Retrograde Percutaneous Recanalization of Chronic Total Occlusion of the Coronary Arteries

Procedural Outcomes and Predictors of Success in Contemporary Practice

Sudhir Rathore, MD, MRCP; Osamu Katoh, MD; Hitoshi Matsuo, MD; Mitsuyasu Terashima, MD; Nobuyoshi Tanaka, MD; Yoshihisa Kinoshita, MD; Masashi Kimura, MD, PhD; Etsuo Tsuchikane, MD, PhD; Kenya Nasu, MD; Mariko Ehara, MD; Keiko Asakura, MD; Yasushi Asakura, MD; Takahiko Suzuki, MD

Background**—**Retrograde approach through collaterals has been introduced for percutaneous recanalization of chronic total occlusion (CTO) of the coronary arteries. We investigated the safety and efficacy of retrograde approaches used for percutaneous recanalization of CTO in a consecutive series of patients.

Methods and Results**—**We studied 157 consecutive patients who underwent retrograde CTO recanalization between 2003 and 2008 at a single center. A total of 118 (75.2%) of these patients have had previously failed antegrade attempts. Septal, epicardial, and saphenous vein graft collaterals were used in 67.5%, 24.8%, and 7.6% of cases, respectively. Collateral channel was crossed by guide wire successfully in 115 (73.2%) cases, and the procedure was successful by retrograde approach in 103 (65.6%) cases. Collateral channels (CCs) were graded as follows: CC0, no continuous connection; CC1, continuous thread-like connection; and CC2, continuous, small sidebranch-like connection. CC1, collateral tortuosity <90°, and angle with recipient vessel <90° ($P<0.0001$) were significant predictors of success. Epicardial channel use ($P=0.01$), CC0, corkscrew channel ($P<0.0001$), angle with recipient vessel >90° ($P=0.0007$), and nonvisibility of connection with recipient vessel were found to be significant predictors of procedural failure. The CC dissection was observed in 6 patients, with 1 needing coil embolization and others who were managed conservatively. The major adverse cardiac events were low, with 1 coronary artery bypass graft, 1 Q-wave myocardial infarction, 5 non–Q-wave myocardial infarctions, and no deaths in this group of patients.

Conclusions**—**The retrograde approach in CTO percutaneous coronary intervention is effective in recanalizing CTO. The success rate by retrograde approach was 65.6%, and final success was 85% in this group with acceptable overall adverse events. We have identified predictors of failure related to collateral morphology. **(*Circ Cardiovasc Intervent*. 2009;2:124-132.)**

Key Words: chronic total occlusion ■ coronary angioplasty ■ retrograde approach ■ collateral circulation ■ coronary disease

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Successful recanalization of chronic total occlusion (CTO) of the coronary arteries has been associated with improved survival, improved left ventricular systolic function, reduced angina, and increased exercise capacity.[1–3] Approximately one third to one half of the patients with significant coronary artery disease on angiography have at least 1 CTO.[4,5] However, they account of only 10% to 15% of all percutaneous coronary intervention (PCI) activity[6] and most patients are treated with either coronary artery bypass grafting or medical therapy. Procedural success rate for CTO has improved over time but is still low and is mainly due to the failure to cross the lesion with the guide wire ([2,7–13]). Different strategies and dedicated specific devices for CTO have been developed to improve guide wire crossing and successful recanalization. These include subintimal tracking and re-entry,[14] parallel wire technique,[15] intravascular ultrasound guided wire crossing,[16,17] retrograde approach,[18] controlled antegrade and retrograde tracking.[19]

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Retrograde approach has been described initially via the bypass grafts[20] and more recently the use of septal collaterals has been described[18] to be safe and effective. Retrograde approach for recanalization of CTO has gained popularity recently with improved success rates as shown in several case reports and small series of selected patients.[21,22] Although the retrograde technique has great potential, its technical success rate and procedural outcomes are not been assessed in large series of patients in contemporary practice.

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From the Department of Cardiology, Toyohashi Heart Center, Toyohashi, Japan.

Correspondence to Sudhir Rathore, MD, MRCP, Department of Cardiology, Toyohashi Heart Center, 21-1, Gobudori, Oyama-Cho, Toyohashi, Japan 441-8530. E-mail sudhirrathore@hotmail.com

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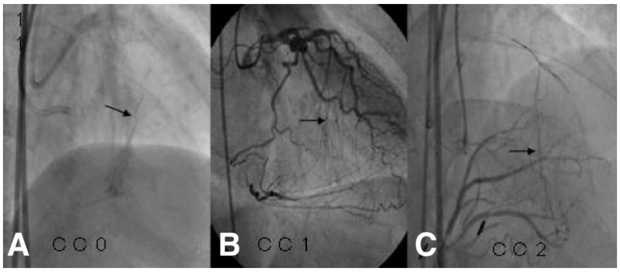

Figure 1. CC0 septal collaterals (A), CC1 septal collaterals (B), and CC2 septal collaterals (C).

The aim of this study was to examine the procedural details, predictors of success, and complications during retrograde approach for recanalization of CTO in a large series of unselected patients.

Methods

Study Population

All patients who have had coronary intervention performed for CTO were screened from a dedicated database where data are entered prospectively between January 2002 and August 2008 at Toyohashi Heart Center (Toyohashi, Japan). A total of 157 patients were identified who have had retrograde attempt to recanalize CTO during any stage of the procedure. The baseline demographics, angiographic characteristics, procedural outcomes, and complications were examined in all 157 patients. All procedural coronary angiograms were reviewed to assess the anatomy and morphology of CTO segment and collaterals used.

Definitions

CTO was defined as a lesion showing thrombolysis in myocardial infarction grade of 0 of 3 months or more in duration. All patients included in this analysis have at least 1 occlusive lesion. Duration of occlusion was estimated on the basis of history of angina, previous myocardial infarction (MI) in the same territory, or proven by previous angiography.

Major adverse cardiac events were defined as death, Q-wave MI, non–Q-wave MI, or urgent revascularization during the same admission. Urgent revascularization was defined as target vessel repeat PCI within 24 hours or urgent coronary artery bypass graft (CABG) surgery.

Q-wave MI was defined as cardiac enzyme (creatine kinase) elevation of >3 times the normal value with concomitant elevation of creatine kinase myocardial-band >3 times and development of Q wave after the PCI. Non–Q-wave MI was defined as elevation of creatine kinase >3 times without development of Q wave after the PCI.

Procedural success was defined as successful guide wire and balloon crossing with residual stenosis >50% and Thrombolysis in Myocardial Infarction grade 3 flow.

The attempt of the retrograde approach was defined as the introduction of the guide wire into the collateral channels (CCs), which was connecting to the target CTO vessel distal to the lesion. Length of the CTO was measured following bilateral simultaneous coronary injections visualizing the filling of both proximal and the distal occluded artery.

Angiographic Assessment of the Collaterals

Angiographic assessment of the collaterals was performed after bilateral simultaneous coronary injection performed in 2 perpendicular projections. Visibility of the CC was assessed after selective injections in the CC, if the coronary angiography was inadequate.

CCs were visually examined from the donor vessel up to the recipient vessel to ascertain the morphology, tortuosity, angle, and the channel diameter measured by calipers in the projection showing the smallest diameter with least foreshortening.

The following definitions were used to describe the morphology of the CCs: CC0, no continuous connection between donor and recipient vessel; CC1, continuous thread-like connection; CC2, continuous, small sidebranch-like connection (Figure 1)[23]; visible, the connection is visible on coronary angiography or on the selective collateral injection all the way extending from donor to recipient vessel; donor vessel, the parent vessel that is supplying the CC to the target vessel; donor vessel angle, the angle that the CC makes with the donor vessel at the point of branching; and CC tortuosity, the most severe angulations seen during the whole course of the collateral angiographically. These were grouped into the following types: (a) <90°; (b) 90° to 180°; (c) >180°, defined as making up to 1 complete half circle and then becoming straight in further course, and (d) corkscrew, defined as making >1 circular bend simultaneously during the whole course. Recipient vessel was defined as the target vessel that is receiving the collateral connection and recipient vessel angle was defined as the angle that the collateral makes while joining the vessel (Figures 2 and 3).

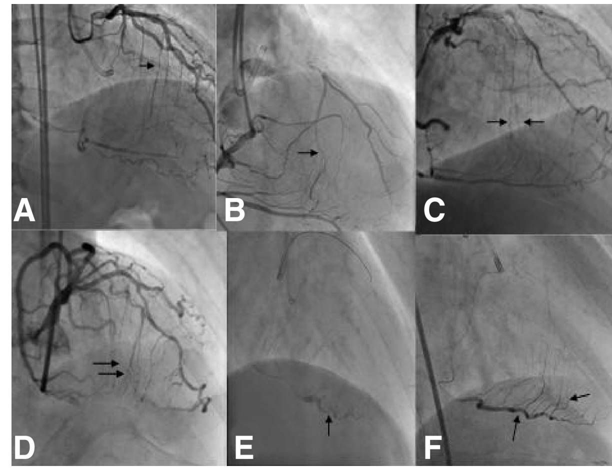

Figure 2. Angiographic appearance showing CC tortuosity <90° (A), >90° (B), and corkscrew (C and D), as marked by arrow. E and F, Tortuous donor vessel with angle of CC >90°.

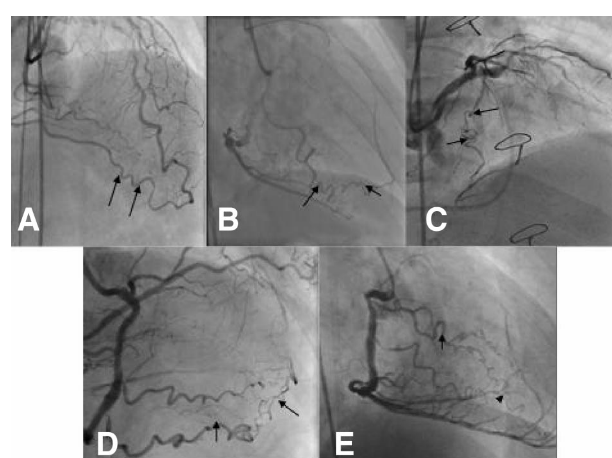

Figure 3. Angiographic appearance showing various tortuous epicardial CC used for retrograde access. A, Collateral connection between left anterior descending and right coronary artery. B, D, and E, Collateral connection from right coronary artery branches (right ventricle branch, conus branch) to left anterior descending artery. C, Collateral connection between left atrial branch from circumflex artery to distal right coronary artery.

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Retrograde Procedural Details

Procedural Technique

The decision and technique to perform retrograde attempt is completely on operator's discretion. The patients were pretreated with aspirin and ticlopidine or clopidogrel and were administered weight-adjusted heparin to keep the activated clotting time (ACT) >250 seconds. The technique of retrograde approach has evolved over time with accumulating experience and emergence of dedicated devices. We have previously described the use of septal CCs and technique of controlled antegrade and retrograde subintimal tracking (CART)[18,19] to facilitate this procedure.

Essentially, simultaneous bilateral coronary injections were performed to assess the CTO segment, and collateral supply to the target vessel was identified for retrograde usage. Septal branch was used in most cases, but suitable epicardial collaterals and saphenous vein grafts (SVGs) were also used. First, the soft plastic jacket guide wire (Rt, Fielder, Fielder FC, or X-treme, Asahi Intec, Japan) was inserted into the target collateral artery with the aid of the microcatheter (Finecross, Terumo, Japan or Transit, Cordis, Miami Lakes, Fla). After the successful crossing of guide wire into the distal target artery, microcatheter was exchanged for small-diameter (1.25-cm) balloon to perform the CC dilatation at low pressure in the case of septal collateral usage. The guide wire was then advanced to the distal end of CTO, and CTO crossing was attempted with various guide wires ranging from soft (Fielder, Fielder FC, X-treme, Asahi Intec) to stiffer guide wires (Miracle series, Cofianza, Asahi Intec). In some cases, the wire penetrated the CTO segment and reached the proximal true lumen and into the guide catheter. This then allowed performing balloon dilatation of the entire CTO segment and thereafter passage of antegrade wire to complete the recanalization in standard fashion.

However, in most cases, the retrograde wire entered the false lumen at the CTO site, and subsequently the CART technique was performed to complete the recanalization. In brief, the CART technique involves passing of the balloon along with the guide wire in the false lumen at the CTO site, and the balloon is inflated to create sufficient space in the false lumen. The antegrade wire can then be introduced into this space, and then can reach the distal true lumen through the passage created by the retrograde balloon. After this procedure, recanalization can be performed in standard fashion.

The important thing to note is that these procedures were performed during the course of development of retrograde procedures. The technique of retrograde approach has evolved over years, starting with retrograde guide wire crossing into proximal true lumen, followed by the kissing wire technique, and CART was introduced in 2005, as described. The CART technique has been continuously improving over the years, with introduction of novel septal collateral dilatation methods and, more recently, reverse CART (this involves introduction of the retrograde guide wire into a subintimal space created antegradely) is been used.

In some cases, the retrograde wire failed to enter the CTO segment, and it was then used as the landmark to complete the case by antegrade approach.

Statistical Methods

Continuous data are presented as mean±SD, and differences were compared using Student *t* test. Discrete variables are expressed as counts and percentages. These were assessed by Fischer exact test and χ^2 test. All statistical tests were 2-tailed.

Logistic regression analysis was performed to assess the relationship between baseline demographics, angiographic characteristics, CC morphology, and the retrograde procedural success. All analysis was performed using SPSS version 15 statistical software (SPSS Inc, Chicago, Ill). Probability values <0.05 are considered significant.

The authors had full access to and take full responsibility for the integrity of the data. All authors have read and agree to the manuscript as written.

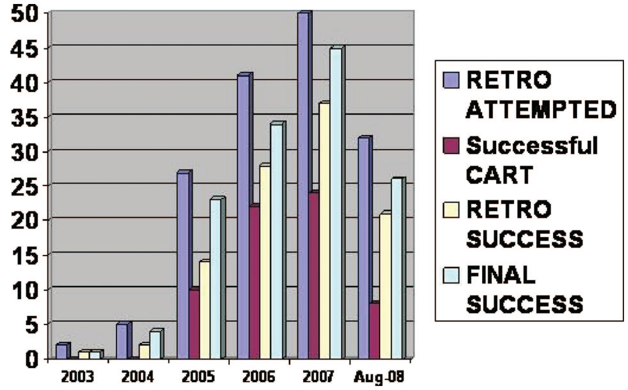

Figure 4. Yearly trends of retrograde approaches used with retrograde success and final success for CTO recanalization.

Results

Procedural Techniques and Patient Population

Between 2003 and 2008, a total of 157 patients underwent attempted retrograde approach for CTO recanalization. During this period, a total of 807 patients with CTO were attempted (650 patients were attempted using antegrade approach only). Of these 157 patients, 118 (75.2%) had previously failed antegrade attempt and in 39 (24.8%), the retrograde approach was chosen before antegrade approach on operator's discretion. As shown in Figure 4, the yearly uptake for retrograde approach has increased since 2005, when the technique became established, and the overall retrograde success was ≈70%, with final procedural success of 85%. The year 2008 represents patients recruited only up to August. The number of cases as shown in Figure 4 increased steadily over recent years, with numeric increase in success rate by retrograde approach (P=0.26).

Retrograde procedural success was achieved in 103 (65.6%) cases, and final procedural success was achieved in 133 (84.7%) cases in this cohort (Table 1). The various CCs used were septal branch, epicardial, and SVG in 106 (67.5%), 39 (24.8%), and 12 (7.6%) cases, respectively. CC was successfully crossed with the guide wire in 115 (73.2%) cases, and balloon could be delivered in 109 (69.4%) of the

Table 1. Procedural Success at Different Stages Via Retrograde Approach

	Total (n=157)
Retrograde procedural success	103 (65.6)
Final procedural success	133 (84.7)
Collateral channel crossed with wire	115 (73.2)
Collateral channel crossed with balloon/microcatheter	109 (69.4)
Procedural success among channel crossed with wire	103/115 (89.5)
Wire entry into proximal true lumen	39 (24.8)
Successful CART performed	64 (40.8)
Collateral channel used	
Septal	106 (67.5)
Epicardial	39 (24.8)
SVG	12 (7.6)

Data are presented as n (%).

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Table 2. Baseline Demographic Characteristics and Vessel in Retrograde Success and Failure Groups

Variable	All Patients (n=157)	Retrograde Success (n=103)	Retrograde Failure (n=54)	*P*
Age, years	64.96±10.57	64.80±10.80	65.28±10.21	0.787
Male	134 (85.4)	88 (85.4)	46 (85.2)	1.000
Diabetes mellitus	58 (36.9)	38 (36.9)	20 (37.1)	1.000
Hypertension	105 (66.9)	72 (69.9)	33 (61.1)	0.288
Hyperlipedemia	64 (40.8)	42 (40.8)	22 (40.7)	1.000
Family history	26 (16.6)	18 (17.5)	8 (14.8)	0.822
Smoking history	52 (33.1)	32 (31.1)	20 (37.1)	0.479
Previous MI	147 (93.6)	96 (93.2)	51 (94.4)	1.000
Previous CABG	28 (17.8)	20 (19.4)	8 (14.8)	0.519
Unstable angina	13 (8.3)	9 (8.7)	4 (7.4)	1.000
CCS class 3 or 4	8 (5.1)	6 (5.8)	2 (3.8)	0.613
Previous PCI	59 (37.6)	48 (46.6)	11 (20.4)	0.002
In-stent restenosis	15 (9.6)	11 (10.7)	4 (7.4)	0.581
Body height, cm	162.87±7.91	162.87±8.09	162.88±7.53	0.994
Body weight, kg	63.84±12.55	64.66±12.62	63.03±12.44	0.442
Body surface area, m^2	1.68±0.17	1.69±0.18	1.67±0.18	0.550
Vessel disease				
vs 1 disease	22 (14)	13 (12.6)	9 (16.7)	
vs 2 diseases	43 (27)	28 (27.2)	15 (27.8)	
vs 3 diseases	92 (58.5)	62 (60.2)	30 (55.6)	0.760
CTO Vessel				
LAD	50 (31.8)	29 (28.2)	21 (38.9)	
RCA	93 (59.2)	65 (62.1)	28 (51.9)	
LCX	12 (7.6)	7 (6.8)	5 (9.3)	
LMS	1 (0.6)	1 (1.0)	0 (0)	
SVG	1 (0.6)	1 (1.0)	(0)	0.582

Data are presented as mean±SD or n (%). CCS indicates Canadian Cardiovascular Society; LAD, left anterior descending artery; RCA, right coronary artery; LCX, left circumflex artery; LMS, left main stem.

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cases. The retrograde procedural success in patients who have had successful guide wire crossed through CC was 103 of 115 (89.5%). Among these cases, the guide wire entered the proximal true lumen of the CTO in 39 (24.8%), and CART was performed in 64 (40.8%) cases to achieve successful recanalization.

Table 6 shows that the success rate was higher in the group who had retrograde approach as first approach when compared with patients with previously failed antegrade approach (83% versus 61.5%; P=0.0.01).

Baseline Patient and Vessel Characteristics

Baseline characteristics of retrograde success (103 patients) and retrograde failure (54 patients) groups are shown in Table 2. Mean age, gender frequency, and risk factor profile were similar in both groups. Most patients had a previous history of MI (94%) and 17% patients had previous CABG, which was similar in both groups. In-stent restenosis and the unstable angina was the underling pathology in 9% and 8% cases, respectively. Two thirds of the patients had 3-vessel disease, which was similar in both groups. There was a higher incidence of previous PCI in the success group. The CTO target lesion was distributed among the right coronary artery in 93 patients (59.2%), the left anterior descending artery in 50 patients (31.8%), the left circumflex artery in 12 patients (7.6%), and the left main stem and SVG in 1 patient each. These results were similar in both groups.

Angiographic and Anatomic Characteristics

Table 3 summarizes the preprocedural angiographic and anatomic characteristics of the successful and failure groups. Significant sidebranch was present at the CTO site in 26 (16.5%) patients, moderate or severe calcification noted in 67 (42.6%) patients, and moderate to severe tortuosity noted in 56 (35.6%) patients, which was similar in both groups. Bridging collaterals were present in 38 (24.2%) patients, and 26 (16.5%) patients had ostial location of CTO, which was also similar in both groups. Mean CTO length was 35 mm and similar in both group. There were no differences noted in the angiographic and morphologic characteristics of CTO in retrograde success and failure groups.

CC Properties

CC properties are shown in Table 4. Use of epicardial CC was associated with retrograde failure (18.4% versus 37.1% in success and failure groups, respectively, P=0.01) and septal branch and SVG usage were not significantly different between the 2 groups. CC0 was associated with procedural

Table 3. Angiographic Characteristics of CTO in Retrograde Success and Failure Groups

Variable	All Patients (n=157)	Retrograde Success (n=103)	Retrograde Failure (n=54)	*P*
Significant side branch	26 (16.6)	16 (15.5)	10 (18.5)	0.656
Tortuousity none or mild	101 (64.3)	66 (64.1)	35 (64.8)	
Moderate	35 (22.3)	23 (22.3)	12 (22.2)	
Severe	21 (13.4)	14 (13.6)	7 (13)	0.993
Calcification none or mild	90 (57.4)	61 (59.2)	29 (53.7)	
Moderate	44 (28.0)	28 (26.2)	16 (29.6)	
Severe	23 (14.6)	14 (13.6)	9 (16.7)	0.695
Ostial				
Aorto-ostial	4 (2.5)	3 (2.9)	1 (1.9)	
Non aorto-ostial	22 (14.0)	15 (14.6)	7 (13.0)	0.878
Bridging collaterals	38 (24.2)	26 (25.2)	12 (22.2)	0.845
CTO Length, cm	35.95±17.65	37.15±18.84	34.76±16.83	0.436
LV ejection fraction, %	52.40±9.0	50.6±10.4	54.20±8.9	0.045

Data are presented as n (%) or mean±SD. LV indicates left ventricular.

failure (2.9% versus 37% in success and failure groups, respectively, $P<0.001$), and CC1 was associated with procedural success (64.7% versus 22.2%, $P<0.001$). CC angle with the donor vessel did not seem to influence the outcome. Corkscrew tortuosity of the CC (10.7% versus 50%, $P<0.001$) and nonvisibility of the CC connection with the recipient vessel (1% versus 29.6%, $P<0.001$) seem to adversely influence the outcome.

In-Hospital Complications

The in-hospital adverse events are shown in Table 5. Total in-hospital major adverse cardiac events were low and similar in both groups (5 [4.8%] versus 2 [3.7%]). There was no in-hospital mortality, and the urgent CABG was performed in 1 patient in the failure group. There was a higher incidence of non–Q-wave MI in the success group (4 [3.9%] versus 1[1.9%], $P=0.04$), and Q-wave MI was noted in 1 patient.

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Table 4. Collateral Channel Properties in Retrograde Success and Failure Groups

Channel Properties	All Patients (n=157)	Retrograde Success (n=103)	Retrograde Failure (n=54)	*P*
Channel used				
Septal	106 (67.5)	74 (71.8)	32 (59.3)	0.1508
Epicardial	39 (24.8)	19 (18.4)	20 (37)	0.0188
SVG	12 (7.7)	10 (9.7)	2 (3.7)	0.2210
CC Type				
0	23 (14.6)	3 (2.9)	20 (37)	<0.0001
1	78 (49.6)	66 (64.7)	12 (22.2)	<0.0001
2	55 (35.8)	33 (32.4)	22 (40.7)	0.02951
Tortuousity				
<90°	72 (53.3)	70 (68.0)	12 (22.2)	<0.0001
90° to 180°	20 (12.7)	13 (12.6)	7 (13.0)	1.0000
>180°	17 (10.8)	9 (8.7)	8 (14.9)	0.2836
Corkscrew type	38 (24.2)	11 (10.7)	27 (50)	<0.0001
Donor vessel angle				
<90°	113 (71.9)	78 (75.7)	35 (64.8)	0.1903
90° to 180°	40 (25.5)	24 (23.3)	16 (29.7%	0.4921
>180°	3 (1.9)	1 (1.0)	2 (3.7)	0.2122
Corkscrew type	1 (0.6)	0 (0)	1 (1.9)	0.3439
Recipient vessel angle				
<90°	116 (73.9)	94 (91.3)	22 (40.7)	<0.0001
90° to 180°	24 (15.3)	8 (7.8)	16 (29.6)	0.0007
Not visible	17 (10.8)	1 (1.0)	16 (29.6)	<0.0001

Data are presented as n (%).

Table 5. In-Hospital Adverse Events in Retrograde Success and Failure Groups

Adverse Event	All Patients (n=157)	Retrograde Success (n=103)	Retrograde Failure (n=54)	*P*
Death	0 (0)	0 (0)	0 (0)	NS
Q-wave MI	1 (0.6)	1 (1)	0 (0)	NS
Non–Q-wave MI	5 (3.2)	4 (3.9)	1 (1.9)	0.04
Urgent CABG	1 (0.6)	0 (0)	1 (1.9)	NS
In-hospital MACE	7 (4.5)	5 (4.8)	2 (3.7)	NS
Aortic dissection	1 (0.6)	0 (0)	1 (1.9)	NS
Delayed tamponade	1 (0.6)	1 (1)	0 (0)	NS
Side branch compromise	8 (5.1)	5 (4.9)	3 (5.6)	NS
Dissection	15 (9.6)	10 (10)	5 (10)	NS
Septal perforation	6 (3.8)	2 (2)	4 (7.4)	NS

Data are presented as n (%). NS indicates not significant; MACE, major adverse coronary event.

Cardiac tamponade and aortic dissection was noted in 1 patient each and was managed conservatively with no long-term sequelae; 1 patient with cardiac tamponade needed pericardiocentesis. Minor dissections of the target artery were noted in 10% of the cases and similar in both groups. Septal collateral perforations were observed in 2 (2%) cases in the success group and 4 (7.4%) cases in the failure group. One patient needed coil embolization, and the rest were managed conservatively with no hemodynamic compromise.

Table 6 describes the in-hospital outcomes in patients in whom the retrograde technique was used as first-time procedure when compared with those after a failed antegrade approach. In-hospital complications were similar in both groups.

Determinants of Retrograde Procedural Success

Results of the logistic regression model are shown in Table 7. There were no significant differences found between age, sex, CC use, CC type, bridging collaterals, CTO length, severe calcification, severe tortuosity, significant branch at the CTO site, CC angle with donor vessel, and ostial location between retrograde success and failure. We found corkscrew tortuosity of the CC and nonvisibility of the collateral connection with the recipient vessel to be the significant predictors of retrograde procedural failure in this series.

Discussion

Our Study

This is the first large series of consecutive unselected patients to study the impact of retrograde recanalization of CTO in contemporary practice. The major findings of this study are as follows: (1) the procedural success with the retrograde approach in unselected population was 65%, with final procedural success of 85% in this cohort of complex patients subset; (2) the procedural success rate was ≈90% after safe crossing of the CC with the guide wire and balloon; (3) the in-hospital major adverse cardiac events and other adverse events were low and comparable with conventional CTO procedures, and the relatively low rate of major adverse cardiac events in this series should take into account (a) the experience of the operators with this technique and specific skills to treat complications and (b) the overall low number of patients compared with experiences with antegrade technique; and (4) the predominant reason of unsuccessful procedure was failure to cross the CC.

Procedural Success Rates

There are mostly case reports available in literature showing the success and overall safety of the retrograde approach in CTO PCI. Recently, Saito[22] described outcomes of retrograde

Table 6. Success Rates and In-Hospital Adverse Events in Patients in Whom the Retrograde Approach Was Used as a First-Time Approach as Compared With Patients With a Failed Antegrade Approach

Variables	All Patients (n=157)	Failed Antegrade (n=118)	First-Time Retrograde (n=39)	*P*
Success rate	103 (65.6)	71 (61.5)	32 (83)	0.0126
Death	0 (0)	0 (0)	0 (0)	NS
Q-wave MI	1 (0.6)	0	1 (2.6)	NS
Non–Q-wave MI	5 (3.2)	3 (2.5)	2 (5.1)	0.4251
Urgent CABG	1 (0.6)	1 (0.8)	0	NS
MACE	7 (4.5)	4 (3.4)	3 (7.6)	0.2590
Aortic dissection	1 (0.6)	1 (0.8)	0	NS
Delayed tamponade	1 (0.6)	1 (0.8)	0	NS
Side branch compromise	8 (5.1)	6 (5.1)	2 (5.1)	NS
Dissection	15 (9.6)	12 (10.2)	3 (7.6)	NS
Septal perforation	6 (3.8)	4 (3.4)	2 (5.1)	NS

Data are presented as n (%). NS indicates not significant; MACE, major adverse coronary event.

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Table 7. Logistic Regression Analysis Showing Relationship Predictors of Retrograde Failure

Variable	Odds Ratio	95% CI	*P*
Channel used (epicardial)	0.515	0.28–9.57	0.656
Recipient vessel angle not visible	47.09	1.65–1340.42	0.024
Tortuousity of channel-corkscrew	8.31	1.63–42.36	0.011
CC1	2.16	0.43–10.74	0.346
Previous MI	0.419	0.04–3.81	0.440
In-stent restenosis	1.71	0.22–12.88	0.599
Bridging collaterals	1.09	0.29–4.00	0.896
Significant sidebranch	1.51	0.33–6.72	0.588
Severe tortuousity	0.757	0.11–4.94	0.771
Severe calcification	2.67	0.51–13.93	0.243
Ostial location	1.34	0.22–7.98	0.744
CTO length >20 mm	0.971	0.93–1.01	0.138
Age	1.01	0.96–1.07	0.547
Male sex	1.72	0.33–8.87	0.512

procedure in 45 selected patients from his individual practice from round the world. He reported successful passage of guide wire through the CC in 82% of the patients and among whom the PCI success was achieved in 84% of the cases. He reported the final PCI was achieved purely by retrograde approach in 69% of the patients. The final success rate by retrograde route is similar to our study, and we have noted a slightly lower success rate of successful guide wire passage through CC in our study (82% versus 73%). This could be explained by higher use of epicardial CC in our series. The study by Saito describes various approaches used during retrograde procedure, with proximal true lumen puncture achieved in 30% and CART performed in 27% of the patients. In our study, CART was performed in 40% of the patients and proximal true lumen puncture was achieved in 25% of the cases.

Sheiban et al[21] described the results of 18 cases with success rates of 69%. The retrograde approach for CTO PCI can be traced back to 1990, when Kahn and Hartzler[20] described retrograde recanalization of 16 patients with 75% success rate via the SVGs. Since then, several case reports have been described[24–29] showing successful recanalization of CTO via retrograde CCs.

Serious attempts have been made form our group to further standardize the retrograde techniques; in this effort, Surmely et al[18] reported from our center the use of coronary septal collaterals as an access for retrograde approach for CTO PCI. They reported the use of septal collaterals in 21 patients, and the successful passage of wire and balloon was achieved in 19 and 17 cases, respectively, with successful retrograde recanalization in 71% of the cases. This series also showed that dilatation of septal collaterals at low pressure is safe and effective. After this series, the use of septal collaterals was popularized, and further refinements were reported during the past few years. Again, Surmely et al[19] reported the novel CART technique to further improve the outcome in retrograde technique following successful passage of CCs with the guide wire. They described this technique in 10 patients with 100% success rates. Since then, the retrograde technique has become the predominant and important strategy in CTO recanalization following antegrade failure or with suitable CCs.

In our series, the success rate was higher in patients in whom the retrograde technique was used as a first-time procedure when compared with those after a failed antegrade approach. This should take into consideration the low number of patients, selection bias, and operator's experience. Also, the patients with a failed antegrade approach represent a complex anatomic group.

Complication Rates

Saito et al[22] described the dissection or minor perforation of the target artery or CC in 13% of cases, with no hemodynamic compromise. No patient in their series experienceed MI, CABG, or death. Sheiban et al[21] reported 1 nonfatal MI in their series of 18 patients. Surmely et al[18] reported the occurrence of 2 septal collateral perforation in their series of 21 cases with minor consequences. However, there are case reports[26] of severe septal hematoma causing MI after septal collateral use. Our series is the first large real-world series demonstrating an acceptable rate of adverse events during retrograde PCI for CTO recanalization.

Predictors of Success

This is the first study providing some insight into the predictors of success and failure via retrograde approach during CTO PCI. We have identified that unsuccessful crossing of the CC is the strongest predictor of retrograde failure. On logistic regression analysis, we have found that severe tortuosity of the CC and the nonvisibility of the connection between the CC and the recipient vessel (CCO) are the only independent predictors of the procedural failure via retrograde approach.

On the other hand, conventional factors such as severe calcification, severe tortuosity, significant sidebranch at the CTO site, CTO length >15 mm, previous MI, previous CABG, and multivessel disease, which are shown to be independent predictors of successful procedure via antegrade approach in various studies,[2,3,12,13,30,31] are not shown to have any significant impact on outcomes during retrograde recanalization in our study.

The possible reason for the earlier observation is that these conventional factors are not important when the retrograde techniques are applied, as the wire manipulation is done in retrograde fashion to gain access to either true or false lumen and to complete the procedure with adjunctive techniques.

Retrograde Approach and CC Use

Retrograde approach has got great potential in the event of antegrade failure or in difficult anatomic subsets. In most antegrade failure cases, subintimal dissection is caused making anatomy more difficult for the repeat procedures. Moreover, the distal cap of CTO lesions is thought to be softer in some cases,[28] and in the event of entry into the false lumen, CART could be performed, along with several other modifications. The other reason why retrograde approach works is that, in some patients with antegrade failure, the proximal

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CTO site is at the bifurcation or at severe bending, causing antegrade wire entry into the false lumen.

There are several CCs developed in patients with CTO lesions ranging from septal to epicardial at various locations in the coronary tree. Usually, septal channels are preferred for retrograde approach because of their morphology and anatomic location. Coronary collaterals may be even present without being visualized angiographically and can be crossed with wires[29]; therefore, it is advisable to perform selective injection of the septal channel in the event of nonvisualization. Epicardial CCs are also useful in some cases, but their extreme tortuosity in some cases makes them difficult to cross.

One should be aware of potentially unexpected complications, as the technique is still evolving, and there have been case reports of cardiac tamponade, mainly after epicardial CC perforation, and damage to the collateral donor artery.

Retrograde approach requires good special devices, such as microcatheters, dedicated guide wires, shorter guide catheters, or longer length guidewires, and should be performed with experienced operators and support staff.

Limitations

There are some limitations to our study. First, this is a retrospective study and there are limitations to such a study. However, we have included all consecutive patients to provide some kind of generalization to the results. Second, the numbers of cases are small and are from a single center. Third, the results of this study could be influenced by selection criteria, operator experience, and varying technique among the operators. Fourth, there is a lack of follow-up beyond the in-hospital phase. Finally, this study does not reflect the actual success rates of current retrograde approaches with the use of dedicated devices because the patients were included during the course of evolution of this technique.

Conclusions

To our knowledge, this is the first large series of consecutive patients treated with various retrograde techniques for CTO PCI in contemporary practice. We have reported overall high success rates and with overall acceptable complication rates. We have also identified certain CC-related factors as predictors for successful outcome. The retrograde procedures for CTO PCI are safe and effective in experienced hands, and further refinement of the technique is needed to improve the overall results.

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Disclosures

None.

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CLINICAL PERSPECTIVE

Procedural success rate for chronic total occlusion of the coronary arteries has been improving over time but is still suboptimal and is mainly due to failure to cross the lesion in the antegrade fashion. Recently, retrograde wire-crossing techniques have been introduced to improve recanalization rates. Therefore, we examined the procedural details of retrograde approaches through collateral channels for the treatment of chronic total occlusion among 157 consecutive patients at a single hospital in Japan from 2003 to 2008. A total of 118 (75.2%) of these patients had a previously failed antegrade approach. Septal, epicardial, and saphenous vein graft collaterals were used in 67.5%, 24.8%, and 7.6% of cases, respectively. The collateral channel was crossed by guide wire successfully in 115 (73.2%) cases, and the procedure was successful by retrograde approach in 103 (65.6%) cases. The success rate with retrograde approach was higher in patients who had the retrograde as the first attempt when compared with patients with previously failed antegrade approaches (83% versus 61.5%; $P=0.01$). The baseline demographics and angiographic features were similar between the success and failure groups. Inability to cross the collateral channel was the predominant reason for failure. We have identified epicardial channel use ($P=0.01$), corkscrew tortuosity of the channel ($P=0.011$), and angle of vessel with collateral $>90°$ ($P=0.024$) as significant predictors of failure. The major adverse cardiac events rate was acceptable (4.5%), and septal collateral perforation was seen in 3.8% of patients. The retrograde procedures for chronic total occlusion percutaneous coronary intervention are safe and effective in experienced hands, and further refinement of the technique is needed to improve the overall results.

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