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Effect of Prior Failure on Subsequent Procedural Outcomes of Chronic Total Occlusion Percutaneous Coronary Intervention (From a Contemporary Multicenter Registry)

Judit Karacsonyi, MD^{1,2}, Aris Karatasakis, MD¹, Dimitri Karpaliotis, MD³, Khaldoon Alaswad, MD⁴, Robert W. Yeh, MD⁵, Farouc A. Jaffer, MD, PhD⁵, Michael R. Wyman, MD⁶, William Lombardi, MD⁷, Aaron Grantham, MD⁸, David Kandzari, MD⁹, Nicholas Lembo, MD⁹, Jeffrey W. Moses, MD³, Ajay Kirtane, MD³, Manish Parikh, MD³, Philip Green, MD³, Matthew Finn, MD³, Santiago Garcia, MD¹⁰, Anthony Doing, MD¹¹, Mitul Patel, MD¹², John Bahadorani, MD¹², Jose Roberto Martinez Parachini, MD¹, Erica Resendes, MS¹, Bavana V.

Corresponding Author: Emmanouil S. Brilakis, MD, PhD, Dallas VA Medical Center (111A), 4500 South Lancaster Road, Dallas, TX 75216, Tel: (214) 857-1547, Fax: (214) 302-1341, esbrilakis@gmail.com.

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Rangan, BDS, MPH¹, Imre Ungi, MD², Craig A. Thompson, MD, MMSc¹³, Subhash Banerjee, MD¹, and Emmanouil S. Brilakis, MD, PhD¹

¹VA North Texas Healthcare System and UT Southwestern Medical Center, Dallas, TX

²Division of Invasive Cardiology, Second Department of Internal Medicine and Cardiology Center, University of Szeged, Szeged, Hungary

³Columbia University, New York, NY

⁴Henry Ford Hospital, Detroit, MI

⁵Massachusetts General Hospital and Harvard Medical School, Boston, MA

⁶Torrance Memorial Medical Center, Torrance, CA

⁷University of Washington, Seattle, WA

⁸Mid America Heart Institute, Kansas City, MO

⁹Piedmont Heart Institute, Atlanta, GA

¹⁰Minneapolis VA Healthcare System and University of Minnesota, Minneapolis, MN

¹¹Medical Center of the Rockies, Loveland, CO

¹²VA San Diego Healthcare System and University of California San Diego, San Diego, CA

¹³Boston Scientific, Natick, MA

Abstract

We sought to examine the impact of prior failure on the outcomes of chronic total occlusion (CTO) percutaneous coronary intervention (PCI). We examined the clinical and angiographic characteristics and procedural outcomes of 1,213 consecutive patients who underwent 1,232 CTO PCIs between 2012 and 2015 at 12 US centers. Mean age was 65 ± 10 years and 84.8% of patients were men. A prior failed attempt had been performed in 215 (17.5%) patients. As compared with patients without prior CTO PCI failure, patients with prior failure had higher Japanese Chronic Total Occlusion (J-CTO) score (2.40 ± 1.13 vs. 3.28 ± 1.29 , $p < 0.0001$), and were more likely to have in-stent restenosis (10.5% vs. 28.4%, $p < 0.0001$) and to undergo recanalization attempts using the retrograde approach (41% vs. 50%, $p = 0.011$). Technical (90% vs. 88%, $p = 0.390$) and procedural (89% vs. 86%, $p = 0.184$) success were similar in the two study groups, however, median procedure time (125 vs. 142 min, $p = 0.026$) and fluoroscopy time (45 vs. 55 min, $p = 0.015$) were longer in the prior failure group. In conclusion, the main finding of our study is that a prior failed CTO PCI attempt is associated with higher angiographic complexity, longer procedural duration and fluoroscopy time, but not with the success and complication rates of subsequent CTO PCI attempts.

Keywords

chronic total occlusion; percutaneous coronary intervention

Introduction

Chronic total occlusion (CTO) percutaneous coronary intervention (PCI) can be challenging to perform with variable success rates, depending on operator experience and expertise.^{1,2} Prior CTO PCI failure has been associated with lower procedural success rates and is part of the Japanese Chronic Total Occlusion (J-CTO) score that was developed to predict the likelihood of successful guidewire crossing within 30 minutes.³ However, prior CTO PCI failure can be due to multiple factors, such as patient instability, limited local experience, or early cessation of recanalization efforts without exploring alternative CTO crossing options. We examined a contemporary multicenter registry to determine the impact of prior failed CTO PCI attempts on the outcomes of subsequent procedures.

Methods

We examined the baseline and angiographic characteristics, and clinical outcomes of 1,232 consecutive CTO PCIs performed in 1,213 patients between 2012 and 2015 at 12 US centers. Enrollment was performed during only part of the study period in some centers due to participation in other studies. Data collection was performed prospectively and retrospectively and was recorded in a dedicated online CTO database (PROGRESS CTO: Prospective Global Registry for the Study of Chronic Total Occlusion Intervention, Clinicaltrials.gov Identifier: NCT02061436).^{2,4-10} The study was approved by the institutional review board of each site.

Coronary CTOs were defined as coronary lesions with Thrombolysis In Myocardial Infarction (TIMI) grade 0 flow of at least 3 month duration. Estimation of the 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. Calcification was assessed by angiography as mild (spots), moderate (involving 50% of the reference lesion diameter) and severe (involving >50% of the reference lesion diameter). Proximal vessel tortuosity was defined as moderate (2 bends >70 degrees or 1 bend >90 degrees) or severe (2 bends >90 degrees or 1 bend >120 degrees). The J-CTO score was calculated as described by Morino et al.¹¹ Study outcomes included technical and procedural success. 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. Procedural success was defined as achievement of technical success with no in-hospital major adverse cardiac events (MACE). In-hospital MACE included any of the following adverse events prior to hospital discharge: death, myocardial infarction, urgent repeat target vessel revascularization with either PCI or coronary artery bypass graft surgery (CABG), tamponade requiring either pericardiocentesis or surgery, and stroke. Myocardial infarction was defined using the Third Universal Definition of Myocardial Infarction.¹²

Patients were classified in two groups based on whether they had a prior unsuccessful CTO PCI attempt or not. Continuous variables were presented as mean $\pm$ standard deviation or median (interquartile range) and were compared using the t-test, or Wilcoxon rank-sum test, as appropriate. Categorical data are reported as frequencies or percentages and compared using the chi-square test. All statistical analyses were performed with JMP 11.0 (SAS

Institute; Cary, North Carolina). A 2-sided P value of <0.05 was considered to indicate statistical significance.

Results

During the study period 1,213 consecutive patients underwent 1,232 CTO PCI at 12 US centers. The baseline patient and angiographic characteristics of the study population are summarized in Table 1. Mean age was 65.5 ± 10 years, 84.8% of the patients were men and 44.2% had diabetes. Nearly all patients had dyslipidemia (94.8 %) and hypertension (90%). Nearly one third of the study population had congestive heart failure (28%) and family history of coronary artery disease (30%), 34% had prior CABG, and 42% had a prior myocardial infarction. Patients with a prior failed CTO PCI attempt had lower rates of congestive heart failure and active smoking, as well as higher ejection fraction and body mass index.

The most common CTO PCI target vessel was the right coronary artery (59%), followed by the left anterior descending artery (22%), and the circumflex artery (19%). The mean J-CTO score was 2.55 ± 1.21 . Antegrade wire escalation was the most common successful crossing strategy (41%), followed by retrograde (27%) and antegrade dissection and re-entry (24%). The overall technical and procedural success were 90% and 89%, respectively.

As compared with patients without prior CTO PCI failure, those with prior failed attempts were more likely to have in-stent restenosis, larger target vessel diameter, higher J-CTO score (which was, however, due to the fact that prior failure is part of the score derivation), and were more likely to undergo CTO crossing using the retrograde approach. The distribution of final successful crossing strategy was similar between CTO PCI patients with and without prior CTO PCI failure, although a primary retrograde or antegrade dissection and re-entry approach was more common in patients with prior CTO PCI failure.

Technical and procedural success were similarly high among patients with and without prior failed CTO PCI attempts (Table 2, Figure A), whereas the incidence of MACE was numerically higher among prior failed cases (4.2% vs. 2.1%, $p=0.067$). Mean procedure duration was significantly longer in the group with prior failed CTO PCI attempts (142 vs. 125 min, $p=0.026$), as was mean fluoroscopy time (55 vs. 45 min, $p=0.015$), whereas mean air kerma radiation dose (4 vs. 3.39 Gray, $p=0.163$) and mean contrast volume (260 vs. 260 ml, $p=0.893$) were similar in the two study groups. Peri-procedural bleeding occurred in 0.9% of the overall study population with similar prevalence in both groups (0.9% vs 0.9 %, $p=0.949$). Peri-procedural bleeding occurred in 11 cases, most of which (10 cases) were access site bleedings, while retroperitoneal bleeding and gastrointestinal bleeding occurred only in one case each.

Discussion

The main finding of our study is that a prior failed CTO PCI attempt is associated with higher angiographic complexity, longer procedural duration and fluoroscopy time, but not with the success and complication rates of subsequent CTO PCI attempts.

Few studies have examined the impact of prior failed CTO PCI attempt on subsequent procedural outcomes. Morino et al. created a five point scoring system combining five baseline clinical and angiographic parameters to assess the difficulty of CTO crossing,³ that was assessed in three subsequent studies.^{3,5,7,13} These five parameters are blunt stump, presence of calcification, within the lesion bending >45°, occlusion length ≥ 20 mm, and prior attempt at CTO PCI. One point was given for each of the parameters, which were associated with lower probability of successful guidewire crossing within 30 minutes. Nombela-Franco et al. validated the J-CTO score in an independent contemporary cohort, and found that all J-CTO score variables except prior failed attempt had significant univariate association with successful guidewire crossing within 30 minutes.¹⁴ Our findings also support a limited role of prior failure in predicting subsequent CTO PCI success. Indeed, prior failure was not included in the recently developed Progress-CTO risk score that is associated with technical success and includes four variables (proximal cap ambiguity, presence of interventional collaterals, moderate/severe tortuosity, and circumflex target vessel).¹⁵

There are multiple potential explanations for the lack of impact of prior failure on CTO PCI outcomes. First, initial failure could be related to limited experience and expertise or lack of equipment at the treating center. Second, it could have been due to a complication. Third, at times a failure can predispose to subsequent success by allowing recanalization of the occlusion after angioplasty of a subintimal dissection plane (investment procedure).¹⁶ The higher incidence of MI in prior failed cases may be related to more frequent use of the retrograde approach in these patients.

Our study has limitations. There was no core laboratory analysis of the study angiograms and no independent event adjudication. The experience of the operator who performed the initial failed procedure is not known. Procedures were performed by centers with significant expertise in CTO PCI, hence, our findings may not be generalizable to less experienced centers and operators. The time interval between the prior failed attempt and the subsequent CTO PCI and the reason for failure was not collected.

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Study data were collected and managed using REDCap electronic data capture tools hosted at University of Texas Southwestern Medical Center.¹ REDCap (Research Electronic Data Capture) is a secure, web-based application designed to support data capture for research studies, providing 1) an intuitive interface for validated data entry; 2) audit trails for tracking data manipulation and export procedures; 3) automated export procedures for seamless data downloads to common statistical packages; and 4) procedures for importing data from external sources.

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Appendix

Participating centers in the study

Appleton Cardiology, Appleton Wisconsin; Columbia University, New York, New York; Henry Ford Hospital, Detroit, Michigan; Massachusetts General Hospital, Boston, Massachusetts; Medical Center of the Rockies, Loveland, Colorado; Piedmont Heart Institute, Atlanta Georgia; St. Joseph Medical Center, Bellingham Washington; St. Luke's Health System's Mid-America Heart Institute, Kansas City, Missouri; Torrance Memorial Center, Torrance, California; VA Minneapolis Healthcare System, Minneapolis, Minnesota; VA North Texas Health Care System, Dallas, Texas, and VA San Diego Healthcare System, San Diego, California.

Figure 1. Technical, procedural success and MACE classified according to prior attempt
Impact of prior failure of chronic total occlusion intervention on the outcomes of subsequent chronic total occlusion percutaneous coronary interventions.
CTO: chronic total occlusion; PCI: percutaneous coronary intervention; MACE: major cardiac adverse events

Table 1

Baseline clinical and angiographic characteristics of the study patients, classified according to whether they had undergone a prior failed percutaneous coronary intervention attempt in the chronic total occlusion target coronary artery.

Variable	Overall (n=1232)	Prior failed CTO PCI attempt (n=215)	No prior failed CTO PCI attempt (n=1,017)	P
Age (years) ^a	65 ± 10	64.4 ± 11	65.6 ± 9.8	0.177
Men	84.8%	81.4%	85.5%	0.135
Body Mass Index (kg/m2) ^a	30.6 ± 6.3	31.6 ± 6.7	30.3 ± 6.2	0.026
Diabetes Mellitus	44.2%	38.8%	45.3%	0.082
Hypertension	90%	89%	90%	0.692
Dyslipidemia	94.8%	95.2%	94.7%	0.738
Smoking (current)	28%	21%	30%	0.014
Left Ventricular Ejection Fraction (%) ^a	50 ± 14	53 ± 13	50 ± 14	0.016
Family History of Coronary Artery Disease	30 %	34%	29%	0.230
Congestive Heart Failure	28%	19%	30%	0.002
Prior Myocardial Infarction	42%	44%	42%	0.540
Prior coronary bypass	34%	31%	35%	0.221
Prior cerebrovascular disease	11%	8%	11%	0.122
Prior peripheral vascular disease	16%	12%	17%	0.106
Baseline creatinine (mg/dL) ^b	1.0 (0.9,1.2)	1.0 (0.9,1.3)	1.0 (0.9,1.2)	0.891
Angiographic characteristics				
CTO Target coronary artery				
• Right coronary artery	59%	58%	58%	0.953
• Left anterior descending artery	22%	23%	22%	
• Left circumflex artery	19%	19%	19%	
Successful Crossing Strategy				
• Antegrade wiring	41%	35%	42%	0.113
• Retrograde	27%	26%	27%	
• Antegrade dissection and re-entry	24%	29%	22%	
First Crossing Strategy				
• Antegrade wiring	70%	52%	70%	<0.0001
• Retrograde	20%	29%	18%	
• Antegrade dissection and re-entry	14%	18%	12%	
Retrograde crossing attempt	42.5%	50.2%	40.8%	0.011
Japanese chronic total occlusion-score ^a	2.55 ± 1.21	3.28 ± 1.29	2.40 ± 1.13	<0.0001
Calcification (moderate/severe)	56.7%	57.4%	56.6%	0.819
Tortuosity (moderate/severe)	34.6%	34.8%	34.5%	0.940
Proximal cap ambiguity	32%	35%	32%	0.423
In-stent restenosis	13.6%	28.4%	10.5%	<0.0001
Interventional Collaterals	59%	60%	59%	0.865

Variable	Overall (n=1232)	Prior failed CTO PCI attempt (n=215)	No prior failed CTO PCI attempt (n=1,017)	P
Side branch at the proximal cap	45%	44%	46%	0.765
Blunt/no stump	64%	58%	64%	0.001
Vessel diameter (mm) ^b	2.75 (2.5, 3)	3 (2.5, 3)	2.75 (2.5, 3)	0.014
Occlusion length (mm) ^b	30 (20, 45)	30 (17, 50)	30 (20, 40)	0.485

^a mean ± standard deviation

^b median (interquartile range)

CTO: chronic total occlusion; PCI: percutaneous coronary intervention; PCI: percutaneous coronary intervention; CTO: Chronic total occlusion;

Table 2

Procedural outcomes of the study patients, classified according to whether they had undergone a prior failed percutaneous coronary intervention attempt in the chronic total occlusion target coronary artery.

Variable	Overall (n=1232)	Prior failed CTO PCI attempt (n=215)	No prior failed CTO PCI attempt (n=1,017)	P
Technical Success	90%	88%	90%	0.390
Procedural Success	89%	86%	89%	0.184
Procedural time (min) ^b	128 (87, 191)	142 (91, 213)	125 (85, 185)	0.026
Fluoroscopy time (min) ^b	47 (28, 76)	55 (33, 82)	45 (27, 74)	0.015
Air kerma radiation dose (Gray) ^b	3.47 (2.03, 5.42)	4.00 (2.20, 5.73)	3.39 (2.00, 5.37)	0.163
Contrast volume ^b	260 (200, 360)	260 (185, 375)	260 (200, 360)	0.893
MACE	2.4%	4.2%	2.1%	0.067
Death	0.4%	0.9%	0.3%	0.183
Acute myocardial infarction	1.1%	2.8%	0.7%	0.006
Repeat percutaneous coronary intervention	0.3%	0.5%	0.3%	0.690
Stroke	0.3%	0%	0.4%	0.357
Emergency coronary bypass	0%	0%	0%	-
Pericardiocentesis	0.6%	1.4%	0.5%	0.134
Periprocedural bleeding	0.9%	0.9%	0.9%	0.949

^a mean ± standard deviation

^b median (interquartile range)

CTO: chronic total occlusion; PCI: percutaneous coronary intervention; MACE: major adverse cardiac events;