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CLINICAL RESEARCH

Successful Recanalization of Chronic Total Occlusions Is Associated With Improved Long-Term Survival

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Objectives This study investigated the impact of procedural success on mortality following chronic total occlusion (CTO) percutaneous coronary intervention (PCI) in a large cohort of patients in the drug-eluting stent era.

Background Despite advances in expertise and technologies, many patients with CTO are not offered PCI.

Methods A total of 6,996 patients underwent elective PCI for stable angina at a single center (2003 to 2010), 836 (11.9%) for CTO. All-cause mortality was obtained to 5 years (median: 3.8 years; interquartile range: 2.0 to 5.4 years) and stratified according to successful chronic total occlusion (sCTO) or unsuccessful chronic total occlusion (uCTO) recanalization. Major adverse cardiac events (MACE) included myocardial infarction (MI), urgent revascularization, stroke, or death.

Results A total of 582 (69.6%) procedures were successful. Stents were implanted in 97.0% of successful procedures (mean: 2.3 ± 0.1 stents per patient, 73% drug-eluting). Prior revascularization was more frequent among uCTO patients: coronary artery bypass grafting (CABG) (16.5% vs. 7.4%; $p < 0.0001$), PCI (36.0% vs. 21.2%; $p < 0.0001$). Baseline characteristics were otherwise similar. Intraprocedural complications, including coronary dissection, were more frequent in unsuccessful cases (20.5% vs. 4.9%; $p < 0.0001$), but did not affect in-hospital MACE (3% vs. 2.1%; p = NS). All-cause mortality was 17.2% for uCTO and 4.5% for sCTO at 5 years ($p < 0.0001$). The need for CABG was reduced following sCTO (3.1% vs. 22.1%; $p < 0.0001$). Multivariate analysis demonstrated that procedural success was independently predictive of mortality (hazard ratio [HR]: 0.32 [95% confidence interval (CI): 0.18 to 0.58]), which persisted when incorporating a propensity score (HR: 0.28 [95% CI: 0.15 to 0.52]).

Conclusions Successful CTO PCI is associated with improved survival out to 5 years. Adoption of techniques and technologies to improve procedural success may have an impact on prognosis. (J Am Coll Cardiol Intv 2012;5:380–8) © 2012 by the American College of Cardiology Foundation

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Percutaneous treatment of chronic total occlusion (CTO) remains a challenge. Despite being commonly encountered in patients undergoing coronary angiography (1,2), recanalization of a CTO is attempted in only 10% to 15% of patients undergoing percutaneous coronary intervention (PCI) (3). CTO PCI procedures may be lengthy and complex, with elevated radiation exposure, increased contrast load, lower procedural success rate, and a higher risk of complication when compared with non-CTO elective PCI (4,5). Moreover, there is uncertainty as to the prognostic impact of percutaneous CTO revascularization. Patients with chronically occluded single-vessel disease are often managed medically regardless of the severity of symptoms and extent of ischemia, as the anatomy is deemed to be stable. Meanwhile, those with multivessel disease involving a CTO may be referred for bypass graft surgery even if other lesions are suitable for PCI (1,6).

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Data from small cohorts in the pre–drug-eluting stent (DES) era do not give a clear picture, with some indicating that successful CTO PCI may improve left ventricular function and survival when compared with failed CTO PCI (7–9), and some not (10,11). A more recent multicenter registry does suggest that successful CTO PCI decreases cardiac mortality, with a reduced requirement for bypass surgery (12). Clarifying the long-term clinical outcomes of CTO PCI is therefore important to justify potential investments in training and technology, and the potential risks involved.

In the present study, we report outcomes from a large cohort of consecutive patients undergoing PCI for CTO in the DES era. The main aim of the study was to assess the effect of procedural success on long-term outcome (mortality, further revascularization).

Methods

Study population. A total of 7,713 consecutive patients underwent elective PCI for stable angina at a single high-volume cardiac center in London, United Kingdom, from October 2003 to May 2010; 6,996 (91%) had completed database records and National Health Service (NHS) numbers, and were included in the analysis. Eight hundred thirty-six (11.9%) procedures were performed for CTOs (Fig. 1). A CTO was defined as a complete obstruction of the vessel with Thrombolysis In Myocardial Infarction (TIMI) flow grade 0 and an estimated duration of ≥3 months (13,14). Patients undergoing an initial unsuccessful procedure but undergoing a subsequent successful attempt were classified as successful. Data were prospectively entered into a clinical database at the time of the PCI by the performing physician. Data collected included patient characteristics (age, previous myocardial infarction [MI]/PCI/coronary artery bypass grafting [CABG], hypertension, diabetes mellitus, hypercholesterolemia, peripheral vascular disease, New York Heart Association functional class, smoking status, chronic renal failure [CRF]: creatinine >200 μmol/l or on renal replacement therapy, left ventricular function, and cardiogenic shock) and procedure-related data (indications for PCI, target vessel, number of diseased vessels, use of intravascular ultrasound/pressure wire, use of DES and glycoprotein [GP] IIb/IIIa inhibitor). The group of patients excluded from the study due to incomplete data entry or absent NHS number contained a similar proportion of CTOs as the study population (9.9%).

A total of 19 individual senior interventional cardiologists performed CTO procedures. All patients were pre-treated with aspirin and clopidogrel (a loading dose of 300 to 600 mg before the procedure). After the procedure, all patients were given aspirin indefinitely and either clopidogrel 75 mg daily for at least 4 weeks after implantation of bare-metal stents (BMS), or for at least 12 months after implantation of a DES. DES used included sirolimus-eluting stents, paclitaxel-eluting stents, zotarolimus-eluting stents, and everolimus-eluting platforms. GP IIb/IIIa inhibitors were given at the discretion of the operator. All CTO interventions were performed via an antegrade approach. A successful PCI was defined as final TIMI flow grade ≥2 and a residual stenosis ≤30% after stent implantation.

Endpoints. In-hospital outcomes recorded included in-hospital death, Q-wave MI (new pathological Q waves in the coronary distribution of the treated artery with an increase of creatine kinase-myocardial band to ≥2 times the reference value or significant elevation in troponin T), and target vessel revascularization (TVR) by both PCI and CABG. Major adverse cardiac event (MACE) was defined as a composite of MI, all-cause mortality, TVR, and stroke. Non-MACE complications recorded included arterial complications, aortic dissection, coronary dissection (dissection defined as unintentional intimal disruption based on angiographic appearance using the National Heart, Lung, and Blood Institute classification system for intimal tears [15]), side-branch occlusion, heart block, and direct current cardioversion. All-cause

Abbreviations and Acronyms

BMS = bare-metal stent(s)
CABG = coronary artery bypass grafting
CI = confidence interval
CRF = chronic renal failure
CTO = chronic total occlusion
DES = drug-eluting stent(s)
GP = glycoprotein
HR = hazard ratio
LAD = left anterior descending coronary artery
MACE = major adverse cardiac event(s)
MI = myocardial infarction
NHS = National Health Service
PCI = percutaneous coronary intervention
sCTO = successful chronic total occlusion recanalization
TVR = target vessel revascularization
uCTO = unsuccessful chronic total occlusion recanalization

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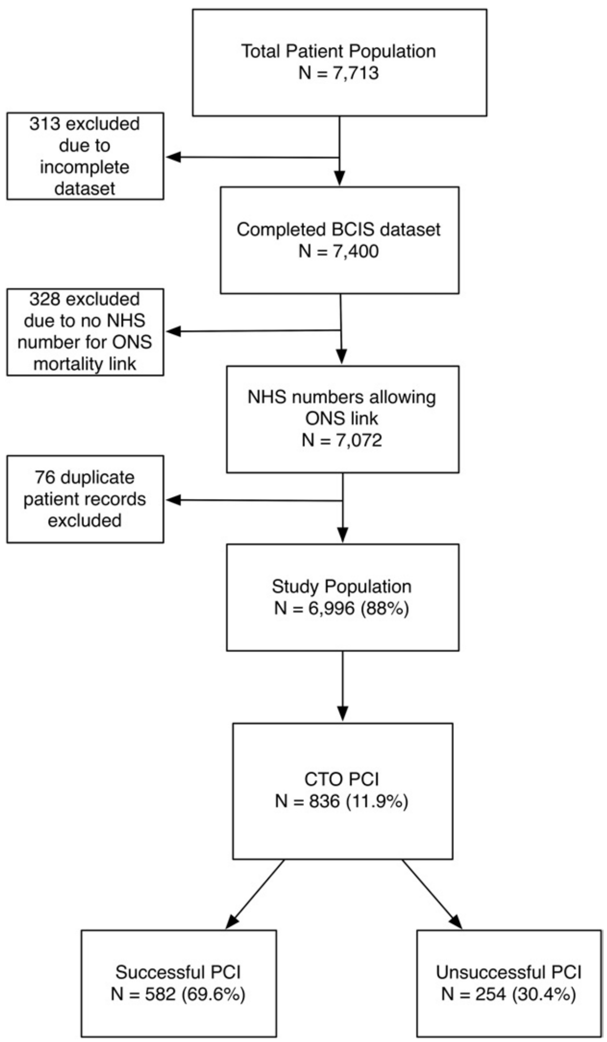

Figure 1. Flow Diagram of Patients Treated by PCI

Patients were treated between October 2003 and May 2010. The flowchart describes patient exclusions and make-up of study population. BCIS = British Cardiovascular Intervention Society; CTO = chronic total occlusion; NHS = National Health Service; ONS = Office National Statistics; PCI = percutaneous coronary intervention.

mortality data were recorded as of September 21, 2010, and obtained via the British Cardiovascular Intervention Society–U.K. Central Cardiac Audit Database. This national database is linked to the U.K. Office of National Statistics and provides live/death status of treated patients. Only patients who had complete database records and NHS unique numbers (allowing live/death status to be assessed) were included in the analysis. A retrospective data quality audit of 100 randomly selected medical records established that 94.8% of data fields, including complications, were entered correctly into the database. Patient outcomes were stratified according to successful (sCTO) or unsuccessful (uCTO) CTO recanalization. Long-term TVR procedures were identified from the interventional database, surgical database, and the patients' electronic clinical records. All surgical revascularization procedures following PCI were identified from the cardiac surgical database.

Ethics. The data were collected as part of a national cardiac audit, and all patient identifiable fields were removed before analysis. The local ethics committee confirmed that formal ethical approval was not required.

Statistical analysis. Clinical characteristics of CTO patients treated successfully versus unsuccessfully, and CTO PCI versus non-CTO PCI were compared using the Pearson chi-square test for categorical variables and Student *t* test for continuous variables. We calculated Kaplan-Meier product limits for cumulative probability of reaching an endpoint and used the log-rank test for evidence of a statistically significant difference between the groups. Time was measured from the first admission for a procedure to outcome (all-cause mortality). Cox regression analysis was used to estimate hazard ratios (HRs) for the effect of procedural success in age-adjusted and fully adjusted models, based on covariates ($p < 0.05$) associated with the outcome. A propensity score analysis was carried out using a nonparsimonious logistic regression model comparing successful and unsuccessful procedures (16). Model discrimination (C-statistic) was assessed using the area under the receiver-operating characteristic curve. Multiple variables were included in the model, including all variables with significant interactions. We then undertook a regression adjustment incorporating the propensity score into a proportional hazard model as a covariate. We used SPSS for Mac version 18.0 (IBM, Armonk, New York) for all analyses.

Results

Of the 836 procedures undertaken, 582 (69.6%) of the CTO PCIs were successful. Follow-up data were obtained out to 5 years (median: 3.8 years [interquartile range: 2.0 to 5.4 years]). Of the 582 that were successful, 570 (97.9%) were successful at first attempt, and 12 (2.1%) were successful at a subsequent attempt.

Patient characteristics. Baseline characteristics stratified according to successful versus unsuccessful CTO PCI are demonstrated in Table 1. Characteristics of 6,160 stable patients undergoing a PCI for non-CTO lesions during the same period are included for comparison. Previous revascularization with both PCI and CABG was more frequent among patients with uCTO versus sCTO PCI. There were similar mean ejection fractions in the 2 groups, but there was a higher number of patients with an ejection fraction <40% in the unsuccessful group. Demographics were otherwise similar between these groups.

Procedural characteristics. Four hundred fifty-one patients (53.9%) had single-vessel disease, with 385 patients (46.1%) having multivessel disease (Table 2). Six hundred sixty-one

Table 1. Baseline Characteristics According to Procedural Success

Variable	sCTO (n = 582)	uCTO (n = 254)	p Value	Non-CTO PCI (n = 6,160)	p Value (sCTO vs. non-CTO)
Age, yrs	62.37 ± 11.5	63.7 ± 11.2	0.113	63.2 ± 10.9	0.201
Female	141 (24.3)	53 (20.8)	0.267	1,709 (27.7)	0.077
Caucasian	352 (60.5)	150 (59.0)	0.482	4,441 (72.1)	<0.0001
Hypertension	372 (63.9)	169 (66.7)	0.456	3,326 (54.0)	<0.0001
Diabetes mellitus	157 (27.0)	73 (28.6)	0.632	1,681 (27.3)	0.909
Hypercholesterolemia	327 (56.1)	156 (61.4)	0.183	3,057 (49.6)	0.0029
Previous MI	185 (31.8)	92 (36.4)	0.231	1,161 (18.8)	<0.0001
Previous CABG	43 (7.4)	42 (16.5)	<0.0001	433 (7.0)	0.811
Previous PCI	123 (21.2)	91 (36.0)	<0.0001	1,289 (20.9)	0.948
Severe angina	264 (45.4)	116 (45.8)	0.681	1,796 (29.2)	<0.0001
LVEF	55.6 ± 9.2	53.5 ± 1.4	0.074	56.0 ± 9.2	0.419
EF < 40%	22 (3.8)	18 (7.1)	0.032	87 (1.4)	<0.0001
CRF (creatinine >200) μmol/l	14 (2.4)	4 (1.6)	0.606	136 (2.2)	0.871
PVD	14 (2.4)	8 (3.2)	0.525	160 (2.6)	0.887
Previous CVA	6 (1.0)	3 (1.2)	0.838	76 (1.2)	0.819

Values are mean ± SD or n (%).
CABG = coronary artery bypass grafting; CRF = chronic renal failure; CTO = chronic total occlusion; CVA = cerebrovascular accident; EF = ejection fraction; LVEF = left ventricular ejection fraction; MI = myocardial infarction; PCI = percutaneous coronary intervention; PVD = peripheral vascular disease; sCTO = successful chronic total occlusion recanalization; uCTO = unsuccessful chronic total occlusion recanalization.

(79.1%) patients underwent single-vessel PCI, with the remainder undergoing CTO PCI as part of a multivessel procedure at the same sitting. Of those with multivessel disease undergoing successful initial single-vessel CTO PCI (n = 210), 53 (25.2%) underwent staged treatment and 162 (74.8%) medical therapy for the remaining disease on the basis of symptoms and burden of ischemia. Of those undergoing single-vessel intervention, CTO PCI was per-

Table 2. Procedural Characteristics According to Procedural Success

	sCTO (n = 582)	uCTO (n = 254)	p Value	Non-CTO PCI (n = 6,160)	p Value (sCTO vs. non-CTO)
Arterial access site					
Radial	125 (21.5)	45 (17.8)	0.210	1,959 (31.8)	<0.0001
Femoral	424 (72.9)	185 (72.8)	0.654	4,176 (67.8)	0.01
Dual site (radial/femoral or bilateral femoral)	23 (3.9)	18 (7.0)	0.500		NA
Brachial	10 (1.7)	6 (2.4)	0.743	104 (0.17)	0.908
Single-vessel disease	321 (55.2)	130 (51.2)	0.101	4,238 (68.8)	<0.0001
Multivessel disease	261 (44.8)	124 (48.8)	0.292	1,922 (31.2)	<0.0001
2-vessel	164 (28.1)	64 (25.2)	0.221	1,121 (18.2)	<0.0001
3-vessel	97 (16.7)	60 (23.6)	0.0007	801 (13.0)	<0.0001
Single-vessel intervention	448 (77.0)	213 (83.8)	0.0004	4,164 (67.6)	<0.0001
Average vessels treated	1.32 ± 0.75	1.19 ± 0.62	0.0015	1.26 ± 0.53	0.019
CTO vessel					
Right coronary artery	192 (42.9)	106 (49.8)	0.0003	NA	NA
Left anterior descending	168 (37.5)	64 (30.0)	0.0005	NA	NA
Left circumflex coronary artery	77 (13.2)	35 (16.4)	0.615	NA	NA
Saphenous vein graft	11 (1.9)	8 (3.7)	0.298	NA	NA
Stent deployed	565 (97.0)	NA	NA	5,821 (94.5)	0.01
No. of stents used	2.31 ± 1.5	NA	NA	1.73 ± 1.1	<0.0001
DES	430 (76.1)	NA	NA	3,843 (62.4)	<0.0001
IVUS	25 (4.3)	9 (3.5)	0.513	382 (6.2)	0.08
Glycoprotein IIb/IIa inhibitor	252 (43.3)	20 (7.9)	<0.0001	1,558 (25.3)	<0.0001

Values are n (%) or mean ± SD.
DES = drug-eluting stent(s); IVUS = intravascular ultrasound; NA = not applicable; other abbreviations as in Table 1.

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Table 3. In-Hospital Outcomes and Complications Post-PCI According to Procedural Success

	sCTO (n = 582)	uCTO (n = 254)	p Value
Complications			
Arterial complications	6 (1.0)	2 (0.8)	0.680
Coronary dissection	12 (2.1)	33 (12.9)	<0.0001
Side-branch occlusion	6 (1.0)	1 (0.4)	0.172
No/slow flow	2 (0.3)	3 (1.2)	0.183
Coronary perforation	2 (0.3)	15 (5.9)	<0.0001
Tamponade	0 (0.0)	1 (0.4)	0.303
In-hospital adverse events			
MACE	12 (2.1)	8 (3.1)	0.393
Death	0 (0.0)	1 (0.4)	0.303
Q-wave MI	7 (1.2)	4 (1.6)	0.861
Reintervention PCI	2 (0.3)	0 (0.0)	0.765
CVA	2 (0.3)	1 (0.4)	0.303
Emergency CABG	1 (0.2)	2 (0.8)	0.576

Values are n (%).
Abbreviations as in Table 1.

formed on the left anterior descending coronary artery (LAD) in 232 (35.1%), left circumflex coronary artery in 112 (16.9%), and right coronary artery in 298 (45.1%) patients. Patients in the successful group were more likely to have undergone LAD intervention, whereas those in the unsuccessful group were more likely to have undergone intervention to the right coronary artery. There was no difference in success rates for the circumflex. Radial access was used in 20.3% of all CTO PCI cases compared with 31.8% of elective non-CTO cases ($p < 0.001$). Dual arterial access sites for contralateral injections were used in a low proportion of cases, and numerically more often in unsuccessful procedures, though this difference was not significant.

Coronary stents were implanted in 565 (97.0%) of sCTO procedures. DES were used in 430 (76.1%) cases; this was broken down into 132 (30.9%) sirolimus-eluting stents, 178 (41.4%) paclitaxel-eluting stents, 89 (20.7%) zotarolimus-eluting stents, and 17 (4.0%) everolimus-eluting platforms; 14 (3.3%) patients received DES of different types. GP IIb/IIIa inhibitors were used in a relatively high proportion of successful cases (43%), compared with 25% of all other elective PCI cases ($p = 0.003$).

Clinical outcomes. Procedural complications and in-hospital MACE. Although intraprocedural complications, including coronary dissection, perforation, no reflow, access site dissection, or hematoma, were more frequent in uCTO cases (20.5% vs. 4.9%; $p < 0.0001$), this did not have an impact on in-hospital MACE (Table 3).

All-cause mortality. Procedural success compared with failure was associated with improved all-cause mortality at 5 years of follow-up (4.5% [95% confidence interval (CI): 1.7% to 6.3%] vs. 17.2% [95% CI: 9.7% to 22.6%]; $p < 0.0001$) (Fig. 2A). Mortality among the sCTO PCI cohort was similar to that of patients undergoing non-CTO PCI indications (4.5% [95% CI: 1.7% to 6.6%] vs. 6.7% [95% CI: 5.6% to 7.5%]; $p = 0.1$) (Fig. 2B).

Target vessel revascularization. Total TVR (CABG or PCI) at median follow-up of 3.4 years (interquartile range: 1.8 to 5.2) was 11.5% (95% CI: 5.4% to 20.2%) for successful patients compared with 22.1% in the unsuccessful cohort (95% CI: 15.3% to 27.5%; $p < 0.0001$). All TVR in the unsuccessful group was surgical. The rate of CABG in the successful group was significantly lower (3.1% [95% CI: 0.9% to 4.4%]; $p < 0.0001$) (Fig. 3). The majority of uCTO patients did not undergo any subsequent revascularization procedure.

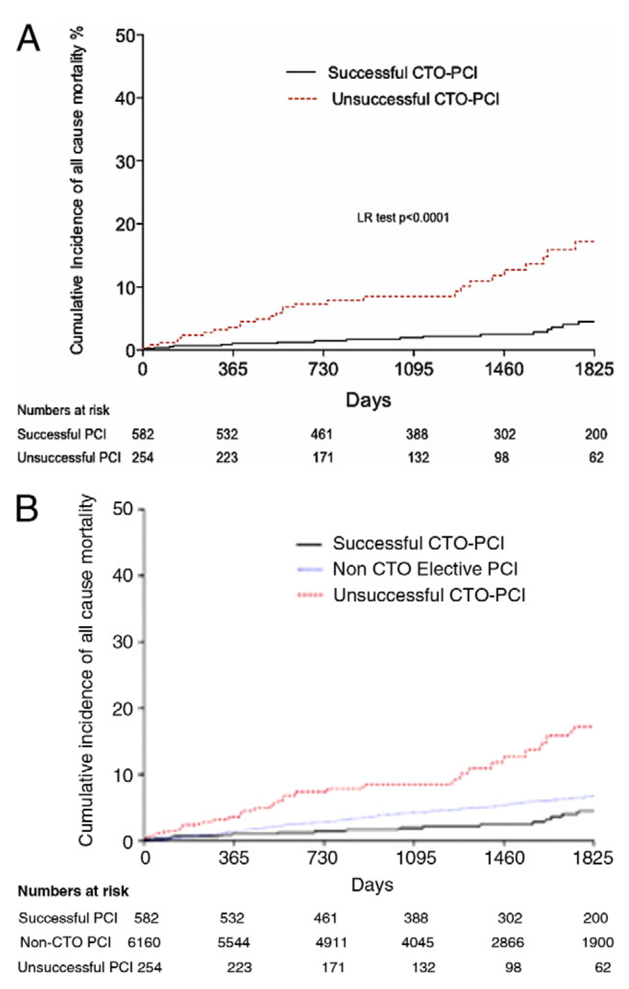

Figure 2. Kaplan-Meier Curves Showing Cumulative Probability of All-Cause Mortality

(A) Kaplan-Meier curves showing cumulative probability of all-cause mortality after percutaneous coronary intervention (PCI) according to procedural success. **(B)** Kaplan-Meier curves showing cumulative probability of all-cause mortality after PCI comparing chronic total occlusion (CTO) and non-CTO PCI.

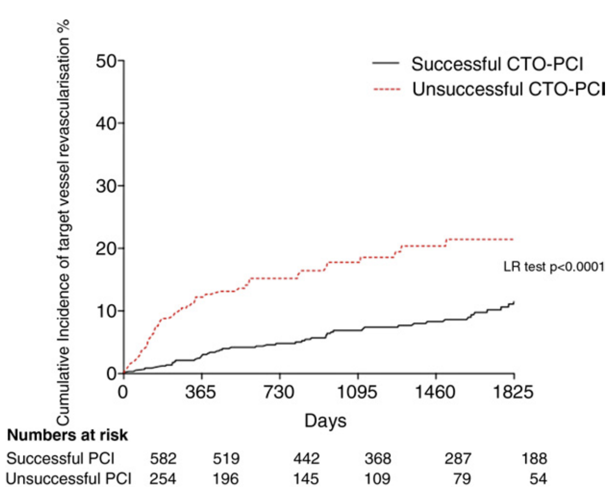

Figure 3. Kaplan-Meier Curves Showing Cumulative Probability of TVR After sCTO and uCTO PCI

LR = log-rank; PCI = percutaneous coronary intervention; sCTO = successful chronic total occlusion recanalization; TVR = target vessel revascularization; uCTO = unsuccessful chronic total occlusion recanalization.

Successful revascularization and all-cause mortality. Over the 5-year follow-up period, patients who were not revascularized following an uCTO procedure had a substantially worse mortality than those who underwent revascularization either with an initial sCTO PCI or an uCTO PCI followed by CABG (21.4% [95% CI: 10.1% to 35.7%] vs. 4.2% [95% CI: 1.2% to 14.8%]; $p < 0.0001$) (Fig. 4).

Predictors of mortality. Cox analysis (Table 4) revealed procedural success to be a predictor of survival compared with procedural failure (HR: 0.27 [95% CI: 0.16 to 0.48]), and this difference was maintained with multiple adjustment (HR: 0.32 [95% CI: 0.18 to 0.58]). Despite the observed increased frequency of successful recanalization in LAD CTO cases, LAD CTO intervention per se was not independently predictive of mortality. Although the number of stents implanted per case was significantly higher in CTO compared with non-CTO PCI ($p < 0.0001$), the use of DES versus BMS was not associated with increased mortality at 5 years. Indeed, there was a trend toward improved mortality (Fig. 5).

Additionally after regression adjustment incorporating the propensity score (C-statistic: 0.78 [95% CI: 0.70 to 0.83]) into a proportional hazards model as a covariate (calculated from age, sex, diabetes, hypertension, hypercholesterolemia, previous CABG, previous PCI, previous MI, multivessel disease, CRF, peripheral vascular disease, cerebrovascular accident, ejection fraction, DES use, LAD intervention, and GP IIb/IIIa use), procedural success remained a predictor of survival (HR: 0.28 [95% CI: 0.15 to 0.52]).

Discussion

Our findings provide long-term follow-up data on the largest single-center series of patients undergoing PCI for a CTO in the DES era reported to date. These data demonstrate that successful percutaneous CTO recanalization was associated with improved 5-year survival, compared with a failed procedure, sCTO and non-CTO PCI cohorts had a similar in-hospital MACE and 5-year survival, suggesting that long-term outcome is not significantly different for patients undergoing successful PCI for a CTO versus a nonoccluded stenosed vessel. The use of DES appeared to be safe, and significantly reduced the need for subsequent revascularization, with TVR rates commensurate with other published series in the DES era (17,18), in comparison with BMS.

Prior studies have described discordant results when evaluating long-term survival following CTO PCI. Older observational studies (14,19) including a meta-analysis (7) have demonstrated a survival benefit if a CTO is successfully treated; however, investigators at the Mayo Clinic reported technical failure of CTO PCI was not associated with increased 10-year mortality (11). The data from the present study are consistent with the Multinational Chronic Total Occlusion Registry (a multicenter study involving 1,791 patients at 3 centers in North America, Italy, and Korea) (12), which also demonstrated improved long-term survival and decreased need for bypass surgery following successful CTO PCI. The authors report a similar rate of procedural success, although the absolute difference in 5 year all-cause mortality was even greater in our cohort. In particular, uCTO PCI patients had a higher 5-year mortality in our study than in the equivalent Multinational Registry cohort (17.2% vs. 8.6%) despite similar demographic characteris-

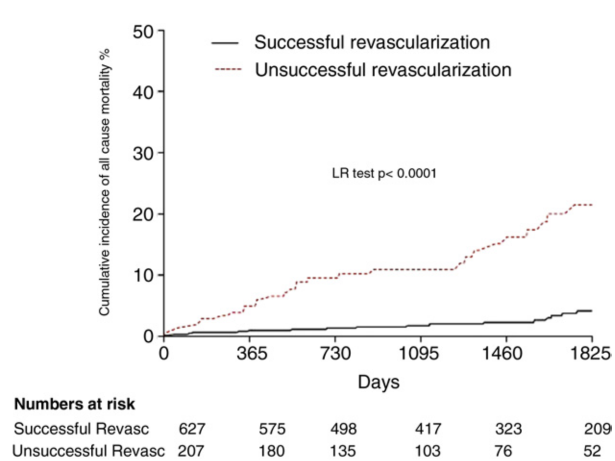

Figure 4. Kaplan-Meier Curves Showing Cumulative Probability of All-Cause Mortality After Successful Revascularization

LR = log-rank; Revasc = revascularization.

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Table 4. Cox Proportional Hazards Model of Univariate and Multivariate Analysis of Predictors of Mortality After PCI for CTO

Variable	Comparator	Univariate (Age Adjusted)	Multivariate*
Age (increase by 1 yr)		1.08 (1.05–1.12)	1.08 (1.05–1.12)
Female	Male	1.41 (0.69–2.91)	NA
Hypertensive	Nonhypertensive	1.31 (0.75–2.29)	NA
Diabetic	Nondiabetic	1.08 (0.57–2.03)	NA
Hyperlipidemia	Nonhyperlipidemia	1.11 (0.63–1.90)	NA
Previous CABG	No previous CABG	2.31 (1.12–4.77)	1.95 (0.91–4.10)
Previous MI	No previous MI	1.84 (1.06–3.21)	1.35 (0.73–2.48)
Previous PCI	No previous PCI	1.21 (0.63–2.33)	NA
Multiple CTO	Single CTO	1.20 (0.38–3.98)	NA
EF >40%	EF <40%	7.63 (3.50–16.64)	3.05 (1.27–7.31)
Creatinine <200 μmol/l	Creatinine >200 μmol/l	4.88 (1.51–15.78)	4.62 (1.36–12.36)
DES	BMS	0.62 (0.25–1.50)	NA
LAD intervention	Non-LAD intervention	0.78 (0.44–1.36)	NA
Success	Failure	0.27 (0.16–0.48)	0.32 (0.18–0.58)

Values are hazard ratios (95% confidence interval). *Adjusted for age, previous MI, previous CABG, CRF, and EF <40%.
BMS = bare-metal stent(s); LAD = left anterior descending coronary artery; NA = not applicable; other abbreviations as in Tables 1 and 2.

tics, left ventricular function, and frequency of subsequent CABG. This may be a consequence of longer follow-up in the present study (median: 3.8 years [interquartile range: 2.0 to 5.4 years] vs. 2.9 years [interquartile range: 1.5 to 4.6 years]), and completeness of follow-up with all deaths captured through the U.K. Office of National Statistics.

As in the Multinational Registry, patients with a history of prior revascularization had a significantly lower rate of procedural success and in turn a worse clinical outcome. This is perhaps not unexpected in the case of previous bypass surgery patients, where vessels may have been occluded for a longer duration, and over long segments, both of which have traditionally been associated with lower success rates using a simple antegrade wire escalation approach.

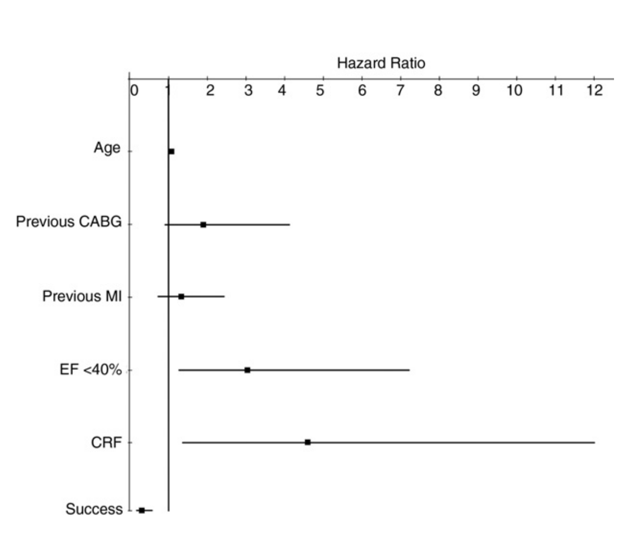

Figure 5. Adjusted HRs of the Cox Analysis for All-Cause Mortality After PCI

95% confidence intervals are given. CABG = coronary artery bypass grafting; CRF = chronic renal failure; EF = ejection fraction; HR = hazard ratio; MI = myocardial infarction; PCI = percutaneous coronary intervention.

In recent years, a number of technological advances and procedural developments have increased the success of PCI for CTOs (7,20). These include retrograde wiring through collateral channels and both antegrade and retrograde subintimal dissection and re-entry techniques. Emerging data from specialist CTO groups in the United States (approximately 90% technical success, 2% MACE) (21), Europe (approximately 83.4% technical success, 2% MACE) (22), and Japan (J group) (approximately 86.6% technical success, 2.3% MACE) (23) show that success rates of 80% to 90% are consistently achievable in experienced hands with a safety profile comparable to standard risk-adjusted PCI. Importantly, procedural success is associated with operator volume (21). In our cohort, 19 individual operators performed CTO procedures during the study period. It is therefore conceivable that a smaller group of high-volume, designated CTO-specific operators may have achieved a higher procedural success rate.

Avoiding CTO revascularization, therefore, on the basis of real or perceived poor success rates, unclear patient benefits, adverse outcomes, time and resource use, or need for coronary bypass surgery may no longer be valid in view of the high success rate and low complication rate in experienced centers (24). Our data add to the growing evidence base that sCTO is associated with improved survival.

Study limitations. As with all observational registry studies, this study was open to selection bias. Although procedural success using solely an antegrade wire escalation strategy was reassuringly high at just under 70%, this may simply imply that more complex patients were excluded from percutaneous revascularization at the outset. Selection bias may also have impacted upon surgical revascularization following uCTO PCI. It is possible that older patients with poor left ventricular function and previous bypass surgery may not have been deemed eligible for further CABG.

Other limitations include the ability to analyze only 91% of individuals who had PCI during this period due to absence of a complete dataset or NHS number, although the excluded group of patients included a similar proportion of CTOs as the study population. Finally, as we report all-cause mortality rather than cardiac death specifically, it is possible that other disease processes could have affected outcome.

As mentioned previously, and as with similar reports, uCTO PCI has been used as a surrogate for medical therapy. However, a randomized trial is required to truly test whether CTO PCI provides prognostic benefit when compared with contemporary optimal medical therapy alone. The Euro CTO (European Study on the Utilisation of Revascularization versus Optimal Medical Therapy for the Treatment of Chronic Total Occlusions) trial will attempt to address precisely this issue (25). This is a study randomizing patients with stable angina and documented evidence of ischemia or viability in the territory supplied by the CTO, to either PCI or optimal medical therapy. The primary endpoint is death and nonfatal MI over a 36-month follow-up period.

Conclusions

Successful CTO PCI is associated with improved survival out to 5 years following intervention. These data suggest that adoption of techniques and technologies to improve procedural success may have an impact on prognosis. A randomized trial is now needed.

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