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Original article

# Comparison of successful percutaneous coronary intervention versus optimal medical therapy in patients with coronary chronic total occlusion

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ABSTRACT

*Background:* Chronic total occlusion (CTO) is a challenging entity in coronary interventions. With improvements in technology and techniques, success rates for percutaneous coronary intervention (PCI) of CTO continue to improve. However, the clinical benefits of PCI remain unclear. The aim of the study was to determine the effectiveness of successful PCI on clinical outcomes using drug-eluting stents in patients with CTO.
*Methods:* From 2004 to 2010, we analyzed 898 patients with at least one CTO who underwent successful PCI ($n$ = 424, 448 lesions) or only medical treatment ($n$ = 474, 519 lesions) from a multicenter registry. The primary outcome was all-cause death.
*Results:* During a median of 2.2 years, incidence rate of all-cause death after successful PCI was lower than that after medical treatment (10.6% and 17.5%, $p$ = 0.004). However, the multivariate Cox proportional hazards model showed that successful PCI was not associated with improvement in mortality compared to medical treatment [adjusted hazard ratio (HR) 0.84, 95% confidence interval (CI) 0.57–1.24, $p$ = 0.38]. Comparable results were obtained after propensity-score matching. Subgroup analysis of propensity-score matched population demonstrated that patients with age under 65 years benefited from successful PCI (HR 0.25, 95% CI 0.08–0.75, $p$ for interaction = 0.005).
*Conclusions:* In patients considered for CTO intervention, medical treatment appears to be associated with a similar mortality compared to successful PCI. Successful CTO PCI might be associated with survival benefit in younger patients compared to medical treatment.


## Introduction

Chronic total occlusion (CTO) is still a challenging entity of percutaneous coronary intervention (PCI) with relatively low procedural success rates in the real world [1]. However, success rates for CTO PCI have improved with advances in technology and techniques [2]. CTO PCI is attempted in 10–15% due to several

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factors including elevated radiation exposure and high likelihood of procedure failure, contrast-induced nephropathy, and acute complications [3–5].

Moreover, there is uncertainty regarding survival benefit of CTO PCI. Several meta-analyses revealed successful CTO PCI was associated with improved short-term and long-term survival compared to failed CTO PCI [6–8]. However, these studies comparing successful versus failed CTO PCI did not account for the observed higher rates of technical complications and nonfatal events directly related to the CTO PCI in patients with failed CTO PCI, contributing to the poor prognosis of these patients. The definite evidence of improved clinical outcomes of successful CTO PCI compared with medical treatment is limited. Therefore, we examined the prognostic impact of successful CTO PCI compared to medical therapy excluding patients with failed CTO PCI.

## Materials and methods

### *Study population*

We consecutively enrolled 1044 patients with at least 1 CTO between January 2004 and December 2010 from a prospective multicenter observational registry of the Catholic University of Korea [9]. A CTO was defined as a coronary artery obstruction with a Thrombolysis In Myocardial Infarction (TIMI) flow grade 0 with estimated duration of the occlusion >3 months on the basis of a history of sudden chest pain, a previous myocardial infarction (MI) in the same target vessel territory, or the time between diagnosis made on coronary angiography and PCI.

After excluding patients who underwent coronary bypass surgery previously ($n$ = 17), 553 patients underwent CTO PCI and 474 patients were treated by medication. The decision of treatment strategy was made by the attending physician of each hospital (Fig. 1). Among 553 patients who underwent CTO PCI, 129 patients (23.3%) had failed PCI of at least 1 CTO. To assess the real therapeutic benefit of CTO PCI, we excluded the patients with failed CTO PCI. Thus, 898 patients with at least 1 CTO (967 lesions) who were treated with successful PCI or medical treatment were available for this study. The study protocol was approved by the ethics committee at each participating center and was followed according to the principles of the Declaration of Helsinki. All patients provided written informed consent.

### *PCI procedure and medical treatment*

Coronary angiography and PCI were performed according to the current standard guidelines. Anti-platelet therapy and peri-procedural anticoagulation were administered according to standard regimens. Pre-dilation, direct stenting, post-adjunct balloon inflation, and administration of glycoprotein IIb/IIIa-receptor blockers were performed at the discretion of individual physicians. Antiplatelet therapy and peri-procedural anticoagulation were administered according to standard regimens. All patients were prescribed aspirin (loading dose, 200 mg) plus clopidogrel (loading dose, 300 or 600 mg) before or during PCI. The PCI of the CTO was performed with contemporary techniques such as bilateral injection; specialized hydrophilic, tapered tip, and stiff wires; microcatheters; parallel wire; and retrograde approach when they became available. A successful PCI procedure was defined as a decrease in minimum stenosis diameter to <30% with TIMI flow grade ≥2 on coronary angiogram. After the procedure, aspirin (100–200 mg per day) was continued indefinitely. All patients were treated with drug-eluting stents and were prescribed clopidogrel (75 mg per day) for at least 6 months. Medications after coronary angiography or PCI included aspirin, clopidogrel, statins, beta-blockers, angiotensin-converting enzyme inhibitors, and angiotensin II-receptor blockers. Patients received the same medications after discharge as they had received during hospitalization except for some intravenous or temporary medications.

### *Endpoints and clinical follow-up*

The primary outcome of this analysis was all-cause mortality during the follow-up period. The secondary endpoints were coronary revascularization and composite of all-cause mortality, MI, and coronary revascularization during follow-up period. Coronary revascularization included repeat PCI or coronary artery bypass grafting on target vessel or non-target vessels. Recurrent MI was defined as the presence of recurrent symptoms and new electrocardiographic changes that were compatible with MI or cardiac markers that were expressed at least two-fold above the normal limit.

Immediate post-procedural and in-hospital events were recorded. Each patient was followed up during an office visit or telephone conversation at 1, 6, and 12 months and then annually. Information about death was obtained from hospital records or telephone conversations with relatives of the patient. Information about death was matched with records from the National Population Registry of the Korea National Statistical Office with a unique personal identification number to validate mortality follow-up data.

### *Statistical analysis*

Differences between groups of continuous variables were evaluated with an unpaired t test or Mann–Whitney rank-sum test. Differences between groups of discrete variables were

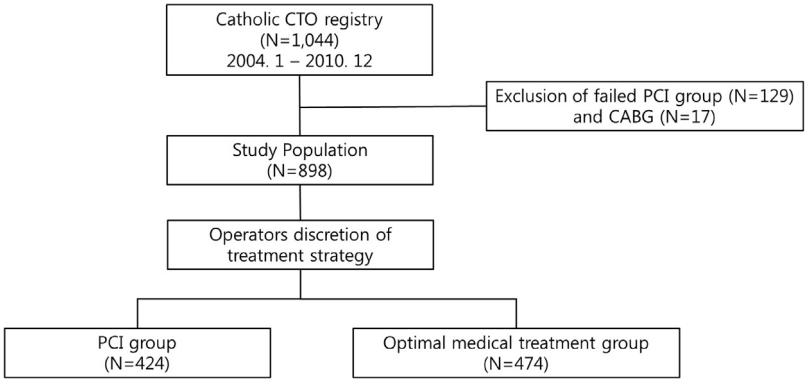


**Fig. 1.** The flow chart of treatment strategy discretion. CTO, chronic total occlusion; PCI, percutaneous coronary intervention; CABG, coronary artery bypass grafting.

**Table 1**
Clinical and angiographic characteristics of patients according to treatment strategy in crude population.

| | Successful PCI ($n=424$) | Medical ($n=474$) | $p$-Value |
|---|---|---|---|
| Clinical characteristics | | | |
| Age, year | 61.3 ± 11.6 | 66.2 ± 11.1 | <0.001 |
| Male (%) | 308 (72.6) | 329 (69.4) | 0.30 |
| Hypertension (%) | 265 (62.5) | 281 (59.3) | 0.34 |
| Diabetes (%) | 176 (41.5) | 225 (47.5) | 0.08 |
| Current smoking (%) | 98 (23.1) | 113 (23.9) | 0.93 |
| Presenting acute MI at other vessel (%) | 58 (13.7) | 92 (19.4) | 0.025 |
| Family history of CAD (%) | 20 (4.7) | 20 (4.2) | 0.75 |
| Chronic kidney disease (%) | 28 (6.6) | 50 (10.5) | 0.04 |
| Prior stroke (%) | 46 (10.8) | 49 (10.3) | 0.97 |
| LVEF (%) | 56.0 ± 11.3 | 52.1 ± 12.6 | <0.001 |
| Discharge medication (%) | | | |
| Aspirin | 412 (97.9) | 433 (95.2) | 0.04 |
| Clopidogrel | 413 (98.3) | 405 (88.1) | <0.001 |
| Statin | 356 (84.3) | 357 (78.5) | 0.03 |
| ACEi/ARB | 323 (76.2) | 331 (72.7) | 0.22 |
| Beta blocker | 318 (75.0) | 302 (66.4) | 0.004 |
| Angiographic characteristics | | | |
| CTO vessel (%) | | | |
| LAD | 180 (42.5) | 138 (29.1) | <0.001 |
| LCX | 95 (22.4) | 138 (29.1) | 0.02 |
| RCA | 162 (38.2) | 230 (48.5) | 0.002 |
| CTO segment (%) | | | |
| Proximal | 200 (47.2) | 217 (45.7) | 0.14 |
| Mid | 188 (44.3) | 154 (32.5) | 0.001 |
| Distal | 48 (11.3) | 122 (25.7) | <0.001 |
| 2 CTO lesions (%) | 12 (2.8) | 30 (6.3) | 0.046 |
| Lesion extent (%) | | | <0.01 |
| Single vessel | 130 (30.7) | 74 (15.6) | |
| Two vessel | 154 (36.3) | 143 (30.2) | |
| Three vessel | 140 (33.0) | 257 (54.2) | |
| Left main disease (%) | 18 (4.2) | 32 (6.8) | 0.11 |
| Total number of stents | 1.77 ± 1.18 | 1.09 ± 4.3 | 0.001 |

Data are presented as mean ± SD and number (percentage) where appropriate.
MI, myocardial infarction; CAD, coronary artery disease; LVEF, left ventricular ejection fraction; ACEi/ARB, angiotensin-converting enzyme inhibitor or angiotensin receptor blocker; CTO, chronic total occlusion; LAD, left anterior descending coronary artery; LCX, left circumflex coronary artery; PCI, percutaneous coronary intervention; RCA, right coronary artery.

analyzed with a chi-square or Fisher exact test as appropriate and were expressed as counts and percentages. We constructed Kaplan–Meier curves for patients treated with successful CTO PCI or with medical treatment to all-cause mortality, and the difference between groups was assessed by log-rank test. A propensity-score analysis was performed to adjust potential confounders with a logistic regression model. Available variables that were considered to be potentially relevant were age, sex, hypertension, diabetes mellitus, smoking, chronic kidney disease, prior stroke, diagnosis of acute MI, left ventricular ejection fraction, CTO vessel, CTO segment, number of CTO, lesion extent, and discharge medications. The predicted accuracy of the logistic model was assessed with an area under the receiver-operating characteristic curve (C statistic), which was 0.754; 95% CI 0.721–0.788. According to the propensity score, patients were selected by 1:1 matching without replacement using the nearest neighbor method. A caliper width of 0.2 SDs was used for matching, because this value has been shown to eliminate almost 99% of the bias in the observed confounders [10]. Baseline clinical and angiographic characteristics were compared within the propensity score-matched group. Success of propensity-score matching was assessed by calculating percentage standardized differences in the baseline characteristics. The presence of less than 10% of a difference supported the assumption of balance between matched groups [11]. Cox proportional hazards regression was applied to compute hazard ratios (HRs) as estimates for mortality. The HRs were adjusted for important co-variables for risk that had significant effects ($p < 0.1$) in the univariate analysis for mortality. All analyses were two-tailed, and clinical significance was defined as $p < 0.05$. Statistical analyses were performed with the statistical package SPSS version 20.0 (SPSS Inc., Chicago, IL, USA), R programming language version 2.12.1 (R Foundation for Statistical Computing, Vienna, Austria), and MedCalc version 12.7 (MedCalc Software, Mariakerke, Belgium).

## Results

### *Baseline clinical and angiographic characteristics in crude and propensity score-matched population*

Among 898 patients with 967 CTO lesions, 424 patients (47.2%, 448 lesions) were treated with successful PCI of CTO lesions and 474 patients (42.4%, 519 lesions) were treated with medication on CTO lesions. Patients with medical treatment were more likely to have older age and history of MI, have presented with acute MI, have chronic kidney disease and lower ejection fraction, and be treated with under use of aspirin, clopidogrel, statin, and beta blocker. Regarding angiographic characteristics, patients with medical treatment tended to have CTO in left circumflex artery and right coronary artery, to have CTO in distal part of coronary artery, and to have complex lesion extent (Table 1). Matching by propensity score yielded 264 pairs with more balanced baseline characteristics (Table 2). The difference in total number of stents was higher in patients with successful CTO PCI after matching. In this registry, statin was prescribed in 713 patients (79.3%). The reason for low statin prescription rate was that LDL-cholesterol

**Table 2**
Clinical and angiographic characteristics of patients according to treatment strategy in propensity score matched population.

| | Successful PCI ($n$ = 264) | Medical ($n$ = 264) | $p$-Value | Standardized difference |
|---|---|---|---|---|
| Clinical characteristics | | | | |
| Age, year | 61.5 ± 09.8 | 61.5 ± 10.5 | 0.99 | 0.11 |
| Male (%) | 199 (75.4) | 201 (76.1) | 0.92 | −1.77 |
| Hypertension (%) | 156 (59.1) | 159 (60.2) | 0.86 | −2.32 |
| Diabetes (%) | 117 (44.3) | 121 (45.8) | 0.79 | −3.05 |
| Current smoking (%) | 71 (26.9) | 64 (24.2) | 0.55 | 6.08 |
| Presenting acute MI at other vessel(%) | 58 (22.0) | 67 (25.4) | 0.41 | −8.03 |
| Family history of CAD (%) | 12 (4.5) | 17 (6.4) | 0.45 | −8.32 |
| Chronic kidney disease (%) | 26 (9.8) | 26 (9.8) | 1.00 | 0.00 |
| Prior stroke (%) | 25 (9.5) | 24 (9.1) | 0.99 | 1.31 |
| LVEF (%) | 54.8 ± 11.3 | 53.6 ± 12.3 | 0.26 | 9.71 |
| Discharge medication (%) | | | | |
| Aspirin | 258 (97.7) | 255 (96.6) | 0.99 | 6.84 |
| Clopidogrel | 255 (96.6) | 256 (97.0) | 0.99 | −2.15 |
| Statin | 220 (83.3) | 214 (81.1) | 0.99 | 5.94 |
| ACEi/ARB | 204 (77.3) | 197 (74.6) | 0.99 | 6.21 |
| Beta blocker | 185 (70.1) | 180 (68.2) | 0.99 | 4.10 |
| Angiographic characteristics | | | | |
| CTO vessel (%) | | | | |
| LAD | 84 (31.8) | 80 (30.3) | 0.78 | 3.27 |
| LCX | 66 (25.0) | 72 (27.3) | 0.62 | −5.17 |
| RCA | 124 (47.0) | 118 (44.7) | 0.66 | 4.56 |
| CTO segment (%) | | | | |
| Proximal | 132 (50.0) | 130 (49.2) | 0.93 | 1.52 |
| Mid | 102 (38.6) | 93 (35.2) | 0.47 | 7.07 |
| Distal | 39 (14.8) | 47 (17.8) | 0.41 | −8.21 |
| 2 CTO lesions (%) | 9 (3.4) | 6 (2.3) | 0.99 | 6.84 |
| Lesion extent (%) | | | 0.79 | |
| Single vessel | 56 (21.2) | 51 (19.3) | | 4.71 |
| Two vessel | 99 (37.5) | 97 (36.7) | | 1.57 |
| Three vessel | 109 (41.3) | 116 (43.9) | | −5.36 |
| Left main disease (%) | 11 (4.2) | 12 (4.5) | 0.99 | −1.86 |
| Total number of stents | 1.8 ± 1.2 | 0.9 ± 1.0 | <0.01 | 76.63 |

Data are presented as mean ± SD and number (percentage) where appropriate.
MI, myocardial infarction; CAD, coronary artery disease; LVEF, left ventricular ejection fraction; ACEi/ARB, angiotensin-converting enzyme inhibitor or angiotensin receptor blocker; CTO, chronic total occlusion; LAD, left anterior descending coronary artery; LCX, left circumflex coronary artery; PCI, percutaneous coronary intervention; RCA, right coronary artery.

**Table 3**
Cumulative clinical outcomes according to successful percutaneous coronary intervention compared to medical treatment.

| | Unadjusted HR (95% CI) | $p$-Value | Adjusted HR (95% CI) | $p$-Value | PS adjusted HR (95% CI) | $p$-Value |
|---|---|---|---|---|---|---|
| All-cause death | 0.53 (0.36–0.75) | 0.001 | 0.84 (0.57–1.24) | 0.38 | 0.85 (0.50–1.45) | 0.55 |
| Coronary revascularization | 1.25 (0.88–1.76) | 0.20 | 1.11 (0.78–1.57) | 0.55 | 1.29 (0.86–1.93) | 0.22 |
| Composite of death, MI, and coronary revascularization | 0.87 (0.68–1.11) | 0.26 | 0.97 (0.75–1.26) | 0.55 | 1.12 (0.81–1.55) | 0.903 |

HR, hazard ratio; CI, confidence interval; PS, propensity score; MI, myocardial infarction.

level was below 70 mg/dL in 130 patients (14.5%) and 55 patients suffered from myalgia and elevated liver enzyme (6.2%).

*Clinical outcomes of the crude and propensity score-matched population*

During the median of 2.2 years (interquartile range: 1.3–3.6), the unadjusted rate of all-cause mortality (i.e. the primary outcome) was significantly reduced for patients who received successful CTO PCI compared to patients with medical treatment (10.6% and 17.5%, $p$ = 0.004) (Table 3). However, after multivariable adjustment, successful CTO PCI was not associated with reduced all-cause mortality compared to medical treatment [adjusted HR: 1.17, 95% confidence interval (CI) 0.78–1.73, $p$ = 0.45] (Table 3). And composite of clinical outcomes did not differ according to treatment strategy (28.3% vs. 29.7%, $p$ = 0.748).

In propensity score-matched population, the cumulative incidence of all-cause mortality was not significantly different between successful CTO PCI and medical treatment (10.2% and 10.6%, $p$ = 0.54, Fig. 2, Table 3). There were no significant differences in the incidences of coronary revascularization and composite of clinical outcomes (Table 3).

*Predictors of clinical outcome*

Older age, lower ejection fraction, chronic kidney disease, left main disease, CTO in left anterior descending coronary artery (LAD), and CTO in proximal part of vessel were independent predictors of all-cause mortality in patients with CTO (Table 4).

*Subgroup analysis of propensity score-matched population*

Significant interaction was observed between treatment strategy and age groups divided by 65 years ($p$ for interaction = 0.005) (Fig. 3). Successful CTO PCI was beneficial to patients with age <65 years. Patients with age <65 years were more likely

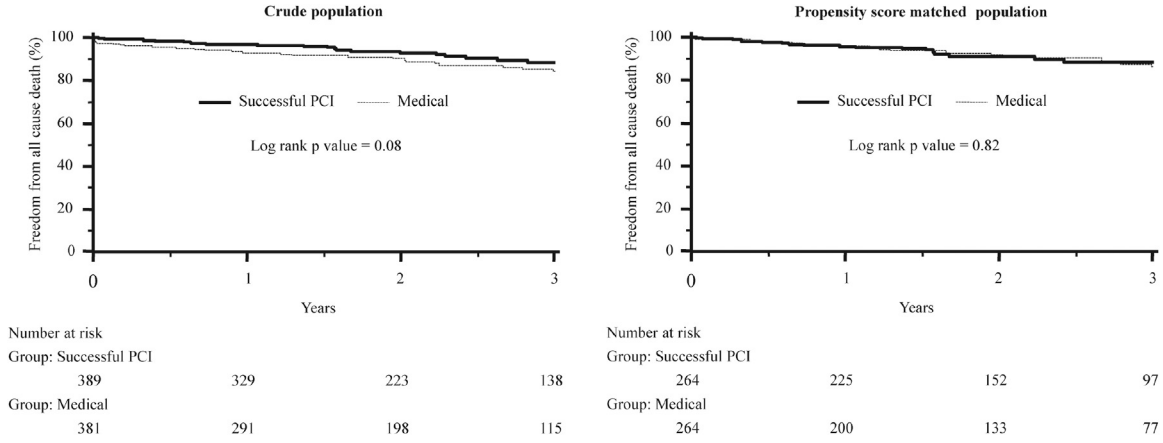


**Fig. 2.** Kaplan–Meier curves of all-cause mortality according to treatment strategy. PCI, percutaneous coronary intervention.

**Table 4**
Independent predictors of all-cause mortality in patients with chronic total occlusion.

| | Adjusted HR | 95% CI | *p*-value |
|---|---|---|---|
| Age (increase by 1 year) | 1.07 | (1.04–1.10) | <0.001 |
| LVEF (increase by 10%) | 0.62 | (0.58–0.78) | <0.001 |
| Chronic kidney disease | 2.69 | (1.65–4.39) | <0.001 |
| Left main disease | 1.82 | (1.04–3.19) | 0.038 |
| CTO in LAD | 1.47 | (1.03–2.11) | 0.001 |
| CTO in proximal part of vessel | 1.50 | (1.05–2.14) | 0.03 |

HR, hazard ratio; CI, confidence interval; LVEF, left ventricular ejection fraction; CTO, chronic total occlusion; LAD, left anterior descending coronary artery.

to be male, hypertensive, and current smoker and less likely to have prior stroke. Patients with age <65 years tended to be treated with intensive medication, have CTO in left circumflex artery, and have multivessel disease (Table 5). Other subgroups did not interact significantly with beta blocker treatment and had comparable rates of mortality.

## Discussion

The present study demonstrated that CTO PCI was not associated with mortality benefit compared to medical therapy. There were significant differences in the baseline clinical and angiographic characteristics of CTO patients who were treated with PCI or medical therapy, which is an inherent limitation of nonrandomized studies. However, these differences were balanced with propensity score matching. In propensity score matched population, the mortality rates were similar between the groups. Interestingly, patients with age ≤65 years benefited from the successful CTO PCI compared to medical treatment.

A previous study showed that incomplete revascularization by PCI leaving untreated CTOs led to higher 3-year mortality [12]. Many studies comparing successful CTO PCI versus failed CTO PCI also showed successful CTO PCI was associated with improved survival [6–8]. However, these studies are not direct data comparing the CTO PCI to medical treatment which might be essential to make decision for interventional cardiologists when they encounter patients with CTOs.

Two randomized controlled trials addressing the usefulness of opening occluded culprit coronary arteries in the subacute post-MI phase showed no survival advantage from PCI with the conservative approach [13,14]. The results of these two studies do not necessarily pertain to CTOs. However, the negative results of these studies suggest that ad hoc PCI would not be beneficial for the CTO lesions. In addition, CTO PCI can disrupt the function of collaterals. After successful CTO PCI and the restoration of an antegrade flow, rapid and progressive derecruitment of collaterals occurs, potentially exposing patients to a higher risk of future ischemic events in case of vessel reocclusion [15]. Successful CTO PCI is also hampered by higher risks of clinical and angiographic restenosis [1]. Although the long-term patency rate of CTO after successful PCI is increased by the use of drug-eluting stents [16], the basic question about the worth of CTO PCI remains.

Previous functional studies after CTO PCI demonstrated a 3–6% advantage of ejection fraction in patients with successful CTO PCI [17–19]. Particularly, the extent of dysfunctional but viable myocardium (<25% of transmural extension) before revascularization was related to improvement in end-systolic volume and ejection fraction [20,21]. Because we do not have information regarding the viability and ischemic burden before PCI, the proportion of patients with viable myocardium is not known. Furthermore, due to the relatively small number of our study patients in addition to unknown viability, the slight improvement in systolic function by successful CTO PCI might not be translated into the mortality benefit.

However, we demonstrated that the successful CTO PCI was associated with reduction of mortality only in patients with age under 65 years. Our study is not consistent with a previous study which showed successful CTO PCI was associated with lower incidence of cardiac death only in patients with age ≥75 years [22]. In our study, younger patients had more complex coronary disease which implies larger ischemic burden than older patients and thereby they might have benefited from successful CTO PCI. On the contrary, older patients can have co-morbid conditions such as stroke and malignancy more frequently so that they might not benefit from successful CTO PCI.

CTO in proximal part of vessel and CTO in LAD were more powerful predictors of mortality than successful CTO PCI. Patients with CTO in proximal part of vessel may have larger ischemic burden than those in mid or distal part of vessel. Previous studies also showed that CTO in LAD were associated with an increased mortality rate [23,24]. Safley et al. reported a significant benefit in survival after successful PCI of CTO in LAD but not after successful PCI in the other two vessels [24]. However, our study did not show significant interaction between treatment strategy and angiographic location of CTO.

Current guidelines state that CTO PCI is reasonable in patients with appropriate clinical indications and suitable anatomy when

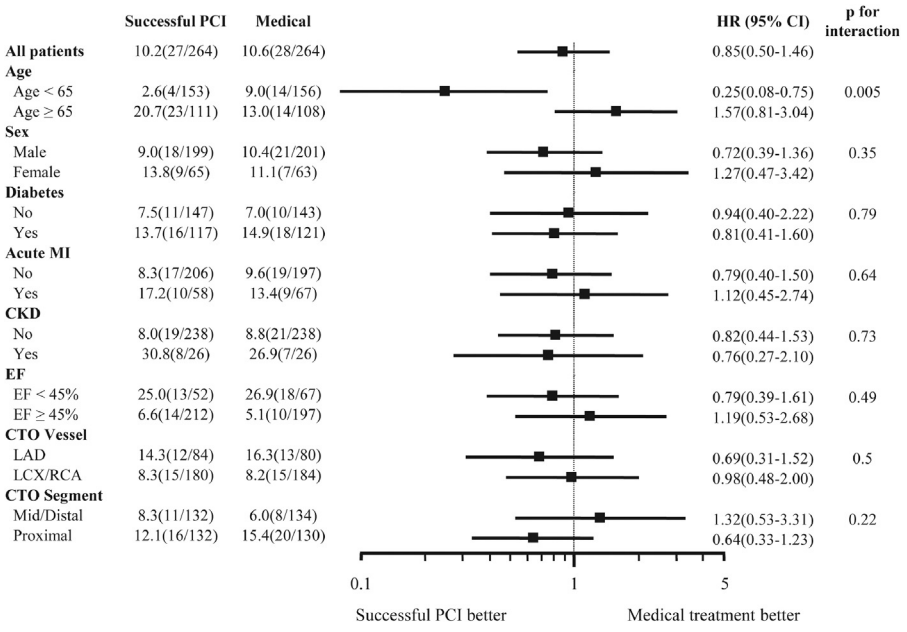


**Fig. 3.** Subgroup analysis for all-cause mortality in propensity score matched group. PCI, percutaneous coronary intervention; HR, hazard ratio; CI, confidence interval; MI, myocardial infarction; CKD, chronic kidney disease; EF, ejection fraction; CTO, chronic total occlusion; LAD, left anterior descending coronary artery; LCX, left circumflex coronary artery; RCA, right coronary artery.

**Table 5**
Clinical and angiographic characteristics of patients according to age in propensity score matched population.

| | Age <65 years ($n$ = 308) | Age ≥65 years ($n$ = 219) | $p$-Value |
|---|---|---|---|
| Clinical characteristics | | | |
| Age, year | 55.0 ± 08.1 | 70.8 ± 02.8 | <0.01 |
| Male (%) | 264 (85.4%) | 136 (62.1%) | <0.01 |
| Hypertension (%) | 164 (53.1%) | 151 (68.9%) | <0.01 |
| Diabetes (%) | 137 (44.3%) | 101 (46.1%) | 0.72 |
| Current smoking (%) | 107 (34.6%) | 28 (12.8%) | <0.01 |
| Acute MI (%) | 79 (25.6%) | 46 (21.0%) | 0.25 |
| Family history of CAD (%) | 22 (7.1%) | 7 (3.2%) | 0.05 |
| Chronic kidney disease (%) | 26 (8.4%) | 26 (11.9%) | 0.24 |
| Prior stroke (%) | 18 (5.8%) | 33 (15.0%) | <0.01 |
| LVEF (%) | 53.9 ± 11.5 | 54.7 ± 12.2 | 0.44 |
| Discharge medication (%) | | | |
| Aspirin | 305 (98.7%) | 208 (95.0%) | 0.02 |
| Clopidogrel | 301 (97.4%) | 210 (95.9%) | 0.33 |
| Statin | 264 (85.4%) | 170 (77.6%) | 0.03 |
| ACEi/ARB | 249 (80.6%) | 152 (69.4%) | <0.01 |
| Beta blocker | 218 (70.6%) | 147 (67.1%) | 0.44 |
| Angiographic characteristics | | | |
| CTO vessel (%) | | | |
| LAD | 88 (28.5%) | 76 (34.7%) | 0.15 |
| LCX | 92 (29.8%) | 46 (21.0%) | 0.03 |
| RCA | 137 (44.3%) | 105 (47.9%) | 0.43 |
| CTO segment (%) | | | |
| Proximal | 158 (51.1%) | 104 (47.5%) | 0.43 |
| Mid | 103 (33.3%) | 92 (42.0%) | 0.05 |
| Distal | 56 (18.1%) | 30 (13.7%) | 0.19 |
| 2 CTO lesions (%) | 8 (2.6%) | 7 (3.2%) | 0.79 |
| Lesion extent (%) | | | 0.02 |
| Single vessel | 50 (16.2%) | 57 (26.0%) | |
| Two vessel | 118 (38.2%) | 78 (35.6%) | |
| Three vessel | 141 (45.6%) | 84 (38.4%) | |
| Left main disease (%) | 15 (4.9%) | 8 (3.7%) | 0.67 |
| Total number of stents | 1.4 ± 1.2 | 1.2 ± 1.1 | 0.08 |

Data are presented as mean ± SD and number (percentage) where appropriate.
MI, myocardial infarction; CAD, coronary artery disease; LVEF, left ventricular ejection fraction; ACEi/ARB, angiotensin-converting enzyme inhibitor or angiotensin receptor blocker; CTO, chronic total occlusion; LAD, left anterior descending coronary artery; LCX, left circumflex coronary artery; RCA, right coronary artery.

performed by operators with appropriate expertise [25,26]. Given the technical complexity, substantial use of resources, and relatively frequent procedural complications, indications for CTO recanalization by PCI might be restricted to appropriate patients, such as those with a small scar, who are substantially symptomatic or who have a large ischemic burden despite optimal medical therapy. Further study will be needed to clarify the appropriate strategy for patients with CTO.

In the present study, even though incomplete revascularization was performed in optimal medical group, there was no difference in terms of mortality between the two groups. It was published that complete revascularization was associated with more favorable long-term mortality in some papers. However, the effect of complete revascularization was different according to patient and lesion subset. In patients with acute MI, complete revascularization might be beneficial in terms of mortality [27]. And incomplete revascularization at the lesion on proximal LAD or in 2 or more vessels may be harmful [28]. On the other hand, in unselected patients undergoing PCI, complete revascularization may not confer a mortality benefit [29].

This study had limitations that are inherent to nonrandomized comparisons, such as selection bias and uneven distribution of risk factors. These differences were balanced with propensity-score matching. However, unmeasured variables were not controlled. Second, because data were from observational registries, detection of events and patient follow-up were less rigorous than in randomized, controlled trials. Despite data collection by dedicated study nurses, review of insurance records, and thorough investigation of survival status, nonfatal events (e.g. MI or revascularization) may have been underreported. Third, we did not evaluate viability, ischemic burden, and the presence of a scar or ischemia in the CTO territory before PCI or medical treatment. However, we demonstrated that CTO PCI without viability measurement, even though it was successful, may not be beneficial. Fourth, we did not enroll the PCI failure group. Therefore, the effect of PCI failure in CTO could not be demonstrated in the present study. Fifth, we did not analyze and record the degree of the collaterals. So, this may be a bias of this present study. Sixth, the number of enrolled patients is relatively small. The large randomized trial, Drug-Eluting Stent Implantation Versus Optimal Medical Treatment in Patients With Chronic Total Occlusion (DECISION-CTO) trial (ClinicalTrials.gov identifier: NCT01078051), would give us further insight about the safety and effectiveness of CTO PCI.

## Conclusion

In conclusion, successful PCI was not associated with improved survival in patients with CTO compared to medical treatment. However, successful CTO PCI was beneficial especially to younger patient (age <65 years). Selection of proper patients for PCI would be essential to improve the survival in patients with CTO.

## Conflicts of interest

None.

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