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Outcomes of Chronic Total Occlusion Percutaneous Coronary Intervention in Patients With Diabetes

Insights From the OPEN CTO Registry

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ABSTRACT

OBJECTIVES Few studies have evaluated the relationship of diabetes with technical success and periprocedural complications, and no studies have compared patient-reported health status after chronic total occlusion (CTO) percutaneous coronary intervention (PCI) in patients with and without diabetes.

BACKGROUND CTOs are more common in patients with diabetes, yet CTO PCI is less often attempted in patients with diabetes than in patients without. The association between diabetes and health status after CTO PCI is unknown.

METHODS In the 12-center OPEN-CTO PCI registry (Outcomes, Patient Health Status, and Efficiency in Chronic Total Occlusion Registry), patients with and without diabetes were assessed for technical success, periprocedural complications, and health status over 1 year following CTO PCI using the Seattle Angina Questionnaire and the Rose Dyspnea Scale. Hierarchical modified Poisson regression was used to examine the independent association between diabetes and technical success, and hierarchical multivariable linear regression was used to assess the association between diabetes and follow-up health status.

RESULTS Diabetes was common (41.2%) and associated with a lower crude rate of technical success (83.5% vs. 88.1%; $p = 0.04$). After adjustment, there was no significant difference between diabetic and nondiabetic patients (relative risk: 0.96, 95% confidence interval: 0.91 to 1.01). There were no significant differences in complication rates between patients with and without diabetes. Angina burden, quality of life, and overall health status scores were similar between diabetic and nondiabetic patients over 1 year.

CONCLUSIONS Although technical success was lower in patients with diabetes, this reflected lower success among patients with prior bypass surgery, without any significant difference in success rate after adjusting for prior bypass and disease complexity. CTO PCI complication rates are similar in diabetic and nondiabetic patients, and symptom improvement following CTO PCI is robust and of a similar magnitude regardless of diabetes status. (J Am Coll Cardiol Intv 2017;10:2174–81) © 2017 by the American College of Cardiology Foundation.

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Diabetes is common among patients who present with coronary chronic total occlusions (CTOs), and is often associated with diffuse, small-vessel, and multivessel coronary artery disease (1,2). Although CTOs are more common in diabetic patients (3), CTO percutaneous coronary intervention (PCI) is performed less frequently in these patients in comparison to patients without diabetes (1). Although coronary artery bypass graft surgery (CABG) is the preferred method of revascularization in patients with diabetes and multivessel disease (4,5), many patients presenting with CTOs have single-vessel disease or have previously been treated with bypass surgery. For these patients, CTO PCI is supported by Appropriate Use Criteria for Coronary Revascularization for diabetic patients (5). Prior studies have suggested similar technical success rates among those with and without diabetes, but reports have been variable with regard to periprocedural complications and long-term major adverse cardiac event rates (6–9). Moreover, although the principal indication for CTO PCI is relief of angina symptoms, no studies have reported whether CTO PCI in diabetic patients is associated with similar improvement in symptoms, function, and quality of life (QoL) compared with patients without diabetes.

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To describe the association between diabetes and technical success, periprocedural complications and long-term patient-reported health status, we leveraged the 12-center OPEN-CTO (Outcomes, Patient Health Status, and Efficiency in Chronic Total Occlusion) registry (10). The OPEN-CTO registry was ideally suited to address these gaps in knowledge, given its unique linkage to each enrolling site's NCDR (National Cardiovascular Data Registry) data to ensure that all eligible CTO PCI patients were included in the registry, thereby ensuring accuracy of technical success and complication data, and given its unique collection of health status data using the Seattle Angina Questionnaire (SAQ) and Rose Dyspnea Scale (RDS) at 1, 6, and 12 months after CTO PCI. Better understanding procedural outcomes and health status trajectories in follow-up after CTO PCI may help providers better describe the risks and benefits of the procedure to patients with diabetes can help inform the future management of patients with coronary CTOs who have diabetes. Furthermore, these insights can inform future randomized trials of PCI versus medical therapy or surgical revascularization in diabetic patients with CTOs.

ABBREVIATIONS AND ACRONYMS

AF = angina frequency

CABG = coronary artery bypass graft surgery

CAD = coronary artery disease

CI = confidence interval

CTO = chronic total occlusion

PCI = percutaneous coronary intervention

QoL = quality of life

RDS = Rose Dyspnea Scale

RR = relative risk

SAQ = Seattle Angina Questionnaire

SS = overall summary score

METHODS

STUDY POPULATION. The OPEN CTO registry is a prospective, single-arm study that enrolled patients with CTOs who underwent attempted PCI at 12 U.S. sites between January 21, 2014, and July 22, 2015. A full description of the study methods has been published previously (10). Eligible patients were >18 years of age and had symptoms suggestive of ischemic heart disease. All patients had a CTO defined as a lesion with TIMI (Thrombolysis In Myocardial Infarction) antegrade flow grade 0 that was thought to have been present for at least 3 months. Patients were treated according to the previously published hybrid algorithm for CTO PCI (11). The CTO PCI operators were required to have a minimum of 2 years of experience performing CTO PCI and to have performed at least 100 CTO PCI procedures before participating in the OPEN CTO registry. Enrollment of all consenting patients undergoing CTO PCI at each center was confirmed via linkage to each hospital's NCDR CathPCI data to prevent bias related to failure to include all patients undergoing CTO PCI in the study. The results of this audit have been previously published, indicating no evidence of significant selection biases (10). Each participating site obtained institutional research board approval, and all patients provided informed consent to participate in the study.

DEFINITIONS. Patients with an established diagnosis of diabetes mellitus were identified upon review of medical records at the time of the index procedure. To fully characterize the duration and severity of diabetes, we also collected the duration of diabetes

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since diagnosis, type of diabetes, insulin dependence, use of oral hypoglycemic medications or insulin, and whether any diabetic microvascular complications had been diagnosed (neuropathy, nephropathy, or retinopathy). Technical success of the CTO PCI procedure was defined as <50% residual stenosis and TIMI flow grade ≥2 without significant side branch occlusions as assessed by the angiographic core lab. Complete revascularization was defined by operators as successful treatment of all physiologically significant coronary stenoses. Periprocedural complication data were collected prospectively at each site by trained study personnel. Periprocedural myocardial infarction was defined as type 4a and 5 myocardial infarction according to European Society of Cardiology/American College of Cardiology/American Heart Association universal myocardial infarction definitions (12). Perforations were classified according to the Ellis classification by review of angiograms at the core lab (13), and a clinically significant perforation was defined as any perforation requiring treatment (10). Major adverse cardiovascular and cerebrovascular events was defined as the composite of death, periprocedural myocardial infarction, emergency coronary bypass surgery, stroke, and clinically significant perforation.

HEALTH STATUS ASSESSMENT. Disease-specific patient-reported health status was assessed using the SAQ. Trained study personnel administered the SAQ during the baseline interview when enrolling each patient in the OPEN-CTO registry. Follow-up health status assessments were completed by a centralized telephone interview conducted by trained study coordinators at 1, 6, and 12 months after CTO PCI. The SAQ is a valid and reliable 19-item questionnaire with a 4-week recall period that measures 5 domains of health in patients with coronary artery disease (CAD): angina frequency (SAQ AF), angina stability, QoL (SAQ QoL), physical limitation, and treatment satisfaction (14,15). Domain scores range from 0 to 100, with higher scores indicating fewer symptoms and better QoL. The frequency of angina from the patients' perspective was captured with the SAQ AF domain, which has been shown to correlate closely with daily angina diaries (16), and QoL was quantified using the SAQ QoL scale. Overall health status was summarized using the SAQ summary score (SAQ SS), which reflects the average of the SAQ physical limitation, AF. and QoL domains (17). Because patients with diabetes may be less likely to report typical angina symptoms, we also examined the relationship between diabetes and dyspnea symptoms using the RDS. The RDS is a 4-item questionnaire with a 1-month recall period that assesses patients' level of dyspnea with common activities (18). Each activity associated with dyspnea is assigned 1 point, such that RDS scores range from 0 to 4, with a score of 0 indicating no dyspnea and increasing scores indicating greater limitation from dyspnea. The RDS has been validated in patients with CAD and shown to be associated with QoL, rehospitalization, and long-term survival in patients with CAD (19).

STATISTICAL ANALYSES. Univariate comparisons between patients with and without diabetes were performed using independent Student *t* tests for continuous variables and chi-square tests for categorical variables. We used hierarchical multivariable modified Poisson regression to identify the adjusted association between diabetes and technical success while accounting for clustering by site. We adjusted for potential confounders identified a priori, based upon clinical experience, including insulin dependence, prior bypass of the target vessel, each component of the J-CTO (Japan CTO) score (blunt proximal cap, severe calcification, vessel bending, and occlusion length ≥20 mm), presence of interventional collaterals, prior stenting of the target CTO lesion, repeat attempt of a previously failed CTO lesion, and vessel treated. Among patients with health status follow-up data (n = 963), we examined the relationship between diabetes and changes in health status over the year of follow-up using the SAQ AF, QoL, and SS scores. Hierarchical multivariable repeated measures linear regression was used to calculate the adjusted association between diabetes and health status over the 1-year follow-up period. The model also adjusted for potential confounders identified based upon clinical experience, including age, sex, race, history of prior MI, prior CABG, congestive heart failure, peripheral artery disease, history of prior PCI, baseline hemoglobin, glomerular filtration rate, insulin use, lesion length, use of beta blockers, long-acting nitrates, calcium channel blockers, and ranolazine, technical success of the PCI procedure, successful CTO crossing strategy, vessel treated, and whether complete revascularization was achieved during the procedure.

Finally, we conducted an additional sensitivity analysis after stratifying the cohort into patients without diabetes, those with diabetes who were on insulin, and non-insulin-dependent diabetic patients. We then repeated models for both the technical success and health status outcomes using the same covariates as described previously for each analysis. The study was supported by an unrestricted grant from Boston Scientific. The sponsor was not involved with design of the analyses or writing, review, or approval of the manuscript. All statistical analyses were performed with SAS version 9.4 (SAS Institute, Cary, North Carolina).

RESULTS

BASELINE PATIENT CHARACTERISTICS. A total of 1000 consecutive patients undergoing CTO PCI were enrolled in the OPEN-CTO registry. The demographic, clinical, angiographic, and treatment characteristics of patients with and without diabetes are presented in Table 1. The majority of patients underwent single-vessel PCI to the target CTO vessel, with no PCI of other CTO or non-CTO lesions (n = 821, 82%). Overall, 412 patients (41%) carried a diagnosis of diabetes mellitus. Patients with diabetes were more likely to have a history of prior myocardial infarction and prior bypass surgery than nondiabetic patients. They also had a greater burden of heart failure, lower hemoglobin, and glomerular filtration rates, and on average, had slightly longer lesions than patients without diabetes. Although a small, statistically significant difference in J-CTO scores was noted between patients with and without diabetes (2.4 ± 1.3 vs. 2.3 ± 1.2; $p = 0.028$), there was no significant difference between diabetic and nondiabetic patients with respect to any of the individual components of the J-CTO score. Among patients with diabetes, 375 (93.8%) had type II diabetes. The mean duration since diagnosis with diabetes was 14.3 ± 11.6 years, and 154 (37.4%) were treated with insulin. Diabetic neuropathy was present in 73 patients (17.7%), nephropathy in 65 (15.8%), and retinopathy in 30 (7.3%).

TECHNICAL SUCCESS AND COMPLICATIONS. Crude rates of technical success were lower in patients with diabetes than those without (83.5% vs. 88.1%; $p = 0.04$). However, this association was attenuated after adjusting for clinical and angiographic characteristics and was no longer statistically significant after adjusting for potential clinical and angiographic confounders (relative risk [RR]: 0.96, 95% confidence interval [CI]: 0.91 to 1.01; $p = 0.12$). This was primarily driven by adjustment for prior CABG, which was independently associated with lower technical success ($p < 0.001$). We observed no significant differences in complication rates between patients who did and did not have diabetes (Table 2). Although a larger number of patients with diabetes experienced contrast-induced nephropathy, this difference was not statistically significant (4 [1.2%] vs. 1 [0.2%];

TABLE 1 Baseline Characteristics of Patients With and Without Diabetes

	Diabetes (n = 412)	No Diabetes (n = 588)	p Value
Age, yrs	65.5 ± 9.9	65.3 ± 10.6	0.787
Male	315 (76.5)	489 (83.2)	0.008
Caucasian	358 (86.9)	544 (92.5)	0.003
History of MI	221 (53.6)	263 (44.7)	0.005
History of CABG	174 (42.2)	191 (32.5)	0.001
Prior PCI	284 (68.9)	372 (63.4)	0.068
History of peripheral arterial disease	89 (21.6)	86 (14.6)	0.004
Body mass index, kg/m^2	32.2 ± 6.4	29.2 ± 5.4	<0.001
Current smoker	50 (12.3)	83 (14.3)	0.370
Glomerular filtration rate	73.0 ± 28.4	79.5 ± 24.1	<0.001
History of stroke or TIA	36 (8.7)	41 (7.0)	0.302
History of CHF	114 (27.7)	115 (19.6)	0.002
Most recent LVEF, %	49.8 ± 13.7	51.8 ± 13.8	0.056
History of lung disease	68 (16.5)	76 (12.9)	0.112
Hemoglobin	13.1 ± 1.8	13.9 ± 1.5	<0.001
Last HbA_{1c}	7.6 ± 1.7	5.8 ± 0.4	<0.001
Beta-blocker on arrival	345 (83.7)	503 (85.5)	0.433
Long-acting nitrate on arrival	182 (44.2)	231 (39.3)	0.122
Ranolazine on arrival	61 (14.8)	86 (14.6)	0.936
Calcium channel blocker on arrival	123 (29.9)	115 (19.6)	<0.001
Last HbA_{1c}	7.6 ± 1.7	5.8 ± 0.4	<0.001
Lesion length	63.7 ± 29.1	59.1 ± 27.9	0.012
Initial crossing strategy			0.140
Antegrade wire escalation	213 (51.7)	334 (56.8)	
Antegrade dissection and re-entry	55 (13.3)	84 (14.3)	
Retrograde wire escalation	56 (13.6)	77 (13.1)	
Retrograde dissection and re-entry	88 (21.4)	93 (15.8)	
Successful crossing strategy			0.163
Antegrade wire escalation	145 (38.9)	230 (42.1)	
Antegrade dissection and re-entry	84 (22.5)	139 (25.5)	
Retrograde wire escalation	38 (10.2)	57 (10.4)	
Retrograde dissection and re-entry	106 (28.4)	120 (22.0)	
CTO vessel			0.476
Left main	5 (1.2)	3 (0.5)	
LAD/diagonal	79 (19.2)	129 (21.9)	
LCx/OM	71 (17.2)	98 (16.7)	
RCA/PDA/RPLV	257 (62.4)	358 (60.9)	
CTO length	63.7 ± 29.1	59.1 ± 27.9	0.012
Occlusion length <20 mm	154 (37.4)	240 (40.8)	0.273
Interventional retrograde collateral vessels present	357 (87.1)	523 (89.4)	0.258
Severe calcification	9 (2.2)	19 (3.2)	0.323
Bending >45°	235 (57.0)	308 (52.4)	0.145
Re-try lesion (previously attempted)	101 (24.5)	123 (20.9)	0.179
J-CTO score	2.4 ± 1.3	2.3 ± 1.2	0.028
Complete revascularization at the time of CTO PCI	310 (75.4)	446 (76.2)	0.767

Values are mean ± SD, n (%), or median (interquartile range).

CABG = coronary artery bypass grafting; CHF = congestive heart failure; CTO = chronic total occlusion; HbA_{1c} = glycosylated hemoglobin; IQR = interquartile range; LAD = left anterior descending coronary artery; LCx = left circumflex coronary artery; LVEF = left ventricular ejection fraction; MI = myocardial infarction; OM = obtuse marginal coronary artery; PCI = percutaneous coronary intervention; PDA = posterior descending coronary artery; RCA = right coronary artery; RPLV = right posterolateral ventricular coronary artery; TIA = transient ischemic attack.

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TABLE 2 Periprocedural Complications Comparing Patients With and Without Diabetes

	Diabetes (n = 412)	No Diabetes (n = 588)	p Value
Perforation	39 (9.5)	49 (8.3)	0.533
Perforation location			0.786
CTO vessel	36 (92.3)	41 (83.7)	
Donor artery	0 (0.0)	1 (2.0)	
Septal collateral vessel	1 (2.6)	2 (4.1)	
Distal collateral vessel	1 (2.6)	4 (8.2)	
Other	1 (2.6)	1 (2.0)	
Septal hematoma	6 (1.5)	8 (1.4)	0.899
Pericardial effusion	9 (2.2)	17 (2.9)	0.489
Hemodynamically significant pericardial effusion	4 (44.4)	9 (52.9)	1.000
Contrast nephropathy	4 (1.2)	1 (0.2)	0.085
Access site hematoma	16 (3.9)	27 (4.6)	0.586
Retroperitoneal bleed	1 (0.2)	1 (0.2)	1.000
Emergency surgery	1 (0.2)	5 (0.9)	0.409
Periprocedural MI	11 (2.7)	15 (2.6)	0.907
Periprocedural stroke	0 (0.0)	0 (0.0)	
Death during procedure	1 (0.2)	4 (0.7)	0.654
Death during hospitalization	3 (0.7)	6 (1.0)	0.743
MACCE	28 (6.8)	42 (7.1)	0.832

Values are n (%).
MACCE = major adverse cardiac and cerebrovascular events; other abbreviations as in Table 1.

p = 0.09). When stratifying the cohort by baseline technical success, we observed no significant difference in complication rates between patients with and without diabetes in either the patients with technical success of the index CTO PCI or those with unsuccessful index CTO PCI procedures (Online Tables 1 and 2).

TABLE 3 Unadjusted Health Status at Baseline and Across the Follow-Up Period Stratified by Diabetes Status

	Diabetes (n = 412)	No Diabetes (n = 588)	p Value
SAQ angina frequency			
Baseline	68.8 ± 27.6	71.7 ± 26.6	0.092
1-month	90.4 ± 19.4	91.2 ± 18.4	0.529
6-months	90.3 ± 20.5	93.4 ± 15.8	0.010
1 year	91.3 ± 19.1	94.3 ± 15.8	0.011
SAQ quality of life			
Baseline	46.8 ± 27.7	50.6 ± 26.9	0.031
1 month	75.0 ± 21.9	75.1 ± 22.1	0.909
6 months	77.9 ± 22.3	81.8 ± 20.7	0.007
1 year	76.1 ± 23.3	80.7 ± 20.5	0.001
SAQ summary			
Baseline	58.4 ± 22.5	63.7 ± 22.2	<0.001
1 month	84.8 ± 16.5	86.1 ± 16.1	0.231
6 months	85.8 ± 17.6	89.5 ± 14.5	<0.001
1 year	85.3 ± 17.1	89.6 ± 13.8	<0.001
Rose Dyspnea Scale			
Baseline	2.3 ± 1.4	1.9 ± 1.5	<0.001
1 month	1.3 ± 1.4	1.0 ± 1.3	<0.001
6 month	1.3 ± 1.4	0.9 ± 1.3	<0.001
1 year	1.4 ± 1.5	0.9 ± 1.2	<0.001

Values are mean ± SD.
SAQ = Seattle Angina Questionnaire.

HEALTH STATUS OUTCOMES. Baseline health status scores were lower among patients with diabetes on the SAQ QoL and SS, and trended towards being lower on the AF scale, consistent with greater baseline health status impairment (Table 3). Similarly, diabetic patients reported greater baseline limitations from dyspnea, with higher RDS scores than patients without diabetes. On average, patients with and without diabetes experienced large and sustained health status improvements after CTO PCI as measured by each SAQ domain and the RDS. We observed no clinically significant difference in SAQ AF, QoL, or SS scores at 30 days, 6 months, or 12 months after CTO PCI (Table 3). After adjustment using multivariable repeated measures regression, there were no significant differences in adjusted health status scores across follow-up between diabetic and nondiabetic patients on any SAQ domain or on the RDS (diabetes vs. no diabetes: SAQ AF: 87.59 ± 1.68 vs. 88.05 ± 1.84; p = 0.64; SAQ QoL: 74.50 ± 2.13 vs. 73.80 ± 2.33; p = 0.58; SAQ SS: 83.01 ± 1.54 vs. 82.70 ± 1.68; p = 0.73, RDS: 1.46 ± 0.14 vs. 1.46 ± 0.13; p = 0.92; a comparison of change scores across the follow-up period is presented in Figure 1). When stratifying the cohort by baseline technical success, we observed no significant difference in health status scores between patients with and without diabetes on either SAQ scales or the RDS, either in the patients with technical success of the index CTO PCI or those with unsuccessful index CTO PCI procedures (Online Figures 1 to 4).

SENSITIVITY ANALYSES. The results of sensitivity analyses stratifying the diabetic population by insulin use were similar to our primary analysis. Technical success was similar in patients who were and were not on insulin (diabetes on insulin vs. no diabetes RR: 0.97, 95% CI: 0.91 to 1.04; diabetes without insulin vs. no diabetes RR: 0.96, 95% CI: 0.91 to 1.01). In comparison to patients who did not have diabetes, health status scores on in each SAQ domain were similar among diabetic patients who were treated with insulin (diabetes on insulin vs. no diabetes, mean, 95% CI of the SE SAQ SS −1.47 points [−2.78, 1.46]; SAQ QoL −1.55 points [−4.70, 1.59]; SAQ AF −0.18 points [−2.66, 2.30]; RDS 0.40 points [0.22, 0.59]), and those who did not require insulin (diabetes without insulin vs. no diabetes, mean [95% CI] SAQ SS 0.36 points [−1.4 to 2.15]; SAQ QoL 0.76 points [−1.72 to 3.25]; SAQ AF −0.45 points [−2.41 to 1.51]; RDS −0.01 points [−0.15 to 0.14]).

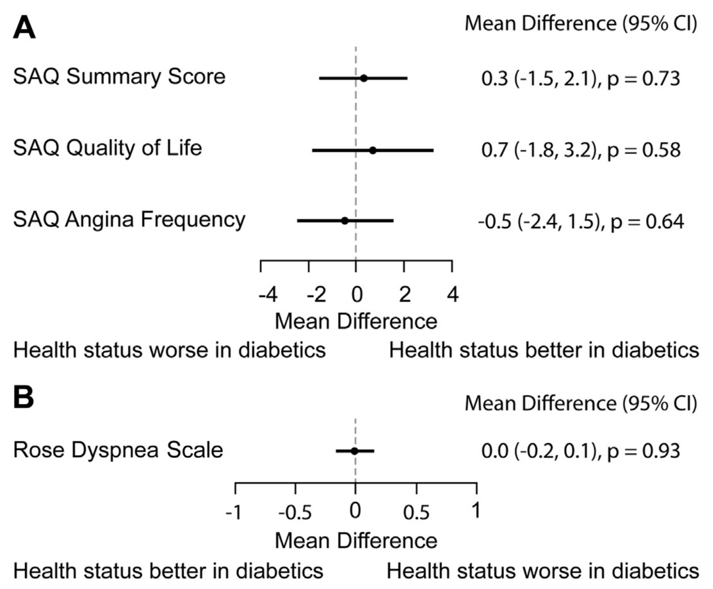
DISCUSSION

Although diabetes is common in patients presenting for CTO PCI, present in 4 of 10 patients, and is associated with a greater burden of comorbidities, longer lesions, and more complex anatomy, we found no difference in the benefits of PCI on patients' health status over the year after treatment. Although crude rates of technical success were lower in diabetics, adjustment for disease complexity, and most importantly, prior bypass surgery, eliminated the difference in technical success rates. This suggests that this observation is driven by differences in the complexity of treating CTOs in the setting of prior bypass surgery, rather than diabetes itself. Moreover, there was no difference in the rate of periprocedural complications in patients with and without diabetes. Collectively, these data support equivalent outcomes from CTO PCI in patients with diabetes as compared with those without it.

This report extends prior insights into the technical success and periprocedural outcomes after CTO PCI in patients with diabetes, several of which were relatively small, single-center case series (6,7). Although Sohrabi et al. (7) reported higher in-hospital MACE rates among diabetic patients undergoing CTO PCI, driven largely by repeat revascularization, our finding that procedural techniques and complication rates were similar between those with and without diabetes was consistent with findings from the large, multicenter PROGRESS CTO registry (Prospective Global Registry for the Study of Chronic Total Occlusion Intervention) (8). Our finding that a modestly lower technical success rate in diabetic patients was attenuated after adjusting for prior coronary bypass surgery, rather than the presence of diabetes itself, explains the observed difference in technical success.

The PROGRESS CTO registry investigators reported similar crossing strategy use, technical success, and MACE rates in patients with and without diabetes (8). We noted similar findings in the OPEN-CTO registry, with no indication that the hybrid algorithm for CTO PCI performed differently in patients with diabetes and found no signal of increased complications. The technical success rate was lower in the OPEN-CTO registry compared with the PROGRESS CTO registry, with higher rates of major adverse cardiovascular and cerebrovascular events among OPEN-CTO patients. This may reflect the consecutive, nonselective enrollment of all CTO PCI patients, confirmed by audit of each center's NCDR CathPCI registry in the OPEN-CTO registry (10). The completeness of enrollment in the OPEN-CTO registry supports the generalizability of these findings among experienced operators using the hybrid technique. Moreover, technical success was core lab adjudicated in the OPEN-CTO registry, whereas prior studies have depended on operator reports of technical success. In total, data from these large studies support that CTO PCI is safe, and as effective, in patients with diabetes as in those who do not have diabetes. Technical success rates were also similar in diabetic patients who did and did not require insulin, suggesting that patients who require insulin can expect high rates of technical success similar to those who do not require insulin and those who do not have diabetes. Although prior trials and professional society guidelines have underscored coronary bypass surgery as the preferred revascularization strategy in diabetic patients with multivessel disease, our results are reassuring and consistent with current recommendations supporting use of CTO PCI in patients with single-vessel CTOs or for patients with recurrent disease after bypass surgery. Future randomized studies are needed to compare medical management versus percutaneous

FIGURE 1 Multivariable-Adjusted Difference in Health Status Scores Across the Follow-Up Period Comparing Patients With and Without Diabetes



Forest plot showing results of multivariable repeated measures linear regression models comparing health status change from baseline through the follow-up period among diabetic patients compared to those without diabetes. **(A)** Differences in health status scores across the follow-up period between patients with and without diabetes as assessed by the Seattle Angina Questionnaire. **(B)** Differences in health status scores across the follow-up period between patients with and without diabetes as assessed by the Rose Dyspnea Scale. CI = confidence interval; SAQ = Seattle Angina Questionnaire.

or surgical revascularization for treatment of these patients.

Because the principal indication for revascularization in these patients is relief of symptoms (20), a critical gap in the current understanding of the outcomes of CTO PCI in patients with diabetes is the lack of short- and long-term health status data. Given that diabetic patients often have diffuse, small-vessel disease involving multiple vessels and their branches, understanding whether symptom relief is similar to those without diabetes after CTO PCI underscores the importance of successful revascularization in these patients. Our study extends previous insights into the outcomes of CTO PCI among diabetic patients through its use of the SAQ to quantify patients' symptoms, function, and QoL 1, 6, and 12-months after CTO PCI. At baseline, diabetic patients had lower health status scores on multiple SAQ domains and the Rose Dyspnea scale. However, we found no significant difference in the health status benefits during follow-up of patients with and without diabetes, either in unadjusted data or after adjustment for technical success, comorbidities, medications, and completeness of revascularization. Similarly, we saw no difference in health status change after CTO PCI when stratifying by insulin use, suggesting these observations are consistent across a broad spectrum of patients with diabetes, regardless of the need for insulin. These data underscore the clinical impact of CTO PCI procedures, and support proceeding with CTO PCI with appropriate clinical indications.

STUDY LIMITATIONS. The OPEN-CTO registry reflects the outcomes of PCI performed by 12 experienced centers, and lower success rates may be observed in the complex lesions often found in diabetic patients when treated by less experienced CTO operators. Therefore, these results may not be generalizable to all care settings. Second, the majority of diabetic patients in the OPEN-CTO registry had type II diabetes and were treated with oral medications alone. It is possible that outcomes would be different in patients with type I or type II diabetics with longstanding insulin requirement, who may have more severe and diffuse coronary disease. Third, the OPEN-CTO registry was a single-arm study of patients who were already selected for management with CTO PCI. Accordingly, there was no comparison to treatment with guideline-directed medical therapy or CABG. Further studies are needed to compare the outcomes of treatment with medical therapy, PCI, and bypass surgery in patients with CTOs and diabetes. Finally, we cannot exclude residual and unmeasured confounding in our results given the observational nature of the study. Only a randomized trial can definitively exclude differential technical success, complication rates, or outcomes comparing patients with and without diabetes.

CONCLUSIONS

We found that lower rates of technical success of CTO PCI among diabetic patients reflected the impact of prior CABG on the difficulty of CTO PCI, and after adjustment for prior CABG and disease complexity, we noted similar rates of technical success. We found the CTO PCI was performed with similar safety in patients with diabetes, and that both patients with and without diabetes experienced large, clinically meaningful improvements in health status after CTO PCI. There were no significant differences in coronary disease-specific health status or dyspnea benefits of CTO PCI in patients with and without diabetes.

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PERSPECTIVES

WHAT IS KNOWN? CTO angioplasty is commonly performed in diabetic patients, who often have diffuse epicardial and small vessel coronary disease. Few studies have examined whether the success rates of CTO PCI and symptomatic improvement after the procedure are comparable in patients with and without diabetes.

WHAT IS NEW? In this prospective, multicenter registry of consecutive patients undergoing CTO PCI, we found no significant difference in the core lab-adjudicated technical success or safety of CTO PCI between patients with and without diabetes, after adjusting for prior bypass surgery. Similar improvements in disease-specific health status were observed in patients with and without diabetes in the year following CTO PCI.

WHAT IS NEXT? Further studies are needed to compare outcomes of CTO PCI, bypass surgery and medical therapy in the management of patients with diabetes and CTOs.

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KEY WORDS angioplasty, chronic total occlusion, diabetes, quality of life, stable coronary artery disease

APPENDIX For online figures and tables, please see the online version of this article.