates were significantly lower, though, for patients who had undergone CABG in the past. Furthermore, and perhaps most importantly, they experienced significantly higher rates of MI and mortality at six-month follow-up. This suggests that there is a higher risk of adverse clinical events in the months following CTO PCI in patients who have undergone prior CABG, even though the immediate procedural complications may be similar. In order to improve outcomes for this group of patients who are at a higher risk, additional research and optimized strategies are needed. Hence, it is crucial to conduct a bigger, multi-center study with longer-term follow-up.

Conflict of Interest
Not available

Financial Support
Not available

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