JACC: CARDIOVASCULAR INTERVENTIONS VOL. 7, NO. 1, 2014

ISSN 1936-8798/$36.00
PUBLISHED BY ELSEVIER INC. http://dx.doi.org/10.1016/j.jcin.2013.08.012

Initial Success Rate of Percutaneous Coronary Intervention for Chronic Total Occlusion in a Native Coronary Artery Is Decreased in Patients Who Underwent Previous Coronary Artery Bypass Graft Surgery

Tomohiko Teramoto, MD, PhD,* Etsuo Tsuchikane, MD, PhD,*
Hitoshi Matsuo, MD, PhD,† Yoriyasu Suzuki, MD,‡ Tsuyoshi Ito, MD,* Tatsuya Ito, MD,‡
Maoto Habara, MD,* Kenya Nasu, MD,* Masashi Kimura, MD, PhD,*
Yoshihisa Kinoshita, MD,* Mitsuyasu Terashima, MD, PhD,* Yasushi Asakura, MD,*
Tetsuo Matsubara, MD,* Takahiko Suzuki, MD, PhD*

Aichi and Gifu, Japan

Objectives This study sought to compare the initial success rate of percutaneous coronary intervention (PCI) for chronic total occlusion (CTO) in a native coronary artery (NCA) in patients with and without previous coronary artery bypass grafting (CABG) and to assess predictive factors.

Background Landmark novel wiring techniques for CTO-PCI have contributed to improvement in the initial success of CTO-PCI. However, challenges persist in CTO-PCI in NCA in pCABG patients.

Methods Patients who underwent CTO-PCI in an NCA were selected and classified into 2 groups: pCABG (206 PCIs in 153 patients) and nCABG (1,431 PCIs in 1,139 patients).

Results CTO was located more often in the left anterior descending artery ($p = 0.0003$), and severe calcified lesions were observed more frequently in the pCABG group ($p < 0.0001$). Although the retrograde attempt was tried more frequently in the pCABG group, the CTO-PCI success rate was significantly lower in the pCABG patients than in the nCABG patients (71% vs. 83%). Longer procedural time and greater radiation exposure were needed in the pCABG patients. Logistic regression analysis among the pCABG patients revealed that intravascular ultrasound use and parallel wiring were positive factors, and lesion tortuosity was a negative factor.

Conclusions The initial success rate of CTO-PCI of an NCA in the pCABG group was significantly decreased compared with that in the nCABG group. Anatomic complexity and unstable hemodynamic state were unfavorable conditions. This study reveals that the issues to be overcome are lying with CTO revascularization in an NCA in pCABG patients. (J Am Coll Cardiol Intv 2014;7:39–46) © 2014 by the American College of Cardiology Foundation

From the *Department of Cardiovascular Medicine, Toyohashi Heart Center, Toyohashi, Aichi, Japan; †Department of Cardiovascular Medicine, Gifu Heart Center, Gifu, Japan; and the ‡Department of Cardiovascular Medicine, Nagoya Heart Center, Nagoya, Aichi, Japan. Dr. Tsuchikane is a consultant for Abbott Vascular Japan, Boston Scientfic Japan, and Asahi Intecc Japan. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

Manuscript received October 24, 2012; revised manuscript received July 25, 2013, accepted August 1, 2013.

The technology and techniques for interventional treatment of chronic total occlusion (CTO) in patients with coronary artery disease have advanced significantly in recent years and have contributed to the higher initial success rate of percutaneous coronary intervention (PCI) for CTO (CTO-PCI) (1,2). Nevertheless, previous coronary artery bypass grafting (CABG) has been reported as a potential procedural hindrance to the recanalization of CTO (3). Successful revascularization by PCI could offer a treatment alternative for previous CABG (pCABG) patients presenting with angina after bypass graft failure. However, clinical outcomes associated with CTO-PCI in a native coronary artery (NCA) in pCABG patients have not been well elucidated. Therefore, the purpose of this study was to review the results of CTO-PCI in an NCA in pCABG patients and to compare the initial success rates of the procedure in patients with and without pCABG. In addition, factors affecting clinical outcomes were also identified.

Abbreviations and Acronyms

CART = controlled antegrade and retrograde subintimal tracking

CI = confidence interval

CTO = chronic total occlusion

IVUS = intravascular ultrasound

MACE = major adverse cardiac event(s)

MI = myocardial infarction

NCA = native coronary artery

nCABG = no previous coronary artery bypass grafting

OR = odds ratio

pCABG = previous coronary artery bypass grafting

PCI = percutaneous coronary intervention

TIMI = Thrombolysis In Myocardial Infarction

Methods

Study design. Consecutive patients who underwent CTO-PCI were extracted from the database at the Toyohashi Heart Center, Toyohashi, Japan, in which data were entered prospectively. The database included relevant patient information as well as angiographic and procedural characteristics. A total of 13,448 PCI procedures performed between May 1999 and November 2011 were included in this study. Of these, 192 CTO lesions located in any small coronary branch vessel were excluded from the study because of the reduced clinical advantage associated with small branch vessel revascularization. The remaining 1,637 lesions identified in 1,292 patients represented the total population of this study. These patients were then classified into 2 study groups: patients with pCABG who had undergone PCI for CTO lesions in an NCA (pCABG; 206 PCIs in 153 patients) and those with no history of CABG (nCABG; 1,431 PCIs in 1,139 patients) (Fig. 1). In this study, all CTO-PCI procedures in the pCABG group were performed in NCAs that had previously been bypassed. The protocol was approved by ethics committees at each participating center, and all participants gave written informed consent.

Definitions. Coronary CTO is defined as a true total occlusion with complete interruption of antegrade blood flow as assessed by coronary arteriography (Thrombolysis In Myocardial Infarction [TIMI] flow grade 0) and with an estimated duration of occlusion of $\geq$3 months. For the procedural disadvantages inherent in this study, we examined the procedure time, fluoroscopy time, and radiation dose. Procedure time was defined as the total duration for which the patient was in the catheter room (from entry into to leaving the catheter lab). Fluoroscopy time and radiation dose were recorded automatically in the cine device. Coronary perforation and distal embolization were examined as in-hospital complications during the procedure. Coronary perforations were classified into 2 types: type A, which included those with epicardial staining without a jet of contrast extravasation, and type B, which included those with a jet of contrast extravasation leading to a hemodynamic effect. Distal embolization was judged by the TIMI frame count, with interruption of coronary flow at the distal end on the final angiogram. Major adverse cardiac events (MACE) were defined as death, Q-wave myocardial infarction (MI), and urgent revascularization required during the same hospitalization as for the initial CTO procedure. Urgent revascularization was defined as repeat PCI of the target vessel within 24 h or urgent CABG after the procedure. Q-wave MI was defined as an increase in creatine kinase >3 times the normal value, with development of Q waves after PCI. Procedural success was defined as residual stenosis <50% with TIMI flow grade 3 without MACE. MI was diagnosed by an increase in the creatine kinase level to 2 times the upper limit of normal.

Guidewire-crossing strategies. Guidewire-crossing strategies were followed in a stepwise manner, as described by Sumitsuji et al. (4) (Fig. 2). As for antegrade approaches, single wiring, parallel wiring, and intravenous ultrasound (IVUS)–guided wiring techniques were included. For retrograde attempts, retrograde guidewire cross, kissing guidewire cross, and controlled antegrade and retrograde subintimal tracking (CART) and retrograde CART techniques were used. These wiring techniques were reported previously by our group (5-7) and by Sumitsuji et al. (4). Wiring strategies for CTO-PCI may be classified into 4 types depending on the direction of the guidewire cross (antegrade or retrograde) relative to CTO and whether ballooning was performed for guidewire crossing. These strategies are addressed in the 2 × 2 contingency table (Table 1) (4). These step-up guidewire-crossing strategies were also followed in the present study.

Statistical analysis. Data distribution was assessed by the *F* test. Variables that did not follow a normal distribution were expressed as medians and interquartile ranges, whereas other continuous variables were expressed as mean ± SE. The Student *t* test or the Mann-Whitney *U* test was used for the comparison of continuous variables, as appropriate. Logistic regression analysis was used to identify the independent predictors of procedural success of CTO-PCI. The predictors of a multivariable model were entered if their

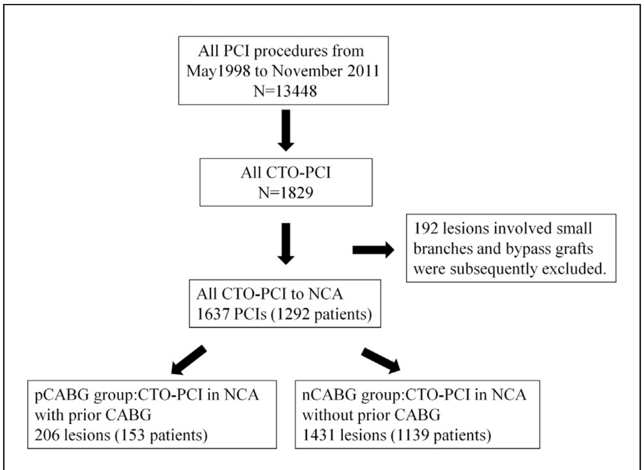

Figure 1. Flow Diagram of the Population in This Study

Percutaneous coronary intervention performed between 1998 and 2011. The flowchart describes lesions, exclusions, and composition of study population. CTO = chronic total occlusion; NCA = native coronary artery; pCABG = previous coronary artery bypass grafting; nCABG = no previous coronary artery bypass grafting; PCI = percutaneous coronary intervention.

univariate p value was at the 0.1 level. The following predictors, which are regarded as well-known factors for the procedural success of CTO-PCI, were evaluated: duration since CABG, IVUS use, parallel wiring, IVUS-guided wiring, retrograde attempt, CART technique, calcified lesion, and tortuous lesion. The results are reported as odds ratios (ORs) with associated confidence intervals (CIs). An OR <1 indicated a lower success rate, whereas an OR >1 indicated a higher success rate. A p value <0.05 was considered statistically significant, and all reported p values were 2 sided. Statistical analysis was performed using SAS software (JMP version 9, SAS Institute, Cary, North Carolina).

Results

Patient and lesion characteristics. Baseline patient characteristics are shown in Table 2. The average age of patients in the pCABG group was significantly older than that of patients in the nCABG group (OR: 68.2; 95% CI: 62.4 to 74.6 vs. OR: 66.0; 95% CI: 58.2 to 73.6; p = 0.002). Renal insufficiency requiring hemodialysis after the procedure (serum creatinine level >2 mg/dl) was observed more often in the pCABG patients than in the nCABG patients (10% [16 of 153] vs. 6% [67 of 1,139]; p = 0.03). Lesion and procedural characteristics in both groups are presented in Table 3. CTO lesions were located predominantly in the right coronary artery. Although this tendency was similar in both groups, CTO of the left circumflex artery was observed more frequently in the pCABG patients. Severe calcified lesions were identified more often in the pCABG patients (23% [47 of 206] vs. 13% [176 of 1,431]; p < 0.0001). Stents were deployed more frequently in nCABG patients than in pCABG patients (66% vs. 56%, p = 0.009). Other angiographic characteristics were similar between the 2 groups.

Initial results of CTO-PCI in an NCA. From 1997 to 2011, the overall success of CTO-PCI was 81.1% (1,329 of 1,637 procedures). The annual transition of the success rate is shown in Figure 3. The initial success rate has increased over time, especially with the advent of the retrograde approach in 2006. Success rates >90% are now being reported. Comparison of the CTO-PCI success rates before 2006 with those reported after 2006 revealed that the overall success rate of CTO-PCI was significantly higher after 2006 (87% [699 of 806] vs. 76% [630 of 831]; p < 0.0001). Moreover, by comparison, the initial success rate of CTO-PCI in NCA was found to be significantly lower in the pCABG patients than in the nCABG patients (83% [1,184 of 1,431] vs. 71% [146 of 206]; p < 0.0001) (Table 3).

Guidewire-crossing strategy. Among 206 PCIs performed in the pCABG patients and 1,431 PCIs performed in the nCABG patients, data pertaining to guidewire strategy were available for 173 and 1,128 PCI procedures, respectively. The guidewire strategies used in overall procedures and in each study group are shown in Table 4. The antegrade wiring strategy was similar between the 2 groups, yet the frequency of retrograde attempts including the CART technique was significantly higher in the pCABG group (47% vs. 37%; p = 0.001). Despite its high use, the frequency of successful revascularization with the CART technique was significantly lower in the pCABG group than in the nCABG group (71% vs. 89%; p = 0.004).

Unique procedural occurrences among pCABG patients. Procedural characteristics among the pCABG patients are shown in Table 5. When patients with successful and failed CTO-PCI in the pCABG group were compared, the length of time since CABG was significantly longer in those who underwent failed procedures than in those who underwent successful procedures (3,831 ± 2,139 days vs. 3,068 ± 2,445 days, p = 0.03). The CTO-PCI was retried in 9 patients in the pCABG group after a failed first attempt. In all 9 patients, the first attempt was via an antegrade approach. The second attempt was successful in 5 of the 9 patients, with the antegrade approach used in 3 and the retrograde approach used in 2 (via 1 bypass graft).

Multivessel CTO-PCI was performed in a single procedure in 15 patients in the pCABG group: 13 had 2 CTOs and 2 had 3 CTOs. Two branches were excluded. In re-tried and multivessel CTO cases, we counted each procedure as 1 CTO-PCI and classified it as successful or failed depending on the outcome. The initial success rate was 77% (23 of 30 cases), which is comparable to the overall success rate in the pCABG group.

The 226 CTO-PCI patients in the pCABG group included 15 patients (6.6%) in whom PCI was performed via

JACC: CARDIOVASCULAR INTERVENTIONS, VOL. 7, NO. 1, 2014
JANUARY 2014:39–46

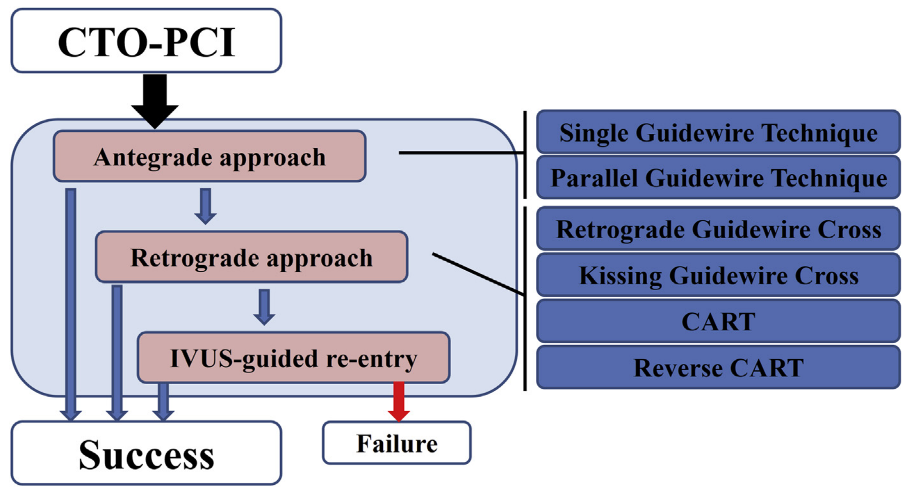

Figure 2. Procedural Steps of Current CTO-PCI

The step-up strategy of wiring for CTO-PCI. In general, the antegrade approach is tried first; if this fails, the strategy is switched to the retrograde approach. Regardless of ante- or retrograde approach, IVUS is essential to differentiate between the false and true lumen (4). CART = controlled antegrade and retrograde subintimal tracking; IVUS = intravenous ultrasound; other abbreviations as in Figure 1.

the collateral circulation with a bypass graft. The initial success rate was 67% (10/15) in this subset. There was no statistical difference in the success rate between bypass graft maneuvering and nonbypass graft maneuvering procedures in this small subset.

Procedural disadvantages and in-hospital MACE rate. Procedural disadvantages and in-hospital MACE rate for both groups are shown in Table 6. Procedure and fluoroscopy duration, radiation exposure, and procedural complications were all regarded as disadvantages of CTO-PCI. The procedure and fluoroscopy durations were significantly longer in the pCABG group than in the nCABG group (procedure duration: 210 ± 98 min vs. 166 ± 77 min, $p < 0.0001$, respectively; fluoroscopy duration: 64 ± 44 min vs. 51 ± 34 min, $p = 0.0002$, respectively). Moreover, radiation exposure was significantly greater in the pCABG group than in the nCABG group (frontal: 6.2 ± 5.9 Gy vs. 4.9 ± 4.0 Gy, $p = 0.0019$, respectively; lateral: 6.0 ± 10.6 Gy vs. 4.3 ± 3.3 Gy, $p = 0.0017$, respectively). The procedural complication of distal embolization occurred in 1.4% of patients with pCABG and 3.2% of patients with nCABG ($p = 0.17$). Type A coronary perforation was observed more often in patients with pCABG (15.5% vs. 14.4%, $p = 0.02$). There was no significant difference in-hospital MACE, although in-hospital death after the procedure occurred in 2 pCABG patients and 5 nCABG patients.

Logistic regression analysis. A logistic regression model was used to identify variables independently associated with the procedural success of CTO-PCI in an NCA with pCABG. IVUS use and the parallel-wiring technique were identified as independent predictors of greater procedural success among pCABG patients (IVUS use: OR: 3.74, 95% CI: 1.31 to 10.67, $p = 0.01$; parallel wiring: OR: 3.29, 95% CI: 1.79 to 6.04, $p = 0.0001$). Moreover, lesion tortuosity was

Table 1. Classification of Retrograde Approach

Dilation of CTO Before Guidewire Cross	Guidewire Cross Direction: Antegrade	Guidewire Cross Direction: Retrograde
No	Kissing guidewire cross	Retrograde guidewire cross
Yes	CART	Reverse CART

CTO = chronic total occlusion; CART= controlled antegrade and retrograde subintimal tracking.

Table 2. Patient Characteristics of pCABG and nCABG Groups

Variables	pCABG (n = 153)	nCABG (n = 1,139)	p Value
Age, yrs	68.2 (62.4–74.6)	66.0 (58.2–73.6)	0.002
Male	82 (125)	932 (82)	0.97
Diabetes mellitus	65 (42)	427 (37)	0.23
Hypertension	91 (59)	690 (61)	0.79
Hyperlipidemia	54 (35)	423 (37)	0.66
Familial history of CAD	15 (10)	138 (12)	0.41
Smoking	28 (18)	284 (25)	0.07
Renal insufficiency	16 (10)	67 (6)	0.03

Values are median (interquartile range) or n (%).

CAD = coronary artery disease; pCABG = previous coronary artery bypass grafting; nCABG = no previous coronary artery bypass grafting.

Table 3. Lesion and Procedural Characteristics of pCABG and nCABG Groups

Variables	pCABG (206 PCIs)	nCABG (1,431 PCIs)	p Value
Target vessel			0.0003
LAD	45 (22)	488 (34)	
RCA	93 (45)	616 (43)	
LCX	64 (31)	323 (22)	
LMT	4 (2)	4 (0.3)	
Calcification			
None	47 (23)	480 (34)	<0.0001
Mild	49 (24)	433 (30)	
Moderate	63 (30)	329 (23)	
Severe	47 (23)	176 (13)	
Tortuosity			0.18
None	164 (80)	1,211 (85)	
Moderate	29 (14)	157 (11)	
Severe	13 (6)	63 (4)	
Major branch at CTO	28 (14)	230 (16)	0.36
In-stent occlusion	20 (10)	178 (12)	0.26
Stent deployment	116 (56)	939 (66)	0.009
Initial success rate of PCI	146 (71)	1,184 (83)	<0.0001

Values are n (%).
LAD = left anterior descending artery; LCX = left circumflex; LMT = left main trunk artery; PCI = percutaneous coronary intervention; RCA = right coronary artery; other abbreviations as in Tables 1 and 2.

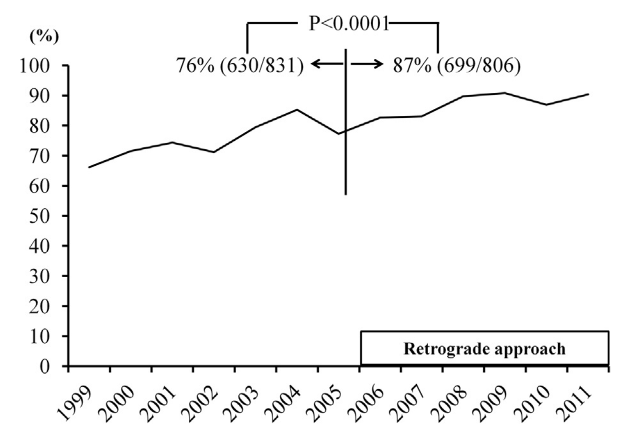

Figure 3. Annual Transition of Success Rate of Overall CTO-PCI

Annual transition of overall success rate of CTO-PCI. The initial success rate of CTO-PCI has improved over time, and in the comparison of before and after the emergence of retrograde attempt (2006), the success rate of CTO-PCI is significantly higher after the emergence of the retrograde attempt than before (before 2006: 76% [630 of 831] vs. after 2006: 87% [699 of 806], $p < 0.0001$). Recently, the success rate has been >90%. Abbreviations as in Figure 1.

identified as an independent predictor of a lower success rate (OR: 0.24; 95% CI: 0.13 to 0.49; $p < 0.0001$) (Fig. 4).

Discussion

The results of this study demonstrate that the initial success rate of CTO-PCI of NCA is decreased in pCABG patients. Novel techniques were often attempted in pCABG patients; however, their efficacy was limited. Although CTO-PCI was a more complicated procedure in pCABG patients, the in-hospital MACE rate was comparable between the 2 groups. Per logistic regression analysis performed for pCABG patients, IVUS use and parallel wiring were associated with greater procedural success, whereas the presence of tortuous lesions was associated with lower procedural success. Although previous CABG has been reported as a factor limiting the success of CTO-PCI (8), details of the techniques involved in each procedure have not been completely described to date. These study findings indicate that procedural details are indeed crucial for ensuring more successful treatment outcomes in patients with pCABG.

Revascularization of CTO lesions in pCABG patients: PCI for occluded graft, NCA, or repeat CABG? Compared with unsuccessful CTO-PCI procedures, the clinical merits of successful CTO-PCI have been established with several reports (9–13). PCI involving an occluded bypass graft is often accompanied by procedural complications such as vessel dissection and distal embolization. Once vessel dissection occurs, multiple stenting is required to cover the lesion completely because of truncation of the internal mammary artery branch. Massive thrombus formation due to decreased blood flow complicates the procedure, especially in vein grafts. Despite successful recanalization with bypass grafts, sufficient blood flow cannot be obtained at times because of factors such as emaciation of vessels and distal embolization. Therefore, CTO-PCI, and not recanalization of bypass grafts, is performed for an occluded NCA.

Repeat CABG has often been associated with a greater risk of adverse outcomes compared with initial CABG (14,15). When comparing CTO-PCI for an NCA with repeat CABG from the perspective of risks and benefits,

Table 4. Adopted Guidewire Strategies in pCABG and nCABG Groups

Variables (%)	pCABG (173 PCIs)	nCABG (1,121 PCIs)	p Value
Guidewiring strategy			
Parallel guidewire technique	49 (28)	335 (30)	0.68
Success	21 (43)	182 (54)	0.13
IVUS guided	24 (14)	121 (11)	0.23
Success	12 (50)	75 (62)	0.27
Overall retrograde attempt (including CART)	82 (47)	300 (37)	0.001
Success	41 (50)	174 (58)	0.19
CART technique	38 (22)	127 (11)	<0.0001
Success	27 (71)	114 (89)	0.004

Values are n (%).
IVUS = intravascular ultrasound; other abbreviations as in Tables 1 and 2.

JACC: CARDIOVASCULAR INTERVENTIONS, VOL. 7, NO. 1, 2014
JANUARY 2014:39–46

Table 5. Unique Procedural Characteristics of Success and Failed CTO-PCI in the pCABG Group

Variables	Success (146 PCIs)	Failed (60 PCIs)	p Value
Days since CABG performed	3,068 ± 2,445	3,831 ± 2,139	0.03
Re-attempt	5 (3)	4 (7)	0.30
Multiple CTOs at once	23 (16)	9 (15)	0.90
Via bypass graft wiring	10 (7)	5 (8)	0.71

Values are n (%).
Abbreviations as in Tables 1 to 3.

Variables	OR (95% CI)	P value
Days since CABG	0.82 (0.63, 1.06)	0.12
IVUS usage	3.74 (1.31, 10.67)	0.01
Parallel wiring	3.29 (1.79, 6.04)	0.0001
IVUS guided	1.25 (0.52, 3.03)	0.62
Retrograde attempt	0.59 (0.31, 1.14)	0.11
CART technique	1.60 (0.74, 3.46)	0.23
Calcified lesion	1.83 (0.90, 3.74)	0.09
Tortuous lesion	0.25 (0.13, 0.49)	<0.0001

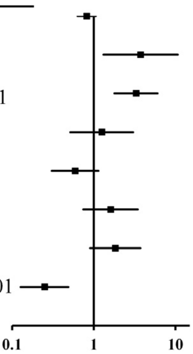

Figure 4. Results of Logistic Regression Analysis

These results include the pCABG patients only; 95% confidence intervals (CIs) are given. The use of IVUS and parallel wiring and vessel tortuosity were independent predictors of procedural success. An odds ratio (OR) of <1 indicates "less success" while that of >1 indicates more success. These results included the pCABG patients only. Abbreviations as in Figures 1 and 2.

lower success rates have been observed after CTO-PCI in patients who have undergone previous CABG. However, repeat CABG is itself associated with higher post-operative mortality rates (15); therefore, it is reasonable to perform CTO-PCI in an NCA before repeat CABG.

Lower success rate of CTO-PCI in pCABG patients. Despite the higher frequency of retrograde procedures using the CART technique in the pCABG group compared with that in the nCABG group, the success rate of CTO-PCI in the pCABG group was significantly lower than that in the nCABG group. This paradoxical finding may be because of the complexity of the procedure. If a retrograde approach is attempted, the operator will be forced to use the micro-channel via the bypass graft, which may provoke ischemia in multiple areas. Moreover, as described previously, once vessel dissection occurs in an arterial graft, multiple stenting is required. For these reasons, procedures using the collateral channel via an arterial bypass graft should be used as infrequently as possible. Although no statistically significant differences were noted, this tendency of avoidance due to bypass graft maneuvering was also observed in our study. The presence of anatomically complex, calcified, tortuous lesions in pCABG patients may also complicate CTO-PCI. The longer procedural duration in failed cases in the pCABG group may reflect the high degree of calcified lesion. The NCA can be dislodged if it is pulled along with the sutures of the bypass grafts, and it is difficult to anticipate the location and course of the NCA during the advancement and manipulation of a guidewire. Dislodgment of the NCA may also provoke complications along a collateral channel. Although the study population was small, our findings suggest that anatomic complexities may give rise to undesired results when retrograde procedures are used for pCABG patients. However, there were no obvious significant differences between successful and failed pCABG cases in terms of other unique occurrences such as re-attempt or multivessel CTO in this study.

Table 6. Procedural Disadvantages, Complications, and In-Hospital MACE in the pCABG and nCABG Groups

Variables	pCABG (206 PCIs)	nCABG (1,431 PCIs)	p Value
Disadvantages			
Procedure time, min	210.3 ± 98.1	165.6 ± 77.3	<0.0001
Fluoroscopy time, min	64.2 ± 44.1	51.2 ± 34.0	0.0002
Radiation exposure dose, Gy			
Frontal	6.2 ± 5.9	4.8 ± 4.0	0.0019
Lateral	5.9 ± 10.6	4.3 ± 3.3	0.0017
Occurrence of complications			
Distal embolization	3 (1.4)	46 (3.2)	0.17
Coronary perforation			
Type A	32 (15.5)	125 (14.4)	0.02
Type B	1 (0.4)	13 (0.9)	0.54
Occurrence of In-hospital MACE			
Death	2 (1.3)	5 (0.4)	0.20
Q-wave MI	1 (0.5)	6 (0.4)	0.76
Urgent CABG	0	5 (0.3)	0.40

Values are n (%).
MACE = major advance cardiac events; MI = myocardial infarction; other abbreviations as in Tables 2 and 3.

The frequency of stent deployment was unexpectedly low in both groups. The database used in this study includes data from the early era of CTO-PCI. The concept of false lumen dilation was not yet established at that time; therefore, the procedure was completed with balloon dilation alone. Once the dissected lesion had healed, a stent was deployed with the belief that the guidewire was present in the true lumen. Because the dissection re-entry technique had come to be widely accepted, the partial false lumen stenting permeated. This transition was probably responsible for the differences in results between patients treated before and after 2006.

Alternative methods for better results with CTO-PCI in the future. Methodology using the antegrade approach has progressed of late. The algorithm for crossing the CTO has been reported by Brilakis et al. (16). If appropriate collateral channels cannot be obtained, the CTO lesion must be approached in an antegrade manner. If the estimated length of the occluded lesion is >20 mm, antegrade dissection and re-entry are recommended. After subintimal crossing with the antegrade guidewire, device-based (Stingray System, BridgePoint Medical Inc., Minneapolis, Minnesota) or guidewire-based (limited antegrade subintimal tracking, LaST method) re-entry into the true lumen should be attempted. The Stingray System is not yet commercially available in Japan; however, a retrograde channel via the bypass graft may be difficult to handle because of the reasons described. A progressive antegrade approach may be an effective substitute for better results of CTO-PCI in pCABG patients.

Feasibility of CTO-PCI for pCABG patients. The procedural disadvantages of CTO-PCI were observed more often in pCABG patients than in nCABG patients, as shown in Table 6. A high amount of radiation exposure leads to radiation-related complications, particularly dermatitis. Therefore, CTO-PCI with long-term radiation exposure may not be justified, regardless of the superiority of this procedure.

Only the occurrence of type A coronary perforation was more frequent in pCABG patients than in nCABG patients; this may be because of the complexities of guidewire manipulation and the use of a stiff guidewire in this group. Furthermore, the devastating coronary perforation that leads to hemodynamic instability is less likely to occur after CABG in conditions where less free space is evident in the pericardial cavity. A positive outcome was the comparable incidence of procedure-related complications and in-hospital MACE between the pCABG and nCABG groups in this study.

Results of logistic regression analysis. In multivariate analysis among the pCABG patients, IVUS use, parallel guide wire technique, and severe tortuosity were the only predictors considered to be significantly associated with procedural success. As parallel wiring has been adopted for an antegrade approach, IVUS has played an exceedingly important role to detect the entry point from the false to true lumen. Although the real reason why these 2 factors were chosen is unclear, this result seems to be reflecting the progress of antegrade CTO-PCI. Although the retrograde approach is a novel and favored development in PCI, it can be established only after an antegrade approach is executed successfully. With regard to lesion morphology, vessel tortuosity and calcification have been well recognized as determinants of the initial success of CTO-PCI (3). In our study, only vessel tortuosity was recognized as the negative independent predictor of procedural success; however, lesion calcification must also be considered an obstacle to CTO-PCI. We assumed that natural vessel tortuosity was increased as a result of bypass surgery; this may have influenced the lower success rate in the pCABG group. Similarly, considering that the length of time since CABG in a successful PCI among pCABG patients was significantly longer than in a failed PCI, the length of time since CABG will affect procedural difficulty.

Study limitations. First, differences in the manner of the procedures as well as clinical settings involved in the performance of PCI could vary among countries; therefore, the results may also be variable. Second, the success of CTO-PCI is highly dependent on a physician's skill and experience. Although experience in performing CTO-PCI has increased in our hospital, the acute success rate will be affected by the operators' technical skill. Because this was a retrospective observational study, there are also inherent limitations. Finally, information regarding long-term clinical outcomes between successful and failed CTO-PCIs in the pCABG patients is lacking.

Conclusions

The initial success rate of CTO-PCI in NCA is decreased in patients with pCABG. Factors concomitant with the CTO-PCI procedure, such as complexity of anatomy, hemodynamic instability leading to ischemia, and exposure to radiation, are all recognized as factors that could be problematic for the interventional cardiologist. The authors of this study encourage that the retrograde approach be accepted more widely, and performed appropriately. Simultaneously, new antegrade methodology such as the dissection re-entry technique is expected to provide better results with CTO-PCI. We believe that an effort to perform these techniques in an easier and simpler manner will decrease the recognized disadvantages involved with the performance of CTO-PCI. This study reveals the concealed issues to be overcome, which are lying with the revascularization of CTO in NCA lesions in patients with pCABG.

Acknowledgments
The authors thank Heidi N. Bonneau, RN, MS, CCA, for her review and editing advice. They also thank Kazuki Shimizu and Kenji Sakamoto for data collection.

Reprint requests and correspondence: Dr. Tomohiko Teramoto, Department of Cardiovascular Medicine, Toyohashi Heart Center, 21-1, Gobudori, Ohyama-cho, Toyohashi, Aichi, 441-8530, Japan. E-mail: tomo.tera@gmail.com.

REFERENCES

1. Galassi AR, Tomasello SD, Reifart N, et al. In-hospital outcomes of percutaneous coronary intervention in patients with chronic total occlusion: insights from the ERCTO (European Registry of Chronic Total Occlusion) registry. EuroIntervention 2011;7:472–9.
2. Kimura M, Katoh O, Tsuchikane E, et al. The efficacy of a bilateral approach for treating lesions with chronic total occlusions the CART

(controlled antegrade and retrograde subintimal tracking) registry. J Am Coll Cardiol Intv 2009;2:1135–41.
3. Morino Y, Abe M, Morimoto T, et al. Predicting successful guidewire crossing through chronic total occlusion of native coronary lesions within 30 minutes: the J-CTO (Multicenter CTO Registry in Japan) score as a difficulty grading and time assessment tool. J Am Coll Cardiol Intv 2011;4:213–21.
4. Sumitsuji S, Inoue K, Ochiai M, Tsuchikane E, Ikeno F. Fundamental wire technique and current standard strategy of percutaneous intervention for chronic total occlusion with histopathological insights. J Am Coll Cardiol Intv 2011;4:941–51.
5. Ito S, Suzuki T, Ito T, et al. Novel technique using intravascular ultrasound-guided guidewire cross in coronary intervention for uncrossable chronic total occlusions. Circ J 2004;68:1088–92.
6. Surmely JF, Katoh O, Tsuchikane E, Nasu K, Suzuki T. Coronary septal collaterals as an access for the retrograde approach in the percutaneous treatment of coronary chronic total occlusions. Catheter Cardiovasc Interv 2007;69:826–32.
7. Surmely JF, Tsuchikane E, Katoh O, et al. New concept for CTO recanalization using controlled antegrade and retrograde subintimal tracking: the CART technique. J Invasive Cardiol 2006; 18:334–8.
8. Thompson CA, Jayne JE, Robb JF, et al. Retrograde techniques and the impact of operator volume on percutaneous intervention for coronary chronic total occlusions an early U.S. experience. J Am Coll Cardiol Intv 2009;2:834–42.
9. Mehran R, Claessen BE, Godino C, et al. Long-term outcome of percutaneous coronary intervention for chronic total occlusions. J Am Coll Cardiol Intv 2011;4:952–61.
10. Safley DM, House JA, Marso SP, Grantham JA, Rutherford BD. Improvement in survival following successful percutaneous coronary intervention of coronary chronic total occlusions: variability by target vessel. J Am Coll Cardiol Intv 2008;1:295–302.
11. Suero JA, Marso SP, Jones PG, et al. Procedural outcomes and long-term survival among patients undergoing percutaneous coronary intervention of a chronic total occlusion in native coronary arteries: a 20-year experience. J Am Coll Cardiol 2001;38:409–14.
12. Aziz S, Stables RH, Grayson AD, Perry RA, Ramsdale DR. Percutaneous coronary intervention for chronic total occlusions: improved survival for patients with successful revascularization compared to a failed procedure. Catheter Cardiovasc Interv 2007;70:15–20.
13. Jones DA, Weerackody R, Rathod K, et al. Successful recanalization of chronic total occlusions is associated with improved long-term survival. J Am Coll Cardiol Intv 2012;5:380–8.
14. Di Mauro M, Iaco AL, Contini M, et al. Reoperative coronary artery bypass grafting: analysis of early and late outcomes. Ann Thorac Surg 2005;79:81–7.
15. Yap CH, Sposato L, Akowuah E, et al. Contemporary results show repeat coronary artery bypass grafting remains a risk factor for operative mortality. Ann Thorac Surg 2009;87:1386–91.
16. Brilakis ES, Grantham JA, Rinfret S, et al. A percutaneous treatment algorithm for crossing coronary chronic total occlusions. J Am Coll Cardiol Intv 2012;5:367–79.

Key Words: chronic total occlusion ■ coronary artery bypass grafting ■ retrograde approach.