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Traditional Antegrade Approach Versus Combined Antegrade and Retrograde Approach in the Percutaneous Treatment of Coronary Chronic Total Occlusions

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Objectives: The goal of this study was to compare the antegrade-approach and bilateral-approach strategies for chronic total occlusion (CTO). Background: The retrograde approach has been reported for difficult CTO lesions. Methods: This study assessed 96 consecutive patients with 119 CTO lesions. The lesions were treated with either an antegrade approach (A group) or a combined bilateral antegrade and retrograde approach (B group). The specific intervention techniques, in-hospital success rate, and major adverse cardiac and cerebrovascular events (MACCE) were compared. Results: Lesions with well-developed septal collaterals with nontortuous microchannels were preferentially chosen for the B group versus A group (P < 0.001 and 0.008, respectively). Compared with the A group, there were more CTO lesions located in the right coronary artery in the B group (P < 0.001). In the B group, the CTO lesions had a longer length and needed stiffer wires for crossing than in the A group (P = 0.001 and 0.046, respectively). The technical success rate was 94% and 86% for the A group and the B group, respectively (P = 0.127). In-hospital complications were not different between the two groups. The B group needed a higher radiation exposure dose and a greater exposure time than the A group (P < 0.001). In the B group, use of the retrograde method significantly increased the final success rate. Conclusions: These results suggest that all CTO lesions should first be managed with an antegrade approach. When there is difficulty crossing the lesion, switching to a bilateral approach is an option for lesions with well-developed collaterals. © 2009 Wiley-Liss, Inc.

Key words: chronic total occlusion; antegrade approach; retrograde approach

INTRODUCTION

There is now an increasing body of published evidence demonstrating that successful percutaneous recanalization of occluded coronary vessels subtending viable myocardium not only reduces angina and improves quality of life but also improves left ventricular function and is strongly associated with enhanced survival [1,2]. However, the perceived procedural complexity of angioplasty in chronic total occlusion (CTO) represents the most common reason for referral to bypass surgery or for choosing medical treatment [3,4]. Percutaneous coronary intervention (PCI) for CTO remains technically challenging, and in spite of advances in equipment and operator expertise, published success rates are 60–80% [1,2,5]. A new strategy of a combined antegrade and retrograde approach for CTO has been developed in Japan and has become more popular during recent years [6–8]. The goal of this study was to investigate selection bias, feasibility, and safety between the antegrade approach and the bilateral approach strategy for PCI for CTO.

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Conflict of interest: Nothing to report.

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MATERIALS AND METHODS

Procedural Protocol

This study assessed 96 consecutive patients admitted to the Kusatsu Heart Center, Japan between March, 2006 and December, 2007 with CTO lesions in coronary arteries. The CTO lesions were treated with either an antegrade approach strategy (A group) or combined antegrade and retrograde approach strategy (B group). In the combined bilateral approach group, the retrograde approach was always tried first, and then the antegrade approach was performed after successful or failed retrograde attempts. The duration of the occlusion was estimated from previous angiographic data, the date of a myocardial infarction in the distribution of the occluded vessel, or a worsening of angina status. All patients provided written informed consent for PCI and retrospective survey.

Description of the Technique

Before conducting PCI for the CTO lesion, a careful review of the diagnostic angiogram was conducted, demonstrating a well-formed ipsilateral or contralateral collateral supply clearly delineating the vessel course distal to the occlusion. Collateral filling of the recipient artery was assessed according to the Rentrop classification [9]. The continuity of the microcollateral branch was checked, and the number of continuous microcollateral branches was also counted (Fig. 1).

Most patients accepted bilateral femoral punctures and 8-Fr guide catheters for orthogonal projection and contralateral injection, demonstrating a clear target vessel course. When the distal vessel was visible from the ipsilateral collateral flow, one side of the femoral artery punctured with a single 8-Fr guide catheter was used for PCI.

If there were one or more arterialized and noncorkscrew interventricular septal or epicardial branches providing collateral to the target lesion, the lesion was favored for an attempt via the retrograde approach at first, and the antegrade approach was performed thereafter.

A retrograde approach via septal or epicardial collaterals was accessed via the patent contralateral coronary artery and was crossed with a hydrophilic floppy wire with transit support (Terumo, Japan). A super-selective contrast injection was normally performed to visualize the appropriate size and course of the selected collateral branch via transit catheter, to avoid overlapping other collaterals.

After successful wire crossing of the collateral, the transit catheter was changed to an over-the-wire (OTW) balloon system. Sequential low-pressure dilatation of the collateral branch was performed with a 1.25- or 1.5-mm OTW balloon to allow the delivery of a balloon catheter to the distal CTO site and further manipulation. The soft wire crossing would then be attempted through the distal cap via the retrograde approach. If this soft wire failed to cross distal cap, another intermediate wire or stiff wire was exchanged for penetrating the distal CTO cap. The wiring procedure was supported with the backup of the OTW balloon catheter or even an anchoring technique by balloon inflation. After penetration of the distal end of the CTO lesion by an intermediate wire or stiff wire, the wire was advanced as far as possible and a distal channel was also further created by small balloon dilatation. Using the retrograde wire as a land marker, antegrade recanalization was also attempted. An attempt was then made to pass the antegrade guidewire through the proximal cap, the middle portion of the CTO, and the distal-created channel to the distal true lumen. During the wiring for the proximal cap or the distal cap, low-pressure inflation of the OTW balloon was sometimes done to increase the backup for wiring through the hard plaque. A parallel wire technique would sometimes be used for redirecting the second wire into the true channel when the first wire had obviously penetrated into a false lumen.

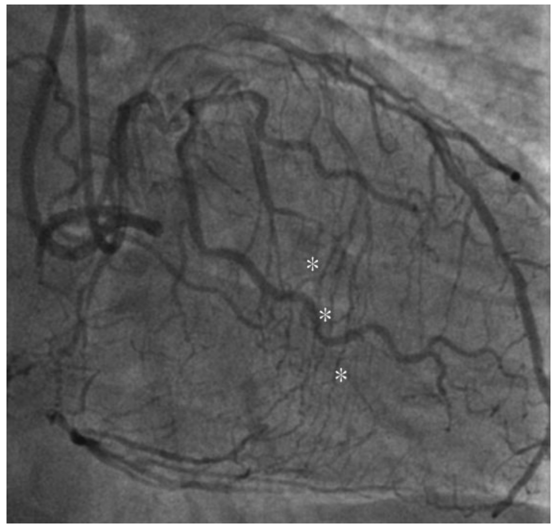

Fig. 1. Example of counting continuous micro-collaterals. The collateral branches originate from the proximal left anterior descending artery and supply to distal right coronary artery. Three continuous micro-collaterals can be identified by initial bilateral coronary injection (*).

The wire selection strategy for the proximal cap or distal cap was based on the stiffness step-up method. The progressively stiffer wire approach began with Fielder wire, followed by Asahi intermediate wire, Miracle 6 g, Miracle 12 g, and finally Conquest Pro 12 g. Conquest Pro 12 g was reserved for puncturing purposes for especially hard lesions.

If the collateral branch was tortuous or noncontinuous based on the initial bilateral angiogram, the PCI procedure was tried via the antegrade approach directly. In this situation, penetrating the proximal fibrous cap required progressively stiffer wires based on the same stiffness step-up strategy.

Concomitant Medications

At the start of the procedure, intravenous heparin was administered at a dose of 70 IU/kg to achieve an activated clotting time of 250 to 350 sec. Antiplatelet therapy with 100 mg aspirin and 200 mg qd ticlopidine was administered, starting 3 days prior to the procedure. Aspirin was continued indefinitely, and ticlopidine was administered for a minimum period of 1 year. The dosing of ticlopidine was restricted by the insurance system in Japan.

Definitions

A CTO is defined as either complete interruption or minimal antegrade flow (TIMI grade 0 or 1 flow) [10] and estimated occlusion duration >3 months. The duration of the CTO was estimated from previous angiographic data or from clinical information (acute myocardial infarction, sudden change in angina pattern) or electrocardiographic changes consistent with the location of the occlusion.

Technical success was defined as restoration of antegrade flow, with a TIMI grade 2 or 3 flow, and also a final residual stenosis less than 30% as assessed by quantitative coronary angiography. In addition, it should be documented that the distal wire position was in the true lumen by either a coronary angiogram or IVUS examination. In-hospital major adverse cardiac and cerebrovascular events (MACCE) were defined as death, non-ST-elevation, or ST-elevation MI, the need for target vessel revascularization (TVR), or cerebrovascular accident. Non-ST-elevation MI was defined as any increase of total creatine kinase more than three times higher than normal, without new abnormal ST-elevation or Q waves. Procedural success was defined as technical success without in-hospital MACCE.

A successful retrograde approach was defined as passing through the collateral branch and successfully wiring through the distal cap of the CTO lesion without any complications, including collateral perforations and subendocardial hematoma.

Angiographic restenosis was defined as stenosis of >50% by quantitative coronary angiography at follow-up angiography.

Statistical Analyses

Continuous data are presented as means ± standard deviations (SD), and differences were compared using a Student's *t* test. Discrete variables are expressed as counts, and percentages and differences were assessed using a chi-square test. All statistical tests were two-tailed. A *P* value of <0.05 was considered statistically significant. All analyses were performed using SPSS version 11 statistical software (SPSS, Chicago, IL).

TABLE I. Baseline Clinical Characteristics and Diseased Vessel Number of Patients

	A-group ($n = 59$)[a]	B-group ($n = 46$)[a]	*P*
Age	65.05 ± 11.2	65.04 ± 10.6	0.998
Male	52 (88.1%)	41 (89.1%)	0.874
Smoking	18 (30.5%)	14 (30.4%)	0.994
Body mass index (BMI)	25.0 ± 4.7	25.1 ± 3.6	0.892
Obesity (BMI > 29.9)	6 (10.2%)	7 (15.2%)	0.436
Diabetes	29 (49.2%)	24 (52.2%)	0.759
Hypertension	37 (62.7%)	26 (56.5%)	0.521
Hyperlipidemia	37 (62.7%)	34 (73.9%)	0.224
Acute MI	2 (3.4%)	0 (0%)	0.240
Old MI	13 (22.0%)	17 (37.0%)	0.093
Prior PCI history	37 (62.7%)	36 (78.3%)	0.086
Prior CABG history	3 (5.1%)	4 (8.7%)	0.462
PAOD	25 (42.4%)	20 (43.5%)	0.910
Old CVA	3 (5.1%)	4 (8.7%)	0.462
Hemoglobin	13.3 ± 1.9	13.4 ± 1.6	0.889
Creatinine	1.1 ± 0.8	1.0 ± 0.3	0.398
Renal failure (Cr > 1.09 mg/dl, upper limit in KHC)	16 (27.1%)	8 (17.4%)	0.239
LVEF (%)	56.33 ± 14.0	56.4 ± 13.9	0.970
LV failure (EF < 50%)	21 (37.2%)	13 (28.2%)	0.456
Wall motion index	1.3 ± 0.4	1.2 ± 0.4	0.257
Disease vessel number			
One vessel disease	6 (10.2%)	6 (13.0%)	
Two vessel disease	16 (27.1%)	14 (30.4%)	0.798
Triple vessel disease	37 (62.7%)	26 (56.5%)	

[a]Nine patients with two CTO lesions, who accepted different PCI strategies for different lesions, were double-counted in the different groups.
MI, myocardial infarction; PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft surgery; PAOD, peripheral artery occlusive disease; CVA, cerebrovascular accident; KHC, Kusatsu heart center; LV, left ventricle; EF, ejection fraction.

RESULTS

Table I displays baseline clinical and demographic characteristics. The study enrolled 96 patients with 119 CTO lesions. Fifteen patients had two CTO lesions, and nine of these patients accepted different PCI strategies for different lesions. These nine patients were double-counted in the different groups in Table I. Additionally, eight patients accepted a second intervention via the same approach strategy, five patients because of 6-month restenosis, and three patients because of a failed first attempt. A notable number of patients had multi-vessel disease in both groups. There were more patients with old myocardial infarctions and prior PCI history in the B group than in the A group

TABLE II. Baseline Angiographic Characteristics of Lesions

	A-group ($n = 69$)	B-group ($n = 50$)	P
Target lesion			
LAD	21 (30.4%)	11 (22.0%)	<0.001[a]
LCX	29 (42.0%)	4 (8.0%)	
RCA	19 (27.5%)	35 (70%)	
De novo lesion	63 (91.3%)	44 (88.0%)	0.556
Lesion location			
Ostial	16 (23.2%)	7 (14.0%)	0.502
Proximal	16 (23.2%)	13 (26.0%)	
Middle	29 (42.0%)	26 (52.0%)	
Distal	8 (11.6%)	4 (8.0%)	
Bifurcation branch at proximal stump	55 (79.7%)	45 (90.0%)	0.130
Proximal taper stump	45 (65.2%)	23 (46.0%)	0.037[a]
Distal taper stump	62 (89.9%)	43 (86.0%)	0.519
Calcification grade			
Moderate	24 (34.8%)	24 (48.0%)	0.349
Heavy	17 (24.6%)	10 (20.0%)	

LAD, left anterior descending artery; LCX, left circumflex artery; RCA, right coronary artery.
[a]$P < 0.05$.

TABLE III. Baseline Characteristics of Collateral Circulation

	A-group ($n = 69$)	B-group ($n = 50$)	P value
Collateral grade			
Grade 1	6 (8.7%)	1 (2.0%)	0.174
Grade 2	14 (20.3%)	7 (14.0%)	
Grade 3	49 (71.0%)	42 (84.0%)	
Collateral location			
Inter-ventricular septum (IVS)	19 (27.5%)	30 (60%)	<0.001[a]
Free wall (FW)	46 (66.7%)	13 (26.0%)	
Both IVS and FW	4 (5.8%)	7 (14%)	
Continuous micro-collateral (MC) number			
MC No. 0–1	43 (62.3%)	16 (32.0%)	0.001[a]
MC No. 2–4	24 (34.8%)	24 (48.0%)	
MC No. 5–7	2 (2.9%)	10 (20.0%)	
Tortuous MC	49 (71.0%)	23 (46.0%)	0.008[a]
Bridging collateral	14 (20.3%)	15 (30.0%)	0.223

[a]$P < 0.05$.

TABLE IV. Intervention Characteristics Including Specific Technique and Devices

	A-group ($n = 69$)	B-group ($n = 50$)	P
Stiff wire (>Miracle 6 g)	40 (58%)	38 (76%)	0.041[a]
Miracle wire (6 or 12 g)	36 (52.2%)	37 (74.0%)	0.016[a]
Conquest pro 12 g	6 (8.7%)	5 (10.0%)	0.808
Parallel wire technique	33 (47.8%)	16 (32.0%)	0.083
Proximal anchoring	6 (8.7%)	10 (20.0%)	0.074
Distal anchoring	0 (0%)	11 (22.0%)	<0.001[a]
Contra-lateral injection	54 (78.3%)	50 (100%)	<0.001[a]
Amplatz catheter	42 (60.9%)	44 (88.0%)	0.001[a]
Tornus usage	4 (5.8%)	1 (2.0%)	0.308
IVUS for CTO ostium	13 (18.8%)	10 (20.0%)	0.874
IVUS usage	66 (95.7%)	45 (90.0%)	0.224

IVUS, intravascular ultrasound; CTO, chronic total occlusion.
[a]$P < 0.05$.

($P = 0.093$ and 0.086, respectively). The other baseline clinical characteristics, including age, sex, obesity, diabetes mellitus, hypertension, peripheral artery occlusive disease, renal failure, prior coronary artery bypass graft surgery, old cerebrovascular accident, left ventricle failure rate, and number of diseased vessels, had no significant differences between the A group and the B group.

Table II shows the baseline angiographic characteristics of the 119 CTO lesions.

The bilateral approach strategy was preferentially selected for RCA-CTO lesions ($P < 0.001$). The antegrade approach strategy was preferentially selected for CTO lesions with a proximal tapering stump ($P = 0.037$). There were no significant differences in angiographic estimated calcification grade, lesion location, de novo lesion, bifurcation branch at the proximal stump, or the distal tapering stump between the groups. The most distal stumps had a tapering morphology in both groups (89.9% and 86.0%, respectively).

Table III lists collateral circulation grade classified by the Rentrop criteria, collateral location, continuous microcollateral number, and tortuous character. There was no difference in collateral grade as classified by Rentrop criteria between the groups. However, there were more septal collaterals in the B group than in the A group.

In addition, there were more visible continuous micro-collaterals in the B group than in the A group, suggesting that lesions with tortuous and few continuous micro-collaterals were preferentially selected for the antegrade approach strategy. In contrast, the CTO lesions with arterialized and nontortuous micro-collaterals were preferentially selected for the bilateral-approach strategy.

Table IV lists wire selection and specific techniques for CTO-PCI. The wire step-up strategy was used for wiring the proximal cap and the distal cap. The CTO lesions selected for the B group needed more stiff wire than the A group ($P = 0.041$). The major difference lay in choosing Miracle 6 g or Miracle 12 g wires.

The use of Amplatz catheters and a wiring technique with balloon anchoring back-up was more common in the B group than in the A group. The parallel wiring technique was more common used in the antegrade approach ($P = 0.083$). There were no differences in the utility of intravascular ultrasound for identifying the CTO ostium or for guiding intervention. In addition, there was no significant difference in the Asahi tornus usage rate between the two groups.

Table V shows procedural characteristics and quantitative coronary angiography analysis. The technical

TABLE V. Procedure Characteristics and Quantitative Coronary Angiography Analysis

	A-group ($n = 69$)	B-group ($n = 50$)	P
Technical success	65/69 (94.2%)	43/50 (86.0%)	0.127
Procedure success	62/69 (89.9%)	40/50 (80.0%)	0.129
Stenting rate in success lesions	59/65 (90.8%)	39/43 (90.7%)	0.990
Stent type			
DES	48/59 (81.4%)	24/39 (61.5%)	0.036[a]
BMS	4/59 (6.8%)	2/39 (5.1%)	
Hybrid of DES and BMS	7/59 (11.9%)	13/39 (33.3%)	
Stent length	36.7 ± 21.1	51.8 ± 27.7	0.002[a]
Stent No.	1.3 ± 0.7	1.8 ± 0.9	0.005[a]
Lesion length	35.1 ± 17.3	46.9 ± 21.3	0.001[a]
Prereference diameter	2.6 ± 0.6	2.7 ± 0.5	0.880
Preminimal lumen diameter	0	0	NS
Prediameter stenosis (%)	100	100	NS
Postreference diameter (mm)	3.2 ± 0.5	3.4 ± 0.5	0.049[a]
Postminimal lumen diameter (mm)	2.8 ± 0.6	2.9 ± 0.6	0.59
Postdiameter stenosis (%)	11.9 ± 10.4	17.7 ± 16.7	0.028[a]
Post-TIMI			
Grade 0 (failure)	4 (5.8%)	6 (12.0%)	0.423
Grade 2	8 (11.6%)	4 (8.0%)	
Grade 3	57 (82.6%)	40 (80.0%)	
Radiation exposure time (min)	55.1 ± 31.5	101.3 ± 43.0	<0.001[a]
Radiation exposure dose (mGy)	3319.7 ± 1865.1	5724.7 ± 3451.3	<0.001[a]

DES, drug eluting stent; BMS, bare metal stent; TIMI, thrombolysis in myocardial infarction; NS, nonsignificant.
[a]$P < 0.05$.

success rate was 94.2% in the A group and 86.0% in the B group ($P = 0.127$, Fig. 2). The procedure success rate was 89.9% in the A group and 80.0% in the B group ($P = 0.129$). The stenting rates for technical success lesions were 90.8% and 90.7% in A group and B group, respectively. There were more lesions with hybrid drug-eluting stent (DES) and bare metal stent (BMS) implantation in B group than A group ($P = 0.036$). Among the total DES implantations ($n = 92$) including pure DES and hybrid of DES and BMS, there were 87 sirolimus-eluting stents (94.6%) and 5 paclitaxel-eluting stents (5.4%). Both stent length and lesion length were longer in the B group than in the A group ($P = 0.002$ and 0.005, respectively). The postreference diameter was larger in the B group than in the A group, although the post-PCI diameter stenosis was higher in the B group than in the A group ($P = 0.028$).

However, the exposure time and exposure dose were significantly higher in the B group than in the A group ($P < 0.001$). The post-PCI TIMI grade was not different between the groups. Successful procedures with TIMI 3 flow were 82.6% in the A group and 80.0% in the B group. In the A group, four patients had failures with the antegrade approach. The reason for failed intervention in three patients was false lumen creation with long dissection. The other patient with an RCA lesion had a failed intervention due to an inability to cross the lesion by wire. In the B group, seven patients had a failed bilateral approach in which the initial retrograde approaches all failed to cross the tortuous

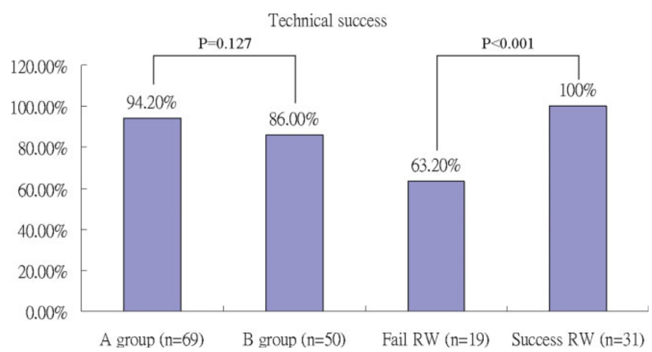

Fig. 2. The respective technical success in both groups and subgroup analysis of the B group; difference in final results between the successful retrograde-approach subgroup and failed retrograde-approach subgroup. RW, retrograde wiring. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

collateral micro-channel. Further antegrade approaches in these patients resulted in false lumen creation and long dissection, coronary extravasations, and failing to penetrate the hard lesion by wire in 4, 2, and 1 patients, respectively.

Table VI shows in-hospital MACCE rate, coronary artery trauma, and renal failure rate.

The in-hospital MACCE rate and other complications, including wire perforation, coronary dissection >10 mm with TIMI 2 flow, and acute renal failure with elevated creatinine > 1.0 mg/dl, were similar in

TABLE VI. In-Hospital Complication Rate

	A-group ($n = 69$)	B-group ($n = 50$)	P
In-hospital MACCE			
Death	0	0	NS
STEMI	0	0	NS
NSTEMI	3 (4.3%)	3 (6.0%)	0.684
TVR	0	0	NS
CVA	0	0	NS
Wire perforation (WP)	5 (7.2%)	7 (14.0%)	0.227
Coronary dissection (CD) >10 mm with TIMI 2 flow	5 (7.2%)	3 (6.0%)	0.789
Complications (WP and CD) were made by			
Antegrade wire (AW)	10 (14.5%)	8 (16.0%)	0.406
Retrograde wire (RW)	0	1 (2.0%, RW:CD)	
Both AW and RW	0	1 (2.0%, AW:WP, RW:WP)	
Acute renal failure with elevated Cr > 1.0 mg/dl	2 (7.2%)	0	0.225
Preventive hemodialysis for RF patients	1 (1.4%)	1 (2.0%)	0.818

STEMI, ST-elevation myocardial infarction; NSTEMI, non-ST elevation myocardial infarction; TVR, target vessel revascularization; CVA, cerebrovascular accident; NS, nonsignificant.

both groups. There were two patients with known renal failure who accepted preventive hemodialysis immediately after the PCI procedure; both patients did not need long-term hemodialysis thereafter.

Figure 2 shows the respective technical success in both groups and subgroup analysis of the B group. The technical success rate was 86% using the combined bilateral approach strategy. In the subgroup analysis, the final success rate was significantly different between the failed retrograde approach subgroup and the successful retrograde approach subgroup ($P < 0.001$). If the retrograde wire failed to cross the collateral branch and advance to the distal cap, the technical success rate was only 63.2%. If the retrograde wire successfully penetrated the distal cap and advanced into the CTO middle portion for some distance, the technical success rate of the combined bilateral approach strategy approached 100%. In the combined bilateral approach strategy, the retrograde approach was able to increase the technical success rate from 63.2 to 86.0%.

In bilateral-approach group ($n = 50$), the guide wires could successfully cross through the collateral branches and penetrate through distal stump in 31 lesions (62%), the wires failed to reach the distal stump in 19 lesions (38%). Among the successful retrograde-approach subgroup ($n = 31$), the balloon catheters were successfully advanced through the collaterals in 21 lesions, and the retrograde wires could completely cross through both distal and proximal stump in 8 CTO lesions.

Failures of the retrograde approach strategy were largely due to tortuous micro-channels and secondarily to coronary artery trauma. Nineteen patients had a failed retrograde approach; 17 of these patients had tortuous micro-collaterals, one patient had extravasations at the septal collateral, and the other patient had a long dissection at the distal coronary artery of CTO lesion.

These 19 patients accepted further antegrade approaches and were able to achieve final success in 12 (63.2%) patients and had final failure in 7 (36.8%) patients.

Table VII shows the half-year follow-up (FU) results. Short-term clinical follow-up was available for 93.3% of the CTO cohort. While these retrospective data were being collected, one-third of the patients had just received a PCI procedure less than 6 months previously. The scheduled half-year angiographic FU rate was 55.4 and 51.1% in the A group and the B group, respectively. The most common half-year MACCE event was TVR (16.7% in the A group, 27.3% in the B group, $P = 0.333$).

There was no patient who needed long-term hemodialysis after PCI. Additionally, there was no patient who suffered from radiation dermatitis in the hospital or at out-patient-clinic follow up.

DISCUSSION

This retrospective study was designed to analyze a newly developed bilateral approach strategy for CTO-PCI performed by one experienced and skilled operator (Dr. Hideo Tamai). Before performing PCI for CTO lesions, some specific considerations about the choice of strategy were applied. This selection bias may have influenced the success rate of the procedure, but it was also an important and necessary key point before making a decision.

Major Issues in Choosing Between the Two Strategies

The antegrade cap may be more fibrous and harder than the distal lesion cap, which may be attributed to the flow dynamics of blood in the vessel and the collaterals involved. In the antegrade approach, there is often difficulty in crossing the lesion with the guidewire in

TABLE VII. Half Year Follow-Up Results

	A-group ($n = 69$)	B-group ($n = 50$)	P
6-month follow-up (FU) rate	36/65 (55.4%)	22/43 (51.1%)	
MACCE			
Death	0	0	NS
STEMI	0	0	NS
NSTEMI	0	0	NS
TVR	6/36 (16.7%)	6/22 (27.3%)	0.333
CVA	0	0	NS
Reason of no angiographic FU			
PCI intervention < 6 months	20 (29.0%)	17 (34.0%)	
Loss of clinical FU	4 (5.8%)	4 (8.0%)	
Patients hesitate for angiographic FU	5 (7.2%)	0 (0%)	
Long-term hemodialysis after PCI	0	0	NS
Radiation dermatitis	0	0	NS

STEMI, ST-elevation myocardial infarction; NSTEMI, non-ST elevation myocardial infarction; TVR, target vessel revascularization; CVA, cerebrovascular accident; NS, nonsignificant; PCI, percutaneous coronary intervention.

the proximal entry and distal reentry. Currently, the reason for this is believed to be the proximal and distal fibrous caps acting as barriers and forcing the guidewire to enter the subintima [11].

In previous studies, traditional predictors for the failure of the antegrade approach have included multi-vessel disease, bridging collateral, a bifurcation branch at the proximal stump, a blunt stump, long lesion length, moderate to severe calcification, vessel tortuosity (>45°), and ostial occlusion [12–15]. If the proximal stump of the CTO is tapering, it is an attractive point for initial selection of the antegrade approach. This point was also demonstrated in this study.

The initial strategy decision mainly focuses on the collateral location and tortuosity of microcollateral. If the collateral is located at the epicardial, the risk of cardiac tamponade related to vessel trauma threatens the patient's life. The septal collateral is more favored for the retrograde approach. If the microcollateral channel is corkscrew, the risk of collateral damage is high. When the duration of CTO is long, the collateral branches increase and become nontortuous, becoming suitable for the retrograde approach.

In this study, there were more continuous micro-collateral branches in the B group than in the A group. The length of the lesion was longer and needed stiffer wire in the B group than the A group. This suggests the age of the CTO lesions of the B group was greater than the A group. Given a distal tapering occlusion, retrograde wire crossing might also be less likely to result in a coronary artery dissection. This is probably because the distal lesion is tapered and the fibrous cap at that end is either very thin or nonexistent.

In this study, a selection bias existed involving lesion length, collateral circulation, and collateral location. If a relatively long CTO lesion was located at the RCA and supplied with well-developed septal collateral, the lesion could be favorably managed using the bilateral approach. If there was a relatively short CTO lesion supplied with a corkscrew micro-collateral branch, noncontinuous micro-collateral connections, or at the epicardial branch, it would be favored for the antegrade approach first.

The Advantage and Disadvantage of Bilateral Approach

In this study, the combination of antegrade and retrograde approaches was always attempted with the retrograde approach first, then the antegrade approach was performed after successful or failed retrograde wiring. This unique protocol was used for evaluating the added benefits and feasibility of the retrograde approach.

Often, the end of the CTO had developed a hard fibrous cap, which is more difficult to penetrate than the middle of the lesion. Therefore, both the proximal and distal fibrous caps disturbed the passage of the antegrade guidewire. Because the antegrade wiring procedure usually creates a subintimal channel, the parallel wiring technique was often required for getting into distal true lumen.

In addition, bridging collateral has proven to be an important predictor of failure intervention for CTO [14,15]. Many channels spread out tree-like from the proximal side within an old CTO lesion. In the retrograde approach, the wire is unlikely to enter these branch channels originating from the proximal stump.

Blunt occlusions can be difficult to cross, especially when a side branch arises at the site of the CTO. Typically, the guidewire will often repeatedly deflect into the side branch and it may be difficult to penetrate the proximal fibrous cap. Old occlusions typically taper at the end to form a convex structure, making antegrade penetration of the distal fibrous cap difficult [16].

The retrograde approach for CTO lesions has recently been reported as a treatment option if there is difficulty with the antegrade route [6–8,11]. In this study, the distal stump was usually tapering and softer than the proximal cap. Compared with the antegrade approach, the retrograde wire can either serve as a marker or create a distal channel that can then be used to facilitate antegrade passage of a second wire. Retrograde wire passage may enable the operator to penetrate the distal end of the lesion more easily in comparison to the antegrade approach.

When the collateral branch is obvious and nontortuous, the above difficult lesion morphologies can be dealt with using the retrograde approach. If the distal cap can be penetrated by a guide wire and successfully dilated by balloon, this method can also shorten the length of the antegrade wiring and raise the success rate of CTO intervention. In the B group, the relatively long CTO lesion required stiff wire, strong back-up from the Amplatz guiding catheter, and a balloon anchoring technique during the intervention. With a successful retrograde approach, the technical success rate reached 100% using the bilateral approach strategy. In contrast, the technical success rate was only 63.2% with a failed retrograde approach, indicating that the technical success rate was raised from 63.2% to average 86.0% using the combination of antegrade and retrograde approach strategies.

In this study, when the bilateral approach was performed for relatively long CTO lesions, the success rate and complication rate were similar to those for relatively short CTO lesions. However, the cost of the bilateral-approach strategy was a longer procedure time and a higher exposure dose than the antegrade approach. There were new complications related to the retrograde approach, which included collateral branch damage and distal coronary dissection. The retrograde long dissection probably needs to be managed with multiple stents. Additionally, compared to intervention of nonoccluded stenosis, recanalization of CTOs requires an experienced operator's skill.

Study Limitations

Our analysis is a retrospective study. The results of the study may have been strongly influenced by selection criteria, operator experience, and technique. A high success rate was observed. It is believed that an important but noncalculated parameter is operator's experience and skill. Therefore, there may be different results under different conditions.

In addition to the characteristics of collateral branches, the other possible bias for selecting antegrade approach might include proximal taper stump, shorter lesion length and less right coronary lesions. The favorable anatomy probably influenced the selection of the strategies.

CONCLUSIONS

When the bilateral approach was performed for relatively long CTO lesions, the success rate and complication rate were similar to those of relatively short CTO lesions. The cost of the bilateral-approach strategy was a longer procedure time and higher exposure dose than the antegrade approach. With the addition of the retrograde approach, the combination of the antegrade and retrograde approaches does significantly elevate the success rate in difficult and hard CTO lesions. The use of the bilateral approach strategy primarily depends on collateral characteristics. When there is difficulty in crossing CTO lesion with an antegrade wire, switching to a bilateral approach is an option for lesions with well-developed collaterals.

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