Original Article

Comparison of long-term clinical outcomes of percutaneous coronary intervention for chronic total occlusion between patients with and without diabetes mellitus: a single-center retrospective observational study

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Background: The prognosis of percutaneous coronary intervention (PCI) for chronic total occlusion (CTO) between patients with diabetes mellitus (DM) and those without DM is unknown. This study aimed to investigate whether DM has adverse effects on CTO PCI patients.

Methods: This single-center retrospective study included consecutive patients who underwent PCI for CTO at the China-Japan Friendship Hospital (Beijing, China) between January 2016 and April 2019. The clinical outcomes during follow-up were compared between patients with DM and those without DM.

Results: The analysis included 187 patients (152 males) aged 62.6±11.5 years. A total of 99 participants (52.9%) had DM, which involved a higher body mass index (BMI) and triglyceride level than those without DM (P<0.05). Participants with DM and those without DM had similar PCI success rates (89.9% *vs.* 95.4%, respectively) and complete revascularization rates (82.8% *vs.* 84.1%, respectively). There were no significant differences between groups in the rates of all-cause mortality, cardiac death, major adverse cardiovascular events (MACEs), readmission, recurrence of angina, target vessel revascularization (TVR), or myocardial infarction (MI) during a median follow-up of 20.5 months. Multivariable logistic regression revealed that CTO in a coronary branch vessel was associated with higher odds of all-cause death (odds ratio (OR): 53.56; 95% confidence interval (CI): 2.48 to 1,155.41; P<0.05) and failure of PCI for CTO (OR: 5.40; 95% CI: 1.263 to 23.098; P<0.05). Additionally, PCI for single CTO was associated with lower odds of MACEs (OR: 0.300; 95% CI: 0.118 to 0.765; P<0.05).

Conclusions: The performance of PCI for CTO has a high success rate in both patients with DM and those without DM, and clinical outcomes are comparable between groups.

Keywords: Ischemic heart disease; chronic total occlusion (CTO); percutaneous coronary intervention (PCI); diabetes; treatment outcome; mortality

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Introduction

Ischemic heart disease is a major cause of morbidity and hospitalization worldwide and is responsible for around 9 million deaths each year (1). The prevalence of ischemic heart disease has increased rapidly over recent years as a result of population aging and lifestyle changes, and China has seen a large increase in hospital admissions for acute coronary syndrome during the last decade (2,3). Various options are available for the management of coronary heart disease (CHD) including revascularization procedures such as coronary artery bypass grafting (CABG) and percutaneous coronary intervention (PCI) (4).

The degree of stenosis of a coronary artery is an important indicator of CHD severity that plays a key role in treatment decision making. Chronic total occlusion (CTO) is observed in around 30–50% of patients undergoing coronary angiography (5), and until recently was managed preferentially with CABG rather than PCI due to the perceived limited success rate of PCI. Although PCI for CTO has had a steep learning curve (6), it is now recognized that the procedural success rate of PCI can reach around 90% in experienced centers (7-9). Furthermore, several studies have shown that successful PCI for CTO is associated with better clinical outcomes than failed PCI (9-11).

Diabetes mellitus (DM) is a well-known risk factor for cardiovascular morbidity and mortality (12). It is a highly prevalent chronic disease affecting more than 420 million adults globally, and it is predicted that the number of people affected by DM will increase to 642 million by 2040 (13). The prevalence of DM has been progressively increasing in China, where the age-standardized prevalence of DM and pre-diabetes is estimated to be 9.7–11.6% (14,15). Notably, recent epidemiological surveys have reported that about 27–45% of patients with CTO have DM (16,17).

The optimal treatment strategy for patients with CTO and DM deserves particular attention due to the treatment-risk paradox and the absence of evidence-based recommendations (18). Clinical studies have suggested that PCI, when performed at high-volume centers by highly experienced operators, is a safe and effective treatment that can provide complete myocardial revascularization in selected patients with CTO and DM (19,20). Nevertheless, there are limited published data evaluating whether DM influences the outcomes of PCI for CTO. Therefore, the aim of this study was to compare the long-term clinical outcomes of PCI for CTO between patients with DM and those without DM. We present the following article in accordance with the STROBE reporting checklist (available at https://dx.doi.org/10.21037/apm-21-2354).

Methods

Study design and patients

This single-center retrospective study included patients who underwent PCI for CTO at the Cardiology Department, Integrated Traditional Chinese and Western Medicine, China-Japan Friendship Hospital (Beijing, China) between January 2016 and April 2019. The eligibility criteria included the presence of at least 1 CTO in a principal coronary artery and revascularization with PCI. The exclusion criteria were: (I) presence of severe coagulation abnormalities, malignant tumor with a life expectancy shorter than 1 year, or other end-stage disease; (II) incomplete medical history or follow-up data; and (III) contraindications to coronary angiography. The study was approved by the Ethics Committee of the China-Japan Friendship Hospital (No. 2020-14-K11) and complied with the principles outlined in the Declaration of Helsinki (as revised in 2013). All participants signed informed consent documents for the procedure itself and the use of their anonymized data in research.

Definitions

We defined CTO was as angiographic evidence of thrombolysis in myocardial infarction (TIMI) flow grade 0 within an occluded arterial segment for more than 3 months (21). We defined DM as current therapy with oral hypoglycemic drugs or insulin, fasting plasma glucose ≥7.0 mmol/L (126 mg/dL), or 2-hour plasma glucose ≥11.1 mmol/L (200 mg/dL) after a standard 75 g oral glucose tolerance test (22). Successful PCI for CTO was defined as the recanalization of the lesion with a residual stenosis level below 30% and a TIMI flow grade 3 (21). Complete revascularization was defined by the operators

as successful treatment of all physiologically significant coronary stenosis (23). Target vessel revascularization (TVR) was defined as any repeat PCI of the target vessel performed for restenosis or any other complication of the target lesion. Chronic kidney disease (CKD) was defined as an estimated glomerular filtration rate <60 mL/min/1.73 m^2 for at least 3 months or chronic dialysis.

PCI procedure

The PCI and stent implantation were carried using standard contemporary techniques such as bilateral injection, the hybrid algorithm, tapered-tip guidewires, stiff wires, parallel wires, microcatheters, and the retrograde approach as these became available. Drug-eluting stents were implanted in successful procedures. Following PCI, all participants were prescribed clopidogrel for least 12 months and lifelong aspirin.

Data collection

Clinical and laboratory data were extracted from the medical records by independent research personnel. The clinical data included baseline information [such as gender, age, body mass index (BMI), and CTO course], clinical history (smoking status, hypertension, CKD, heart failure, peripheral vascular disease, and cerebrovascular disease), symptom evaluation [Canadian Cardiovascular Society (CCS) angina severity classification], other relevant medical information, details of the surgical procedure (such as CTO length, lesion length in the target vessel, total stent length, number of vessels with CTO, CTO location, and PCI success/failure), and postoperative follow-up data.

Follow-up and clinical outcomes

Participants were followed-up by telephone interview, outpatient visit, or physician contact from the day of surgery to 1 April 2020. Those lost to very long-term follow-up were censored at the time of their last contact. The outcomes included all-cause death (death during follow-up due to any reason), major adverse cardiovascular events [MACEs, defined as a composite of cardiac death, myocardial infarction (MI) and TVR], readmission (rehospitalization due to cardiovascular-related diseases), and recurrent angina (the recurrence or worsening of angina after surgery).

Statistical analysis

For the analysis, participants were divided into 2 groups according to the presence of DM. Missing data analysis procedures were used to directly delete missing values. Normally-distributed continuous data were presented as the mean ± standard deviation (SD) and were compared between groups using Student's *t*-test. Non-normally distributed continuous data were described as median and interquartile range (IQR) and were compared between groups using the Wilcoxon rank-sum test. Categorical data were presented as frequencies or percentages and compared between groups using the chi-squared test or Fisher's exact test, as appropriate. A 2-sided P value <0.05 was considered statistically significant. A multivariable model was built by stepwise variable selection with entry and exit criteria set at the P≤0.1 level, and odds ratios (OR), 95% confidence intervals (95% CI) were calculated. All statistical analyses were performed using SPSS 20.0 (IBM Corp., Armonk, NY, USA).

Results

Baseline clinical characteristics of participants

A total of 187 consecutive patients undergoing PCI for CTO were enrolled during the study period. The 187 participants had a mean age of 62.6±11.5 years (152 males aged 60±11 years and 35 females aged 72±8 years). A total of 99 participants (52.9%) had DM. The baseline clinical characteristics of participants are shown in *Table 1*. Participants with DM had significantly higher BMI, fasting blood glucose level, glycated hemoglobin (HbA1c) level, glycated albumin (GA) level, triglyceride (TG) level, and use of angiotensin receptor blockers than those without DM (P<0.05 for all parameters; *Table 1*). Note that, for this analysis, a total of 19 patients (10.2%) were lost to follow-up. There was no significant difference between the DM group and non-DM group in the number of patients lost to follow-up (14 *vs.* 5 cases; P=0.095).

Angiographic and procedural characteristics

Table 2 summarizes the angiographic and procedural characteristics. The majority of participants had multivessel disease, and this was more common in those with DM than in those without DM (85.9% *vs.* 71.6%, P<0.05). Lesions in the lateral circumflex artery (LCX) and CTO of the

Table 1 Baseline clinical characteristics of the participants stratified according to DM status

Characteristic	All (n=187), n (%)	DM (n=99), n (%)	Non-DM (n=88), n (%)	P value
Gender, male	152 (81.3)	82 (82.8)	70 (79.5)	0.556
Age, years	62.6±11.5	62.1±11.0	63.1±12.2	0.541
BMI, kg/m^2	25.7±3.8	27.1±3.7	23.6±2.3	0.004
Clinical history				
Smoker	94 (50.3)	50 (50.5)	44 (50.0)	0.945
Hypertension	138 (73.8)	77 (77.8)	61 (69.3)	0.189
Cerebrovascular disease	46 (24.6)	26 (26.3)	20 (22.7)	0.575
Peripheral artery disease	38 (20.3)	18 (18.2)	20 (22.7)	0.441
Chronic kidney disease	21 (11.2)	10 (10.1)	11 (12.5)	0.604
Prior CABG	2 (1.1)	2 (2.0)	0 (0.0)	
Diagnosis and cardiac function				
NSTEMI	45 (24.1)	27 (27.3)	18 (20.5)	0.276
STEMI	9 (4.8)	4 (4.0)	5 (5.7)	0.737
CCS I	13 (7.0)	6 (6.1)	7 (8.0)	0.611
CCS II	29 (15.5)	18 (18.2)	11 (12.5)	0.284
CCS III	52 (27.8)	26 (26.3)	26 (29.5)	0.619
CCS IV	39 (20.9)	18 (18.2)	21 (23.9)	0.340
LVEF, %	59.3±11.5	57.8±12.4	60.9±10.4	0.100
Laboratory tests				
Homocysteine, μmol/L	15.9±8.4	18.0±11.5	14.0±3.9	0.315
Lactate, mmol/L	2.4±0.5	2.3±0.6	2.6±0.4	0.220
Serum creatinine, μmol/L	76.6±22.7	80.2±28.0	73.8±18.6	0.569
eGFR, mL/min/1.73 m^2	85.1±25.0	86.9±25.0	83.2±25.0	0.311
Fasting glucose, mmol/L	7.4±3.5	8.9±4.0	5.7±1.3	<0.001
Glycated hemoglobin, %	6.7±1.4	7.4±1.6	5.7±0.6	<0.001
Glycated albumin, %	16.7±5.1	19.1±5.5	13.9±2.6	<0.001
Total cholesterol, mmol/L	4.0±1.3	4.1±1.2	4.0±1.3	0.557
Triglycerides, mmol/L	1.9±1.6	2.2±2.0	1.6±0.7	0.012
HDL-c, mmol/L	0.9±0.2	0.9±0.2	0.9±0.3	0.400
LDL-c, mmol/L	2.5±1.0	2.5±0.9	2.5±1.1	0.997
Drug treatment				
Antiplatelet agent	183 (97.9)	98 (99.0)	85 (96.6)	0.344
ACEI/ARB	118 (63.1)	71 (71.7)	47 (53.4)	0.010
ACEI	61 (32.6)	34 (34.3)	27 (30.7)	0.594
ARB	57 (30.5)	37 (37.4)	20 (22.7)	0.030

Table 1 (*continued*)

Table 1 (*continued*)

Characteristic	All (n=187), n (%)	DM (n=99), n (%)	Non-DM (n=88), n (%)	P value
Beta-blocker	152 (81.3)	82 (82.8)	70 (79.5)	0.566
Calcium channel blocker	52 (27.8)	25 (25.3)	27 (30.7)	0.408
Diuretic	35 (18.7)	21 (21.2)	14 (15.9)	0.353
Nitrate	59 (31.6)	34 (34.3)	25 (28.4)	0.383
Statin	179 (95.7)	94 (94.9)	85 (96.6)	0.580

Data are presented as mean ± standard deviation or n (%). DM, diabetes mellitus; BMI, body mass index; ACEI, angiotensin-converting enzyme inhibitors; ARB, angiotensin receptor blocker; CABG, coronary artery bypass graft; CCS, Canadian Cardiovascular Society; eGFR, estimated glomerular filtration rate; HDL-c, high density lipoprotein cholesterol; LDL-c, low density lipoprotein cholesterol; LVEF, left ventricular ejection fraction; NSTEMI, non-ST segment elevation myocardial infarction; STEMI, ST segment elevation myocardial infarction.

LCX were more common in participants with DM than in those without DM (P<0.05 for both parameters; *Table 2*). All other angiographic features were comparable between groups (*Table 2*). The complete revascularization rate was similar for participants with DM (82.8%) and those without DM (84.1%). The overall success rate of PCI for CTO was 92.5%. Furthermore, the success rate of PCI for CTO did not differ significantly between participants with DM and those without DM (89.9% and 95.4%, respectively).

Clinical outcomes

A total of 4 participants (2.1%) died during a median follow-up time of 20.5 months (IQR, 13.0–27.8 months). *Table 3* compares the clinical outcomes between participants with DM and those without DM.

Subgroup analyses

Subgroup analyses of participants in the DM and non-DM groups were carried out to determine whether hypertension, CKD, and incomplete revascularization were factors associated with clinical outcomes (*Table 4*). Hypertension was not associated with any of the clinical outcomes in either the DM or non-DM group. However, CKD was associated with a significantly higher incidence of all-cause death, MACEs, readmission, and recurrence of angina in participants without DM (P<0.05 for all parameters; *Table 4*). Additionally, incomplete revascularization was associated with a significantly higher incidence of TVR, MI, readmission and recurrence of angina in patients without DM (P<0.05 for all parameters; *Table 4*).

Analysis of factors associated with clinical outcomes

The results of the univariable and multivariable regression analyses are detailed in *Table 5*. Multivariable analyses revealed that CTO in a branch vessel was independently associated with higher odds of all-cause death (OR: 53.56; 95% CI: 2.48 to 1,155.41; P<0.05) and higher odds of failure of PCI for CTO (OR: 5.40; 95% CI: 1.263 to 23.098; P<0.05). Furthermore, PCI for single CTO was independently associated with lower odds of MACEs (OR: 0.300; 95% CI: 0.118 to 0.765; P<0.05).

Discussion

The main findings of this study were as follows: (I) among participants with CTO who underwent PCI, those with DM had a higher BMI and triglyceride level and more common use of angiotensin receptor blockers (which would be in accordance with current guidelines) than those without DM; (II) multiple coronary artery disease was common in participants with CTO and DM, with the LCX frequently involved; (III) there were no significant differences in clinical outcomes between patients with DM and those without DM; (IV) CTO of a branch vessel was an independent predictor of cardiac mortality and PCI failure for CTO, while successful treatment of single CTO with PCI was associated with a reduced incidence of MACEs; and (V) in participants without DM, CKD was associated with a worse prognosis. Taken together, our findings demonstrate that PCI has a high success rate in the management of CTO in both patients with DM and those without DM. Furthermore, clinical outcomes after PCI for

Table 2 Angiographical and procedural characteristics stratified according to DM status

Variables	All (n=187), n (%)	DM (n=99), n (%)	Non-DM (n=88), n (%)	P value
Vessels with lesion				
LM	24 (12.8)	14 (14.1)	10 (11.4)	0.571
LAD	146 (78.1)	81 (81.8)	65 (73.9)	0.189
LCX	129 (69.0)	77 (77.8)	52 (59.1)	0.006
RCA	141 (75.4)	76 (76.8)	65 (73.9)	0.645
Ramus	11 (5.9)	6 (6.1)	5 (5.7)	0.913
Total vessels, n	451	254	197	
Multivessel disease	148 (79.1)	85 (85.9)	63 (71.6)	0.017
Vessels with CTO				
LAD	74 (39.6)	36 (36.4)	38 (43.2)	0.371
LCX	60 (32.1)	40 (40.4)	20 (22.7)	0.010
RCA	107 (57.2)	56 (56.6)	51 (58.0)	0.848
Ramus	5 (2.7)	1 (1.0)	4 (4.5)	0.189
Total vessels, n	246	133	113	
Multivessel CTO	51 (27.3)	29 (29.3)	22 (25.0)	0.631
Location of CTO				
Proximal	103 (55.1)	55 (55.6)	48 (50.0)	0.806
Mid	78 (41.7)	44 (44.4)	34 (38.6)	0.690
Distal	43 (23.0)	23 (23.2)	20 (22.7)	0.995
Total vessels, n	246	133	113	
Complete revascularization	156 (83.4)	82 (82.8)	74 (84.1)	0.817
Incomplete revascularization	31 (16.6)	17 (17.2)	14 (15.9)	0.817
Failure of PCI for CTO	14 (7.5)	10 (10.1)	4 (4.5)	0.203
Success of PCI for CTO	173 (92.5)	89 (89.9)	84 (95.4)	0.151
Contrast amount, mL, mean ± SD	269.5±114.3	250±180	240±100	0.473

Data are presented as mean ± standard deviation or n (%). CTO, chronic total occlusion; DM, diabetes mellitus; LAD, left anterior descending artery; LCX, left circumflex artery; LM, left main artery; PCI, percutaneous coronary intervention; RCA, right coronary artery; SD, standard deviation.

CTO are comparable between patients with DM and those without DM.

In the present study, 52.9% (99/187) of participants had DM, while previous research has indicated that 27–45% of patients with CTO have DM (16,17,24). The high prevalence of DM among patients with CTO is consistent with the finding that patients with DM tend to have more severe and widespread coronary atherosclerosis than those without DM (25). Additionally, our cohort contained far more males (81.3%) than females (18.7%), which is consistent with previous studies of patients with CTO (26,27). Interestingly, the female participants were on average 10 years older than the male patients, which might reflect a delay in the disease process in women due to them being at lower risk of coronary atherosclerotic disease before menopause. It is also recognized that women with ischemic heart disease are more likely to receive medical treatment and less likely to undergo PCI than men (28). We also

Table 3 Clinical outcomes for patients with DM and those without DM

Parameter	All (n=187), n (%)	DM (n=99), n (%)	Non-DM (n=88), n (%)	P value
Follow-up time (months), mean ± SD	20.5±9.9	20.2±9.6	20.9±10.2	0.691
All-cause death	4 (2.4)	1 (1.2)	3 (3.6)	0.300
Cardiac death	1 (0.6)	0 (0.0)	1 (1.2)	
MACE	23 (13.7)	12 (14.1)	11 (13.3)	0.871
Myocardial infarction	11 (6.5)	8 (9.4)	3 (3.6)	0.129
Target vessel revascularization	15 (8.9)	8 (9.4)	7 (8.4)	0.824
Readmission	41 (24.4)	18 (21.2)	23 (27.7)	0.324
Angina recurrence	42 (25.0)	17 (20.0)	25 (30.1)	0.130

Data are presented as mean ± standard deviation or n (%). DM, diabetes mellitus; MACE, major adverse cardiovascular event; SD, standard deviation.

Table 4 Subgroup analyses evaluating hypertension, chronic kidney disease, and incomplete revascularization as possible factors associated with clinical outcomes

Subgroup	Stratification factor	All-cause death	Cardiac death	MACE	MI	TVR	Readmission	Angina recurrence
DM (n=85)	HT (n=65), n (%)	0	0	10 (15.4)	7 (10.8)	8 (12.3)	16 (24.6)	16 (24.6)
	Non-HT (n=20), n (%)	1 (5.0)	0	2 (10.0)	1 (5.0)	0	2 (10.0)	1 (5.0)
	P value			0.723	0.671		0.219	0.062
Non-DM (n=83)	HT (n=56), n (%)	2 (3.6)	1 (1.8)	5 (8.9)	2 (3.6)	3 (5.4)	14 (25.0)	17 (30.4)
	Non-HT (n=27), n (%)	1 (3.7)	0	6 (22.2)	1 (3.7)	4 (14.8)	9 (33.3)	8 (29.6)
	P value	0.976		0.094	1	0.207	0.427	0.946
DM (n=85)	CKD (n=8), n (%)	0	0	0	0	0	2 (25.0)	2 (25.0)
	Non-CKD (n=77), n (%)	1 (1.3)	0	12 (15.6)	8 (10.4)	8 (10.4)	16 (20.8)	15 (19.5)
	P value						0.675	0.658
Non-DM (n=83)	CKD (n=8), n (%)	2 (25.0)	1 (12.5)	3 (37.5)	1 (12.5)	0	5 (62.5)	6 (75.0)
	Non-CKD (n=75), n (%)	1 (1.3)	0	8 (10.7)	2 (2.7)	7 (9.3)	18 (24.0)	19 (25.3)
	P value	0.023		0.033	0.265		0.021	0.008
DM (n=85)	CR (n=71), n (%)	1 (1.4)	0	9 (12.7)	5 (7.0)	5 (7.0)	14 (19.7)	14 (19.7)
	Non-CR (n=14), n (%)	0	0	3 (21.4)	3 (21.4)	3 (21.4)	4 (28.6)	3 (21.4)
	P value			0.408	0.092	0.092	0.483	0.884
Non-DM (n=83)	CR (n=69), n (%)	3 (4.3)	1 (1.4)	8 (11.6)	2 (2.9)	3 (4.3)	15 (21.7)	18 (26.1)
	Non-CR (n=14), n (%)	0	0	3 (21.4)	1 (7.1)	4 (28.6)	8 (57.1)	7 (50.0)
	P			0.386	0.043	0.014	0.018	0.075

Data are presented as n (%). CKD, chronic kidney disease; CR, complete revascularization; DM, diabetes mellitus; HT, hypertension; MACE, major adverse cardiovascular event; MI, myocardial infarction; TVR, target vessel revascularization.

Table 5 Logistic regression analysis of factors associated with clinical outcomes

Factor	Regression	All-cause death		MACE		PCI failure for CTO	
		OR (95% CI)	P value	OR (95% CI)	P	OR (95% CI)	P value
CTO in branch	Univariable	13.333 (1.127–157.800)	0.04	1.602 (0.171–15.004)	0.68	7.810 (2.020–30.462)	0.003
	Multivariable	53.56 (2.480–1,155.410)	0.011	2.173 (0.164–28.758)	0.556	5.400 (1.263–23.098)	0.023
Success of single PCI for CTO	Univariable	1.169 (0.119–11.533)	0.893	0.360 (0.146–0.887)	0.026		
	Multivariable	3.410 (0.204–56.889)	0.341	0.3 (0.118–0.765)	0.012		
CKD	Univariable	10.714 (1.400–81.993)	0.022	0.657 (0.172–2.509)	0.538	0.740 (0.154–3.562)	0.707
	Multivariable	4.181 (0.340–51.391)	0.264	0.705 (0.177–2.808)	0.62	0.603 (0.094–3.851)	0.593
CCS IV	Univariable	4.125 (0.560–30.408)	0.164	2.973 (0.662–13.36)	0.155	3.378 (1.171–9.750)	0.024
	Multivariable	4.376 (0.326–58.667)	0.265	3.927 (0.752–20.517)	0.105	2.396 (0.757–7.577)	0.137

CKD, chronic kidney disease; CCS, Canadian Cardiovascular Society; CTO, chronic total occlusion; MACE, major adverse cardiovascular event; PCI, percutaneous coronary intervention; OR, odds ratio; CI, confidence interval.

found that patients with DM had a higher level of TG than those without DM, in agreement with research showing that lipid metabolism disorders often co-exist with DM and accelerate the atherosclerotic process (26). In our study, Patients with DM had significantly higher fasting blood glucose levels, which further analysis found no correlation with mortality. However, Sinnaeve *et al.* demonstrate that fasting blood glucose levels at admission are associated with increased mortality after acute myocardial infarction (AMI), and the increased risk is short-term and 6-month mortality (29).

Diabetes is one important risk factor for CAD. The accelerated atherosclerotic burden and increased CTO lesions complicated observed in diabetic individuals. Compared with non-diabetic individuals, Patients with DM often present with diffuse, small-vessel and multivessel coronary artery disease. The anatomical coronary complexity and metabolic disorders in patients with DM may results in more challenging vessel revascularization and worse long-term prognosis (30). In our study, multivessel disease was significantly more frequent in participants with DM than in those without DM, which is in agreement with previous research (25). Interestingly, the LCX was more commonly involved in patients with DM. Lesions of the LCX are considered to increase the risk of coronary artery perforation and the difficulty of surgery, and CTO of the LCX has been included in a model predicting the success rate of PCI for CTO (31). Nevertheless, we did not observe any significant differences in complete revascularization rate or PCI success rate between the DM and non-DM groups. Although a previous report suggested that the complete recanalization rate was lower for patients with DM than for those without DM (26), other studies have described similar angiographic outcomes for the 2 groups (32), which would be consistent with our results. The high recanalization rate observed in our study is an important finding, because successful recanalization is an independent predictor of long-term survival (33-36). The prevalence of concomitant CTO in patients with MI-associated cardiogenic shock is associated with adverse outcomes. Within a CULPRIT-SHOCK sub-analysis, the presence of a non-infarct related CTO in patients with cardiogenic shock was higher and was associated with a higher rate of death at 30 days and 1 year. while a strategy of culprit-lesion-only PCI seems beneficial regardless of the presence of CTO (37).

Some clinical studies have suggested that patients with CTO and DM are at higher risk of long-term adverse outcomes (such as MACEs, TVR, and death) than those with CTO who do not have DM (36,38). Different from the results of Sanguineti *et al.*, we found that diabetes was not a predictor of cardiac mortality in patients with CTO lesion and CTO recanalisation also cannot reduced cardiac mortality and MACEs among diabetic patients (27). The different results may be come from the development of equipment and technique in recent years. Recently other studies also found no significant difference in the procedural success or safety of CTO PCI and similar improvements in health status following CTO PCI between patients with and without diabetes (26). However, the concept that high-risk patients are less frequently treated than lower

risk individuals, a so-called 'treatment-risk paradox', is not new in the field of PCI (30). A notable finding of the present study was that the clinical outcomes did not differ significantly between participants with DM and those without DM. Our observations are consistent with those of 2 previous studies (32,39), which implies that patients with CTO and DM can achieve the same benefit from PCI as those without DM. Nevertheless, prospective, randomized studies are needed to directly compare the clinical benefits of PCI for CTO between patients with DM and those without.

Previous studies have reported that revascularization is superior to medical therapy as a treatment for CTO in patients with DM (24) and CKD (40). In our study, CKD was associated with a significantly higher incidence of adverse clinical outcomes including all-cause death, MACEs, readmission, and recurrence of angina. The above finding concurs with prior research indicating that renal insufficiency is an important predictor of mortality after PCI for CTO (41,42). However, additional data are needed to fully establish the relevance of CKD to the outcomes of patients with CTO who are treated using PCI.

Our multivariable regression analysis showed that CTO of a coronary branch was associated with increased odds of PCI failure and all-cause death. The presence of DM is a risk factor for collateral circulation formation, and branch lesions can reflect the coronary collateral circulation (CCC) to some extent. The quantity of viable myocardium is associated with the CCC, which may be an underlying factor that impacts on left ventricular ejection fraction (43,44). Therefore, preoperative imaging should be performed to evaluate the viable myocardium supplied by the affected artery and screen for patients predicted to respond to revascularization. The treatment of CAD using invasive PCI has evolved dramatically in the last decades. The main evolvement is the update of stents and the application of new techniques. The next major advance in the evolving field of PCI may be the biodegradable polymer stents and bioresorbable vascular scaffolds, although their efficacy, safety and ultimately their place in therapy remain to be determined.

This study had some limitations. First, this study was a retrospective study, so these results may be prone to selection bias or information bias. Second, this was a single-center study, so it is not known whether the findings are generalizable, and it needs to be further confirmed by multi-center clinical trials. Third, the sample size was small, so the study may have been underpowered to detect some real differences between groups. Fourth, this observational study did not provide a comparison of outcomes with a medically treated arm. Fifth, the data were collected using the hospital information system and telephone follow-up, and it is possible that unknown confounding factors in the information gathering process may have affected the results. Additionally, the results of this study may have been influenced by the selection criteria, operator experience, and varying techniques used by the operators.

Conclusions

Although multiple coronary artery lesions were more common in participants with DM than in those without DM, procedural success rate and clinical outcomes were comparable between the 2 groups. Additionally, coronary branch disease was associated with a higher rate of failure of PCI for CTO.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was approved by the Ethics Committee of the China-Japan Friendship Hospital (No. 2020-14-K11) and complied with the principles outlined in the Declaration of Helsinki (as

revised in 2013). All participants signed informed consent documents for the procedure itself and for the use of their anonymized data in research.

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