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Prevalence and Management of Coronary Chronic Total Occlusions in a Tertiary Veterans Affairs Hospital

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Abstract

Objectives—We sought to determine the contemporary prevalence and management of coronary chronic total occlusions (CTO) in a veteran population.

Background—The prevalence and management of CTOs in various populations has received limited study.

Methods—We collected clinical and angiographic data in consecutive patients that underwent coronary angiography at our institution between January 2011 and December 2012. Coronary artery disease (CAD) was defined as ≥50% diameter stenosis in ≥1 coronary artery. CTO was defined as total coronary artery occlusion of ≥3 month duration.

Results—Among 1,699 patients who underwent angiography during the study period, 20% did not have CAD, 20% had CAD and prior coronary artery bypass graft surgery (CABG) and 60% had CAD but no prior CABG. The prevalence of CTO among CAD patients with and without

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prior CABG was 89% and 31%, respectively. Compared to patients without CTO, CTO patients had more comorbidities, more extensive CAD and were more frequently referred for CABG. Percutaneous coronary intervention (PCI) to any vessel was performed with similar frequency in those with and without CTO (50% vs. 53%). CTO PCI was performed in 30% of patients without and 15% of patients with prior CABG with high technical (82% and 75%, respectively) and procedural success rates (80% and 73%, respectively).

Conclusions—In a contemporary veteran population, coronary CTOs are highly prevalent and are associated with more extensive comorbidities and higher likelihood for CABG referral. PCI was equally likely to be performed in patients with and without CTO.

Keywords

coronary occlusion; percutaneous coronary intervention; coronary artery disease

Introduction

The contemporary prevalence and management of coronary chronic total occlusions (CTO) has received limited study and vary significantly in different patient populations (1–4). Patients with CTOs are more likely to be referred for coronary artery bypass graft surgery (CABG) and less likely to undergo percutaneous coronary intervention (PCI) (1,5,6), however, the choice of coronary revascularization strategy is highly dependent on local practice patterns and expertise. Recent developments in CTO PCI techniques have enabled high procedural success rates, while maintaining low risk for procedural complications (7–11). These developments are especially important for the veteran population, which is known to have high coronary artery disease (CAD) burden (12). The goal of the present study was to evaluate the prevalence and contemporary management of coronary CTOs at a Veterans Affairs tertiary referral center with expertise in CTO PCI.

Materials and Methods

Patients

We retrospectively reviewed the coronary angiograms and medical records of all consecutive patients who underwent diagnostic coronary angiography at our institution between January 1, 2011 and December 31, 2012. Clinical information such as demographics, cardiac history, comorbidities, procedural data and outcomes, and cardiac catheterization results were collected and analyzed to evaluate for the prevalence and clinical management of patients with coronary CTOs. Of the patients who had multiple cardiac catheterizations during the study period, only the first procedure was included in the present analysis. Patients who underwent angiography as part of a research protocol were excluded if the index cardiac catheterization occurred prior to January 1, 2011. The study was approved by the institutional review board of our institution.

Significant CAD was defined as ≥1 lesion of ≥50% luminal diameter stenosis. CTO was defined as a total coronary artery occlusion of ≥3 month duration with Thrombolysis in Myocardial Infarction (TIMI) 0 flow. Estimation of occlusion duration was based on first onset of anginal symptoms, prior history of myocardial infarction in the target vessel

territory, or comparison with a prior angiogram. The decision to undergo CTO revascularization was at the discretion of the interventional cardiologist and the patient. CTO PCI technical success was defined as successful CTO revascularization with achievement of <30% residual diameter stenosis within the treated segment and restoration of TIMI grade 3 antegrade flow. CTO PCI procedural success was defined as technical success without in-hospital major adverse cardiac events (MACE). In-hospital MACE included any of the following adverse events prior to hospital discharge: death from any cause, Q-wave myocardial infarction, recurrent angina requiring urgent repeat target vessel revascularization with PCI or coronary bypass surgery, tamponade requiring pericardiocentesis or surgery, or stroke.

Statistical Analysis

Continuous parameters were presented as mean ± standard deviation and compared using the student's *t* test or Wilcoxon rank-sum test, as appropriate. Nominal parameters were presented as percentages and compared using Pearson's chi-square test. A p value <0.05 was considered statistically significant. Statistical analyses were performed using JMP 10.0.2 software (SAS Institute, Cary, North Carolina).

Results

Patients

Between January 1, 2011 and December 31, 2012, 1,699 consecutive patients underwent diagnostic coronary angiography at our institution; 80% of them had CAD (20% with and 60% without prior CABG, Figure 1). At least one coronary CTO (total of 1,003 CTO lesions) was present in 624 patients. The prevalence of CTO was 37% among all patients and 46% among patients with CAD. The prevalence of coronary CTOs among CAD patients without prior CABG was 31% while the prevalence of coronary CTOs among CAD patients with prior CABG was 89% (Figure 1).

CTO in patients with CAD and without prior CABG

At least one CTO was present in 319 of 1,015 patients (31%), who had a total of 402 CTOs (24% of patients had >1 CTO). Compared to patients without a CTO, patients with a CTO were more likely to have both cardiac and non-cardiac comorbidities, presented more frequently with stable angina and had more extensive CAD (Table I). In the 244 patients with 1 CTO, most CTOs were located in the right coronary artery (RCA) (59%), followed by the circumflex (21%) and left anterior descending artery (LAD) (20%). Most RCA and LAD CTOs were located in the proximal or mid-vessel segment, whereas circumflex CTOs were more evenly distributed along the vessel (Figure 2). Thirty-two of the 402 CTOs (8%) were due to in-stent restenosis (ISR) in 31 patients.

Coronary revascularization was performed in 81% of the CTO patients versus 69% of the non-CTO patients (p<0.001, Table I and Figure 3). CTO patients were more likely to undergo CABG, but equally likely to undergo PCI to any vessel compared to patients without a CTO. CTO PCI was attempted in 30% of the CTO patients with 84% per patient procedural success rate (79 of 94 patients, Figure 3). Patients with prior myocardial

infarction, peripheral arterial disease, and chronic kidney disease were more likely to receive medical therapy without coronary revascularization (Table II). Patients with left main disease, 3-vessel disease, or a circumflex CTO were more likely to undergo CABG than PCI, whereas patients with 1 or 2-vessel disease CAD and LAD CTOs were more likely to undergo PCI.

Forty-six patients presented with acute ST-segment elevation myocardial infarction, eight of whom (17%) had a non-culprit CTO. All eight patients underwent primary PCI of the culprit vessel and one patient subsequently underwent CABG. CTO PCI was later attempted in two patients (29%) with a technical success rate of 50%.

CTO in patients with CAD and prior CABG

During the study period, 305 of 344 patients (89%) with prior CABG were found to have 601 CTO lesions (66% of whom had >1 CTO). A total of 21 CTO lesions (3.5%) in 19 patients were due to in-stent restenosis. PCI was performed in 182 patients (60%) of whom 46 patients (15% of total) underwent CTO PCI (Figure 4). Two patients (0.6%) underwent redo CABG, whereas the remaining 40% received medical therapy only.

CTO PCI outcomes

During the study period, 152 CTO PCI attempts were made in 140 patients with an 80% technical success rate (78% procedural success). Technical success was 82% among non-prior CABG patients and 75% in prior CABG patients (80% and 73% procedural success rates, respectively). The CTO PCI attempt rate was significantly higher among patients without prior CABG (58% vs. 25%, $p<0.001$). Major complications in CTO PCI patients occurred in four patients (2.9%): two patients had post-procedural myocardial infarction (one of whom died), one patient had concomitant PCI of a non-CTO lesion which required urgent revascularization due to stent thrombosis, and one patient had an acute stroke.

Discussion

The main findings of this study are that: (a) the prevalence of CTO in non-CABG patients with CAD was 31%; (b) LAD and RCA CTOs were located mostly in the proximal and mid-vessel segments, whereas circumflex CTOs were more evenly distributed throughout the vessel; (c) patients with CTO were more likely to be referred for CABG but were equally likely to receive PCI to any vessel as those without CTO; and (d) CTO recanalization was attempted in nearly one third of patients with CTO lesions with high success and low complication rates.

The reported prevalence of CTOs among patients undergoing cardiac catheterization varies widely. In the largest study reported to date (prospective 3-center Canadian registry), the prevalence of CTO was 18.4% among patients with CAD (defined as ≥50% stenosis in ≥1 vessel) without prior CABG and 54% among patients with prior CABG (1). Using the same definition of CAD, Kahn et al. identified a CTO in 35% of 287 patients with CAD at a single institution within one year (2). In a German multicenter prospective registry spanning 64 hospitals and private practices, Werner et al. reported a CTO prevalence of 33% in 2,002 patients presenting with stable angina and first angiographic diagnosis of CAD (4). In a

previous study investigating the frequency of CTO in a veteran population, Christofferson et al. reported a CTO prevalence of 52% in patients with CAD (defined as ≥70% stenosis in ≥1 vessel) and an overall prevalence of 24.5% in 8,004 non-CABG patients undergoing diagnostic angiography over a ten year period (3). The contemporary prevalence of CTOs in our veteran population was 31% among non-CABG patients presenting with CAD, which is higher than the prevalence reported by Fefer et al., but similar to the prevalence reported by Kahn et al. and by Werner et al. Moreover, nearly all (89%) patients with prior CABG had a CTO, which is higher than the prevalence reported by Fefer et al. for prior CABG patients (54%). One potential explanation may be greater CTO burden in this group prior to CABG; however, an alternative explanation may be the rapid progression of proximal disease with subsequent occlusion of the bypassed vessels (13,14).

Approximately half of the CTO lesions in our study were located in the RCA territory with the majority in the proximal and mid-vessel segments of the coronary vasculature. This is similar to what has been reported in other populations, in which RCA CTOs account for 47% to 64% of all CTO lesions; moreover, more than half of these occlusions are located within the proximal or mid coronary artery segment (1–4).

Similar to prior studies (1,15), patients with CTOs in our cohort were more likely to undergo CABG compared to non-CTO patients (30% vs. 16%, $p<0.001$), which is consistent with the superior clinical outcomes of CABG compared to PCI among patients with advanced multivessel coronary artery disease (16). In contrast to prior studies, the rate of PCI to any vessel in patients with a CTO was comparable to that of patients without a CTO (50% vs. 53%, p=0.48). The CTO PCI attempt rate in our population (15% and 30% for patients with and without prior CABG, respectively) is significantly higher than the attempt rate reported in prior studies (10%–13.6%) (1,5). This is likely related to (a) the high prevalence of CTO in our population; (b) high cardiac and non-cardiac disease burden of the study patients; and (c) local expertise in treating CTOs. Our study did not perform longitudinal follow-up to detect long-term outcomes post PCI, however, successful CTO PCI has been associated with significant improvements in angina and left ventricular ejection fraction as well as a reduced need for subsequent CABG (17,18). A decision to proceed with CTO PCI should always take into account the risk for complications (7). CTO PCI success rates were lower among prior CABG patients, consistent with a recent report from a multicenter CTO PCI registry (19).

Limitations

Our study has important limitations. Nearly all patients were men (as expected in a veteran population) and the study findings may not be extrapolated to women. Clinical outcomes and improvement in symptoms related to management chosen are not reported, therefore no conclusion can be made on the effect of increased percutaneous revascularization rates of CTOs in this population. Moreover, coronary revascularization (with either PCI or CABG, including CTO PCI) carries risks for complications that should be carefully weighed against the potential benefits. The external validity of our study findings may be limited by the wide variability in the CTO attempt and success rates among various institutions and various populations.

Conclusions

In conclusion, our study demonstrates that in a contemporary cohort of veterans referred for cardiac catheterization, nearly one in three non-CABG patients with significant CAD were found to have a CTO. Compared to patients without a CTO, CTO patients had more comorbidities, were more likely to undergo CABG, but were equally likely to undergo PCI to any vessel. CTO PCI was associated with high success and low complication rates.

Abbreviations

BMI	body mass index
CABG	coronary artery bypass graft
CAD	coronary artery disease
CHF	congestive heart failure
CKD	chronic kidney disease
CTO	chronic total occlusion
CVA	cerebrovascular accident
ISR	in-stent restenosis
LAD	left anterior descending artery
LCx	left circumflex artery
LVEF	left ventricular ejection fraction
MACE	major adverse cardiac event
MI	myocardial infarction
OM	obtuse marginal artery
PCI	percutaneous coronary intervention
RCA	right coronary artery
TIMI	Thrombolysis in Myocardial Infarction

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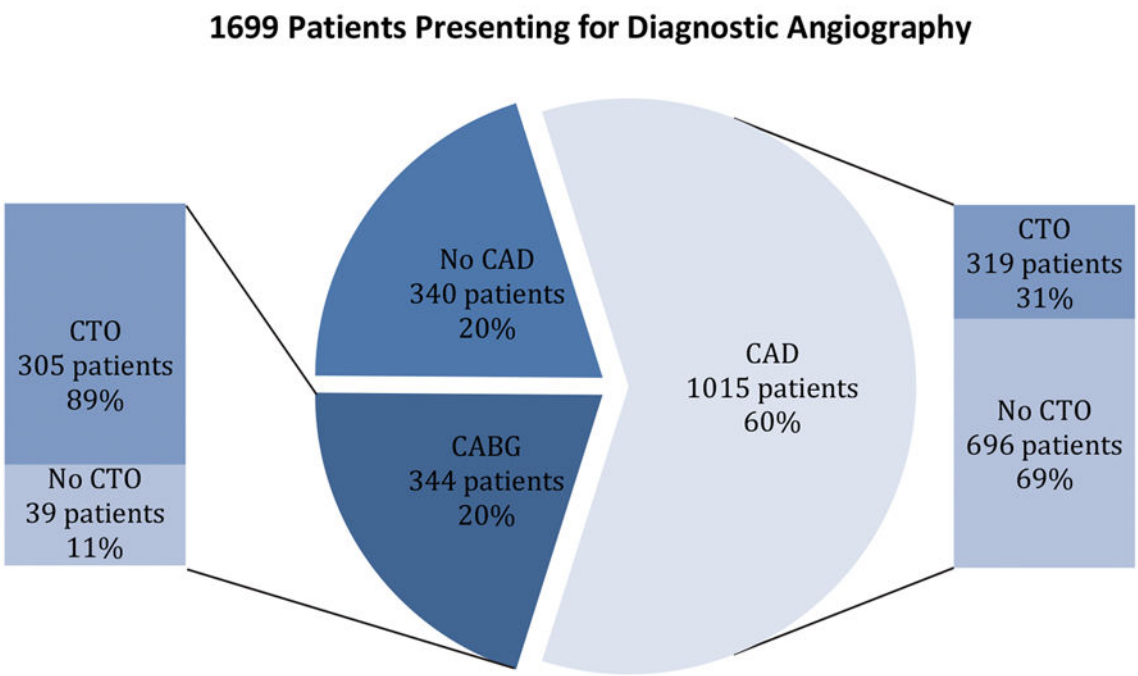

Figure 1.

Patients Presenting for Diagnostic Angiography

Prevalence of coronary artery disease and coronary chronic total occlusions in the study population.

CABG=coronary artery bypass graft; CAD=coronary artery disease; CTO=chronic total occlusion

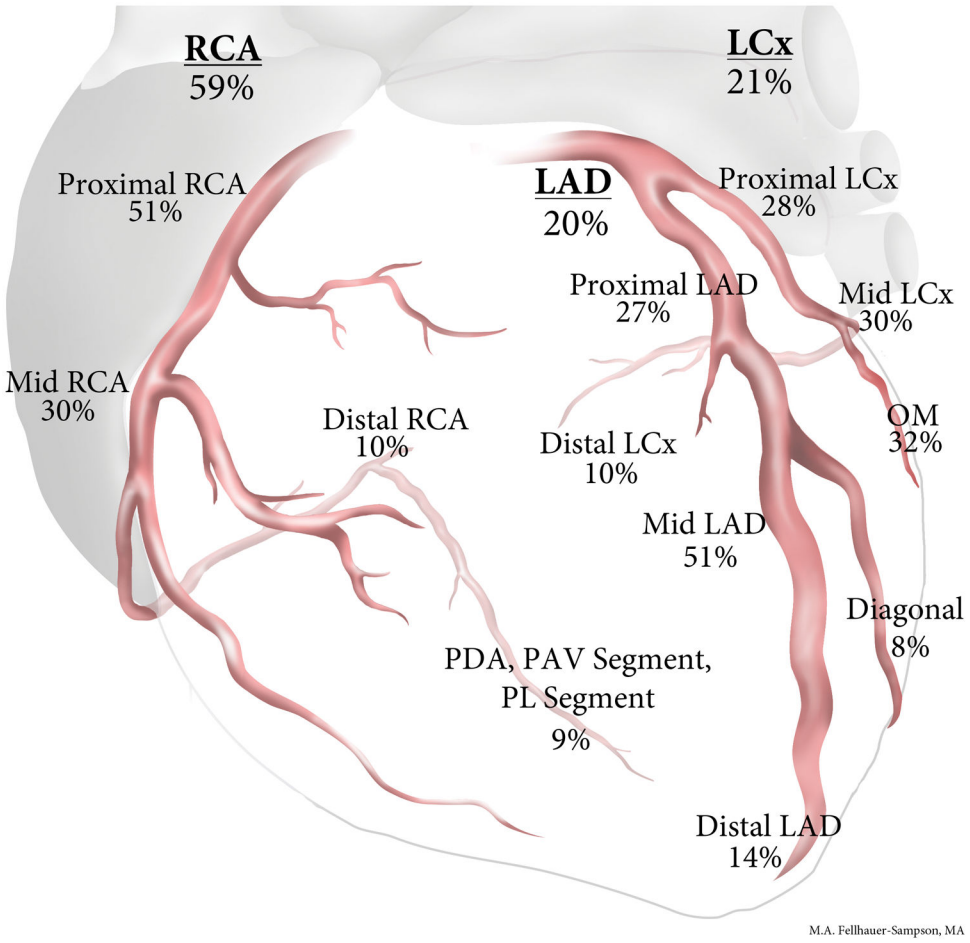

Figure 2.

Distribution of CTOs in patients with one CTO

Distribution of coronary chronic total occlusions among the study patients.

CTO=chronic total occlusion; LAD=left anterior descending artery; LCx=left circumflex artery; OM=obtuse marginal artery; PAV=posterior atrio-ventricular vessel; PDA=posterior descending artery; PL=posterolateral; RCA=right coronary artery

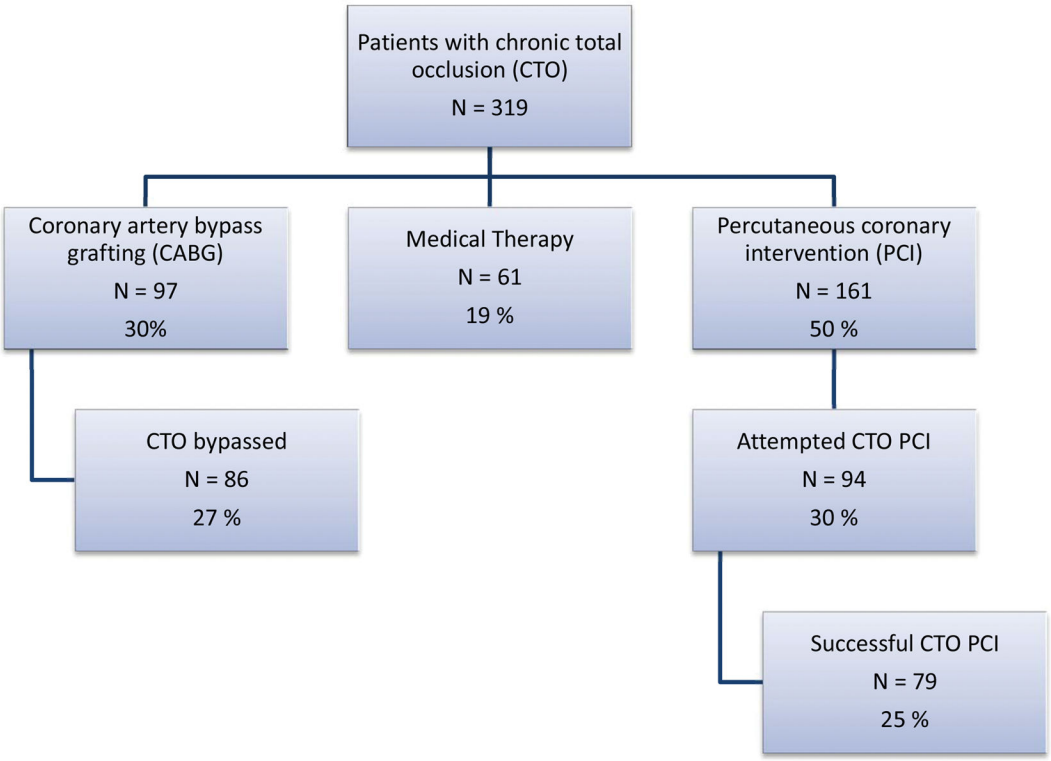

Figure 3.

Revascularization Strategy in non-CABG patients

Flow chart depicting coronary revascularization strategies for patients with coronary chronic total occlusion(s) who did not have prior coronary artery bypass graft surgery.

CABG=coronary artery bypass graft; CTO=chronic total occlusion; PCI=percutaneous coronary intervention

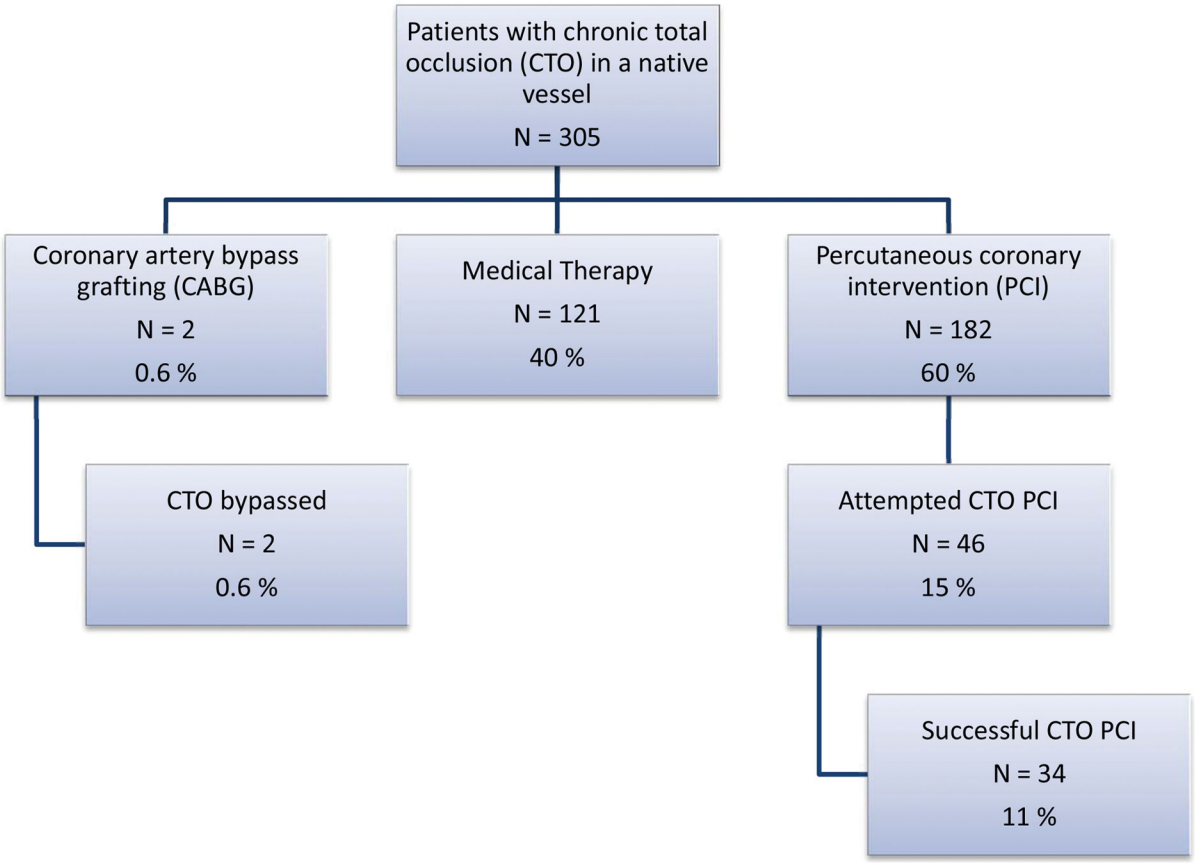

Figure 4.

Revascularization Strategy in prior CABG patients

Flow chart depicting coronary revascularization strategies for patients with coronary chronic total occlusion(s) who had prior coronary artery bypass graft surgery.

CABG=coronary artery bypass graft; CTO=chronic total occlusion; PCI=percutaneous coronary intervention

Table I

Baseline characteristics of non-CABG patients with coronary artery disease in the study population, classified according to the presence of a coronary chronic total occlusion.

Variable	Non-CTO Group (n = 696 patients)	CTO Group (n = 319 patients)	*P*
Age (years)	64 ± 9	65 ± 8	0.07
Male	687 (99%)	318 (100%)	0.14
Ethnicity			0.92
Caucasian	504 (72%)	234 (73%)	
Black	152 (22%)	67 (21%)	
Hispanic	28 (4%)	14 (4%)	
Other	12 (2%)	4 (1%)	
BMI (kg/m^2)	30 ± 6	30 ± 6	0.79
Hypertension	623 (90%)	281 (88%)	0.50
Dyslipidemia	596 (86%)	280 (88%)	0.36
Diabetes mellitus	317 (46%)	167 (52%)	0.04
Prior CVA	78 (11%)	55 (17%)	0.008
Prior CHF	167 (24%)	106 (33%)	0.002
Prior MI	181 (26%)	125 (39%)	<0.001
Prior PCI	232 (33%)	111 (35%)	0.65
Tobacco Use			
Past	552 (79%)	275 (86%)	0.009
Current	264 (38%)	138 (43%)	0.11
Peripheral arterial disease	98 (14%)	77 (24%)	<0.001
Family history of early CAD	176 (25%)	64 (20%)	0.07
CKD	105 (15%)	55 (17%)	0.38
Clinical presentation			0.03
Stable angina	212 (30%)	118 (37%)	
Acute coronary syndrome	259 (37%)	102 (32%)	
Other	225 (32%)	99 (31%)	
Ejection fraction (%)			<0.001
LVEF ≥ 40%	551 (82%)	211 (66%)	
LVEF < 40%	123 (18%)	107 (34%)	
3-vessel disease	140 (20%)	177 (55%)	<0.001
Left Main disease	73 (10%)	59 (19%)	<0.001
Treatment chosen			<0.001
Medical/No Intervention	216 (31%)	61 (19%)	
PCI to any vessel	368 (53%)	161 (50%)	
CABG	112 (16%)	97 (30%)	
Medications			
Aspirin	660 (95%)	316 (99%)	0.001
Beta-blocker	635 (91%)	305 (96%)	0.01
ACEI/ARB	506 (73%)	227 (71%)	0.61

Variable	Non-CTO Group (n = 696 patients)	CTO Group (n = 319 patients)	*P*
Statin	652 (94%)	307 (96%)	0.15
Long-acting nitrate	152 (22%)	76 (24%)	0.48
Insulin	147 (21%)	78 (24%)	0.24

Data is presented as mean ± standard deviation or number (percent).

ACEI=angiotensin-converting enzyme inhibitor; ARB=angiotensin-receptor blocker; BMI=body mass index; CABG=coronary artery bypass graft; CAD=coronary artery disease; CHF=congestive heart failure; CKD=chronic kidney disease; CTO=chronic total occlusion; CVA=cerebrovascular accident; LVEF=left ventricular ejection fraction; MI=myocardial infarction; PCI=percutaneous coronary intervention

Table II

Coronary revascularization among patients without prior CABG who were found to have a coronary chronic total occlusion.

Variable	Medical Therapy (n = 128 patients)	PCI (n = 94 patients)	CABG (n = 97 patients)	Overall P	*P* for Medical therapy vs. PCI	*P* for Medical therapy vs. CABG	*P* for PCI vs. CABG
Age (years)	66 ± 9	64 ± 9	64 ± 7	0.26	0.09	0.16	0.63
Male	127 (99%)	94 (100%)	97 (100%)	0.47	0.39	0.38	N/A
Ethnicity				0.19	0.07	0.43	0.41
Caucasian	92 (72%)	79 (78%)	69 (71%)				
Black	32 (25%)	14 (15%)	21 (22%)				
Hispanic	4 (3%)	4 (4%)	6 (6%)				
Other	0 (0%)	3 (3%)	1 (1%)				
BMI (kg/m^2)	29 ± 7	31 ± 6	30 ± 6	0.09	0.05	0.22	0.48
Hypertension	109 (85%)	83 (88%)	89 (92%)	0.32	0.50	0.13	0.43
Dyslipidemia	112 (88%)	82 (87%)	86 (89%)	0.95	0.95	0.79	0.76
Diabetes mellitus	69 (54%)	47 (50%)	51 (53%)	0.85	0.56	0.84	0.72
Prior CVA	26 (20%)	13 (14%)	16 (16%)	0.44	0.21	0.47	0.61
Prior CHF	52 (41%)	35 (37%)	19 (20%)	0.003	0.61	<0.001	0.007
Prior MI	69 (54%)	30 (32%)	26 (27%)	<0.001	0.001	<0.001	0.44
Prior PCI	56 (44%)	30 (32%)	25 (26%)	0.02	0.07	0.005	0.35
Tobacco History	114 (89%)	77 (82%)	84 (87%)	0.31	0.13	0.57	0.37
Peripheral arterial disease	39 (30%)	15 (16%)	23 (24%)	0.04	0.01	0.26	0.18
CKD	31 (24%)	12 (13%)	12 (12%)	0.03	0.03	0.03	0.93
Clinical presentation				0.001	<0.001	0.04	0.10
Stable angina	32 (25%)	47 (50%)	39 (40%)				
Acute coronary syndrome	50 (39%)	21 (22%)	31 (32%)				
Ejection fraction (%)				0.009	0.07	0.003	0.25
LVEF ≥ 40%	73 (57%)	64 (69%)	74 (76%)				
LVEF < 40%	55 (43%)	29 (31%)	23 (24%)				
Number of vessels with CAD				<0.001	0.04	<0.001	<0.001
1	23 (18%)	27 (29%)	2 (2%)	<0.001	0.06	<0.001	<0.001
2	41 (32%)	35 (37%)	14 (14%)	0.001	0.42	0.002	<0.001
3	64 (50%)	32 (34%)	81 (84%)	<0.001	0.02	<0.001	<0.001

Variable	Medical Therapy (n = 128 patients)	PCI (n = 94 patients)	CABG (n = 97 patients)	Overall P	*P* for Medical therapy vs. PCI	*P* for Medical therapy vs. CABG	*P* for PCI vs. CABG
Left Main disease	18 (14%)	4 (4%)	37 (38%)	<0.001	0.02	<0.001	<0.001
CTO Artery				0.001	<0.001	0.88	0.002
RCA	67 (64%)	38 (51%)	40 (62%)	0.23	0.10	0.77	0.23
LAD	14 (13%)	27 (36%)	8 (12%)	<0.001	<0.001	0.85	<0.001
LCx	24 (19%)	9 (13%)	17 (26%)	0.09	0.07	0.63	0.03
>1 CTO	23 (18%)	20 (21%)	32 (33%)	0.03	0.54	0.009	0.07

Data is presented as mean ± standard deviation or number (percent).

BMI=body mass index; CABG=coronary artery bypass graft; CAD=coronary artery disease; CHF=congestive heart failure; CKD=chronic kidney disease; CTO=chronic total occlusion; CVA=cerebrovascular accident; LAD=left anterior descending artery; LCx=left circumflex artery; LVEF=left ventricular ejection fraction; MI=myocardial infarction; PCI=percutaneous coronary intervention; RCA=right coronary artery

Table III

Published studies reporting the prevalence of coronary chronic total occlusions.

	Country	CTO prevalence among CAD patients without prior CABG	CTO prevalence among prior CABG patients
Fefer et al.(1)	Canada	18.4%	54%
Kahn et al.(2)	USA	35%	NR
Werner et al.(4)*	Germany	33%	NR
Christofferson et al.(3)†	USA	52%	NR
Present study	USA	31%	89%

CABG=coronary artery bypass graft; CAD=coronary artery disease (≥50% stenosis in ≥1 vessel); CTO=chronic total occlusion; NR=not reported

*In patients presenting with stable angina

†CAD defined as ≥70% stenosis in ≥1 vessel