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Different Strategies of Retrograde Approach in Coronary Angioplasty for Chronic Total Occlusion

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Background: Retrograde approach through the collateral channels has been recently proposed and has the potential to improve the success rate of percutaneous coronary intervention (PCI) in chronic total occlusion (CTO) lesions of the coronary arteries. Methods: The author performed retrograde approach for CTO lesions in 45 patients from January 2006 to January 2007 at different medical institutions worldwide. The details of the techniques were examined retrospectively. Results: The septal branch route was used in 93% of the cases. The author classified the strategies into six types after the successful crossing of a guidewire into the target artery distal to the CTO lesion through the collateral channels. Among them, "Just landmark," "Controlled antegrade and retrograde subintimal tracking," and "Proximal true lumen puncture" strategies were used most frequently (32, 27, and 30%, respectively). The retrograde guidewires could be successfully passed distal to the CTO lesion in 37 patients (82%), among them the final PCI success was achieved in 31 patients, yielding the PCI success by pure retrograde approach of 69%. The final success rate among 45 patients including 42 patients with previous failed attempts was 84% (38 patients). There were no serious complications related to the retrograde approach. Conclusions: Retrograde approach with different strategies, mainly through septal arteries, can provide a high success rate with PCI, as shown in 83% of patients with previous failed attempts at traditional PCI for CTO lesions, with there being no serious complications. More experience of this technique and its refinement are required for further improvement of PCI techniques for CTO lesions.

Key words: total occlusions; percutaneous coronary intervention; collaterals; retrograde approach; CART; retrograde true lumen tracking; catching the retrograde guidewire; reverse anchoring

BACKGROUND AND OBJECTIVES

It has been shown that successful recanalization of chronic total occlusion (CTO) of coronary arteries can reduce the need for subsequent coronary artery bypass surgery [1] and also increase the long-term survival of such patients [2,3]. Although the introduction of new devices and the wide range of sophisticated guidewires, which have been developed for CTO angioplasty, have improved the success rate of percutaneous coronary intervention (PCI) [4,5], PCI for CTO lesions is still technically challenging. Recently, retrograde approach through the collateral channels was introduced as a new technique in PCI for CTO lesions [6]. Although it is expected to be a breakthrough to improve the success rate, its technical overviews or results in large patient series have not been yet reported. The technical details and the rates of success and complications were examined retrospectively by analyzing 45 patients data, which were treated by the author in various medical institutions worldwide.

METHODS

Patient Population

Since the author's technique for retrograde approach in PCI for CTO lesions was established by January 2006, 220 patients were retrospectively examined whose target lesions were consistent with CTO, and who were treated by the author between January 2006 and January 2007 inclusive. In this study period, if the

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previous failed attempts for the CTO lesions were performed through antegrade approach (42 patients) and/or if retrograde approach seemed feasible (3 patients), the retrograde approach was chosen in preference to the antegrade approach. Finally, 45 patients were included in this study. The target PCI procedures were performed mainly within Japan (26 patients including 18 in the Author's hospital and 8 patients in outside hospitals), but also in South Korea, Netherlands, United States, Taiwan, Malaysia, Indonesia, China, and Hong Kong (1, 1, 1, 1, 2, 2, 5 and 6 patients, respectively).

Definition of Chronic Total Occlusion, Retrograde Approach, and Success

Chronic total occlusion as the lesions was defined with TIMI 0 antegrade flow and the duration of occlusion $\geq$3 months. Lesions with TIMI $\geq$ 1 antegrade flow or the duration of occlusion $<$3 months were excluded. The duration of occlusion was defined as the interval from the last diagnostic coronary angiograms with total occlusion in patients with a previous angiogram, or from the first onset of clinical symptoms suggesting the ischemic heart disease in patients without a previous angiogram to the timing of the coronary intervention.

The attempt of the retrograde approach was defined as the introduction of a guidewire into the collateral channels, which was connecting with the target coronary artery distal to the target CTO lesion. PCI success was defined as the successful recanalization of CTO lesions with resultant TIMI grade 3 flow.

General Strategy in PCI for CTO Lesions

The indication for coronary intervention for CTO lesions. If the patients had anginal symptoms caused by the CTO lesions, they were eligible for PCI treatment. The CTO lesions with the evidence of partially or completely reversible distal ischemia, even if not causing any obvious anginal symptoms, were also considered as an indication for PCI therapy. The CTO lesions with complete necrosis of the distal myocardium were generally not eligible for PCI, as such treatment would be unlikely to make a difference.

The guideline for the termination of the procedures. The termination of angioplasty procedures followed the guideline proposed previously [5]. Briefly to describe: 30 min from the arterial sheath insertion to the successful crossing of angioplasty guidewires through the CTO lesion was considered essential to reduce the dose of radiation exposure and the amount of contrast dye, and to increase the patients comfort during the angioplasty. If the lesion could not be crossed by the angioplasty guidewires within 30 min from the sheath insertion, the procedure was terminated. If the total duration of the procedure exceeded 90 min and/or if the total amount of the contrast dye injected exceeded 300 ml, the procedure was also discontinued.

However, in certain cases, the guideline criteria were surpassed if the successful angioplasty for the lesion was thought quite important in order to avoid the coronary artery bypass surgery, and if the probability of the successful cannulation into the CTO lesion was expected to be high.

Retrograde Approach

System setup. In all of the patients, two 7-French guiding catheters were used. Biradial and brachial with femoral approaches were used in 4 and 1 patients, respectively. In one patient, only one guiding catheter was used. Bi-femoral approach using two guiding catheters was used in the remaining 39 patients. Ninety-centimeter guiding catheters (Launcher, Medtronic, USA) of EBU-SH for left and SAL-SH for right coronary arteries were mainly used for the retrograde access. In one patient, one short EBU-SH and one normal EBU-SH guiding catheters were placed simultaneously in a relatively large left main coronary artery. Normally, the retrograde approach is first started before commencing the antegrade approach after giving full dose heparin with a resulting ACT level $\geq$250 sec. Antiplatelet regimen with aspirin and Ticlopidine/Clopidogrel was continued.

Crossing the collateral channels. First, a microcatheter (Progreat® or Finecross®, TERUMO, Japan, or Transit®, Cordis, USA) was inserted into the target collateral artery with the aid of a floppy guidewire (Runthrough® or Runthrough-Hypercoat®, Terumo), and then the guidewire was exchanged to a plastic-jacket hydrophilic guidewire (Fielder®, Fielder-FC®, or Fielder X-treme®, ASAHI Intecc, Japan, or Whisper-LS®, or MS®, Abbott, USA). The tip of the hydrophilic guidewire was shortly bent by $\sim$45°. Occasionally, small volumes of contrast dye following nitrates were injected through the microcatheter to visualize the collateral connection. The hydrophilic guidewire and the microcatheter were alternatively advanced. If the hydrophilic guidewire reached the target artery distal to the CTO lesion, we tried to insert it as far as possible in order to prevent spontaneous loss of catheter position with the movement of the beating heart.

After successful crossing of a hydrophilic guidewire into the target coronary artery, the microcatheter was attempted to be passed into the target artery. When the microcatheter did not pass through, the microcatheter was exchanged with a balloon catheter (Ryujin®-OTW 1.25 mm $\times$ 10 mm, Terumo, Lacross® 1.30 mm $\times$ 10 mm, Goodman, Japan, or Maverick®-OTW 1.50 mm

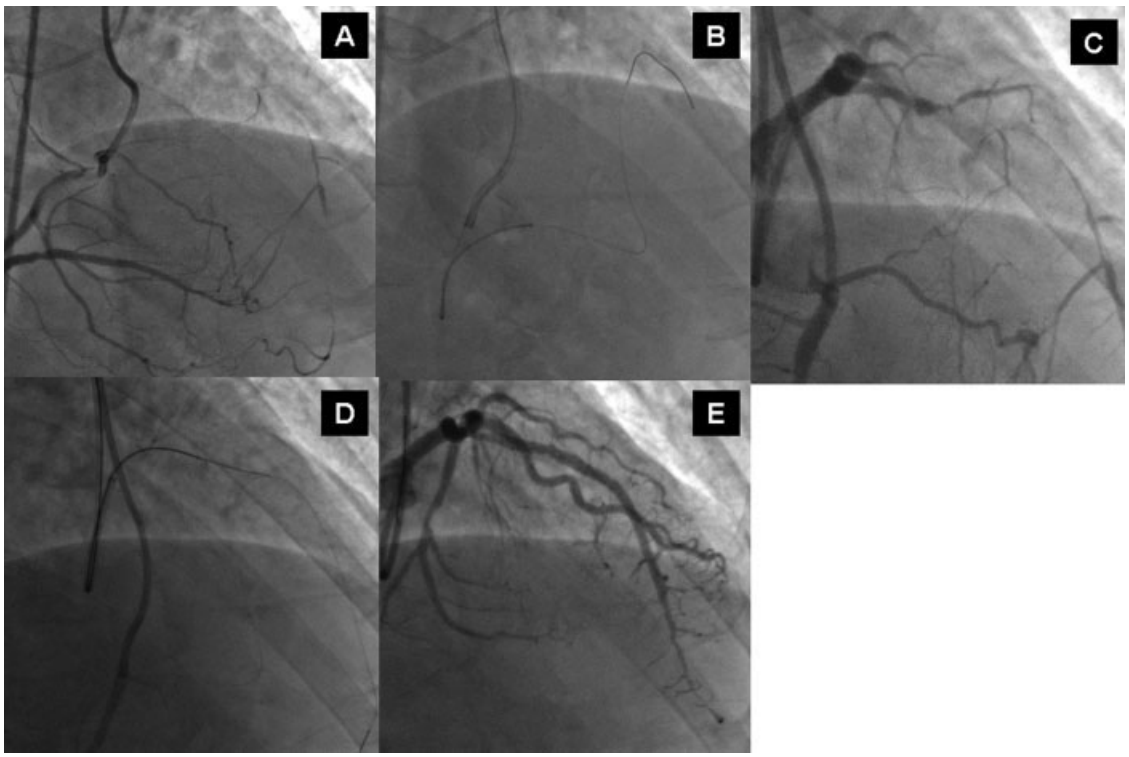

Fig. 1. An example of septal route. (A) Control angiogram. (B) A Fielder-FC guidewire crossing a septal branch. However, it went into the distal LAD. (C) Simultaneous bilateral angiogram clearly shows the CTO lesion. (D) Retrograde guidewire was a good landmark for antegrade guidewire navigation. This is a good example of "Just landmark" strategy. (E) Final angiogram.

× 15 mm, Boston Scientific, USA) by using an extension guidewire. If the collateral route was a septal artery, it was dilated along the entire segment by low-pressure inflations (≤4 atm) in order to prevent possible entrapment of the catheter. If both microcatheter and balloon catheters did not cross, Tornus® catheter (ASAHI Intecc) was used. After the catheters crossed the collateral route, the guidewire was exchanged to a Miracle® 3 g guidewire (Miracle 3: ASAHI Intecc).

Selection of the collateral routes. The collateral arteries were considered as the possible candidates for the collateral routes, if they showed the visible connection with the target artery distal to the CTO lesion, and did not show excessive tortuosity, be it whether they were epicardial or septal in nature. In this study group, collateral routes through septal branches (Fig. 1), apical connection (Fig. 2) or left atrial branch (Fig. 3) were used.

Different strategies after crossing a guidewire. After the retrograde guidewire was successfully exchanged to a Miracle 3, a penetration was attempted via the distal cap of the CTO lesion, and it was advanced retrogradely to the part as proximally as possible. If the distal cap was too hard for a Miracle 3, the guidewire was exchanged to a stiffer guidewire such as Miracle 6 or 12, or Conquest-Pro® or Conquest-Pro® 12 (ASAHI Intecc). While keeping the retrograde approach, the antegrade approach was also commenced. After successful penetration of the tip of the retrograde guidewires into the CTO lesions, one or the combinations of the following six different strategies were used.

Kissing guidewire. If the CTO lesion was relatively soft, the retrograde guidewire could advance relatively easily to the proximal part within the lesion. If the tip of the retrograde guidewire came near the proximal cap of the CTO, it was aimed at its tip with the antegrade guidewire, and finally, both the antegrade and retrograde guidewires met.

Just landmark. Even if the antegrade guidewire could meet the retrograde guidewire, the retrograde one was used as a landmark for antegrade guidewire manipulation. This approach reduced the use of contrast dye.

Controlled antegrade and retrograde subintimal tracking or reverse CART. As described by Surmely [6], the balloon inserted into the subintimal space within the CTO lesion retrogradely can be dilated in order to make the target space for the antegrade guide-

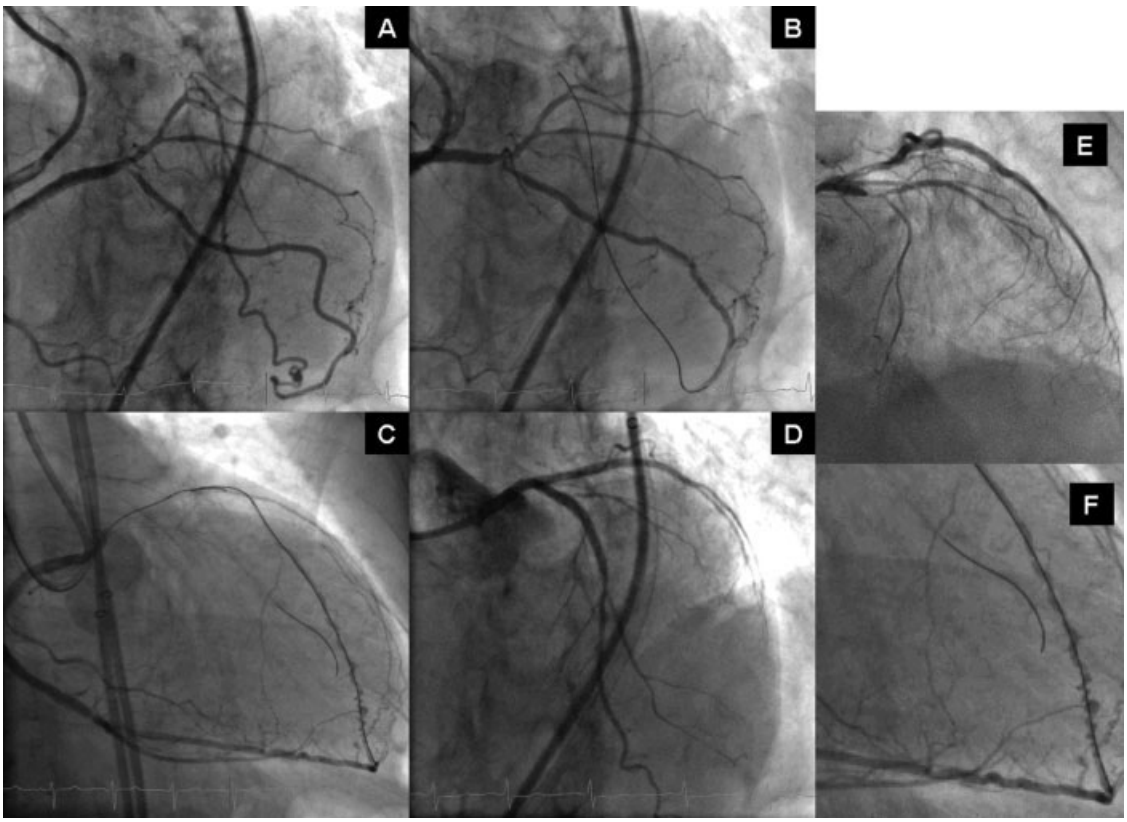

Fig. 2. An example of apical route. (A) Control angiogram shows that LAD is filled from RCA though an apical connection. (B) After a guidewire is crossed through the apical route, LAD is no longer filled by contrast dye. (C) Apical collateral route shows false spasm. (D) Final angiogram. (E) Diagnostic angiogram shows CTO in proximal LAD. (F) Enlarged image of false spasm of LAD.

wire access. This space is definitely connected with the distal true lumen, so that the antegrade guidewire can easily reach the distal true lumen. This novel method is named controlled antegrade and retrograde subintimal tracking (CART) technique. On the contrary, the balloon inserted into the subintimal space within the CTO lesion antegradely can be dilated in order to make the target space for the retrograde guidewire penetration. This reverse method is called Reverse CART technique. However, since the guidewire manipulation is much more difficult through the retrograde than antegrade approach because of the long course and many angulations over the entire course, this technique was difficult.

Retrograde true lumen tracking. The part of the artery just distal to the CTO lesion was sometimes filled by contrast dye either from ipsi- or contra-lateral injection. If this part was very tortuous but hidden, it might be difficult to track the true lumen by an antegrade guidewire. In this case, a hydrophilic guidewire was easily able to track this hidden tortuous part from the retrograde route. The case in Fig. 4 was a good example.

Retrograde proximal true lumen puncture. The retrograde guidewire was passed through the CTO lesion and went directly into the true lumen proximal to the CTO (Fig. 3). After the balloon inflation, which was inserted retrogradely into the CTO lesion, a floppy guidewire was passed through the lesion from the proximal to the distal lumen. This strategy is often difficult due to the same reason for reverse CART technique.

Catching the retrograde guidewire. If complex dissection was created after the retrograde balloon inflation in the previous ''retrograde proximal true lumen puncture'' strategy, no guidewire could be crossed through lesion antegradely. In this situation, after introducing the retrograde guidewire into the antegrade guiding catheter, a microcatheter was placed over this guidewire and changed it with a 300-CM Rotablator® floppy guidewire. By pushing this guidewire to the proximal part of the antegrade guiding catheter, the distal tip of the rotablator guidewire finally reached the proximal end of the antegrade guiding catheter and could be caught manually. Then, a balloon was put into the CTO lesion antegradely over the retrograde

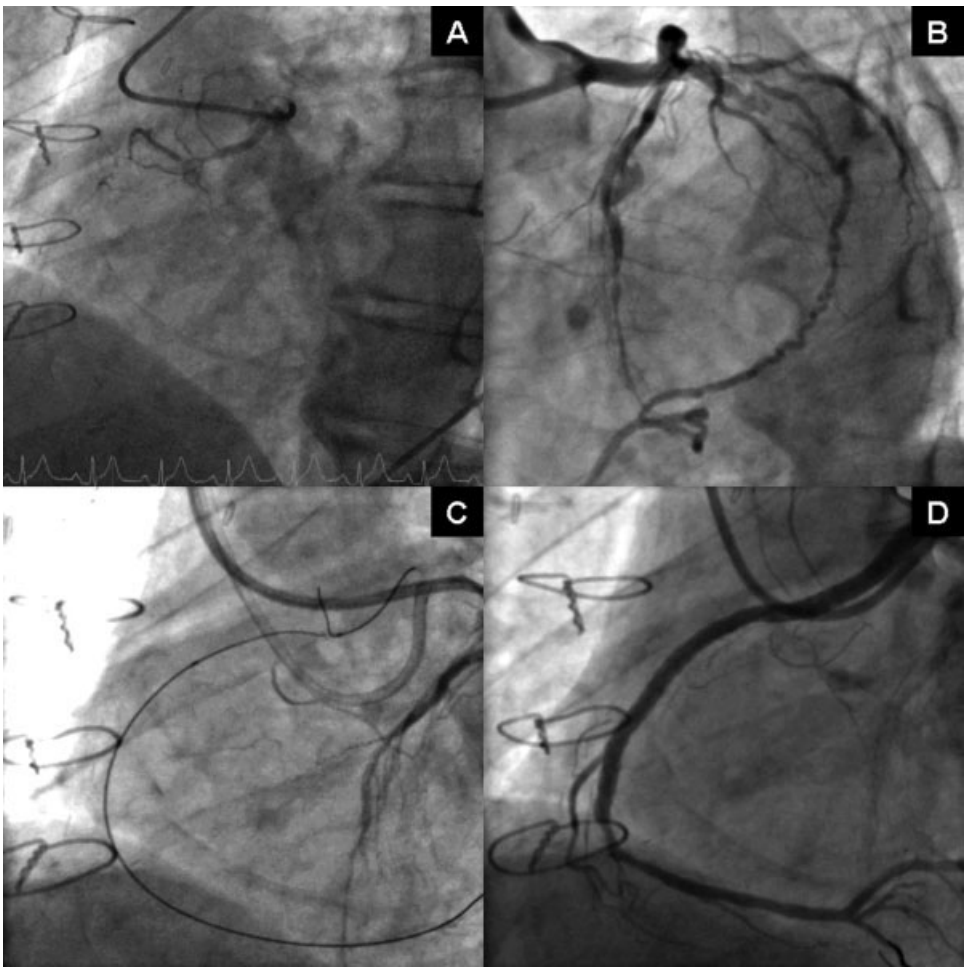

Fig. 3. An example of left atrial branch route. (A) Control angiogram shows a CTO lesion in the anomalous RCA. (B) There is a good left atrial route between LCX and distal RCA. (C) A retrograde guidewire (Miracle 3) penetrates the CTO lesion completely into the proximal true lumen ("Retrograde proximal true lumen puncture" strategy). (D) Final angiogram.

guidewire (Fig. 5). The use of a rotablator guidewire was essential because of smaller diameter. If a standard 0.014-inch 300-CM exchange guidewire was used, it could have never been pushed to the proximal part of the antegrade guiding catheter because of significant resistance within the microcatheter.

Adjunctive techniques. The success of PCI through the retrograde approach could be achieved only when it is combined with the several sophisticated techniques described earlier, which had been developed in the antegrade approach for CTO lesions. Beside the well-known double guidewire technique [5], they included the following:

Anchoring balloon technique. To achieve strong backup support by the antegrade guiding catheter, a small-sized second balloon was inserted and dilated in the branch proximal to the CTO lesion [7]. This increased the penetration power of a first balloon through the CTO lesion.

Coaxial anchoring balloon technique. Sometimes the CTO lesion was so hard that no guidewire could pass into the lesion even by using the stiffest guidewire such as a Conquest-Pro 12. In this case, an OTW balloon was inflated in the lumen. This balloon inflation provided the strong backup support for guidewire penetration, which was manipulated through the OTW balloon.

Reverse anchoring balloon technique. When no balloon could get into the CTO lesion retrogradely due to the rigidity of the lesion in ''retrograde true lumen puncture'' strategy, another balloon was inflated in the lumen proximal to the CTO lesion. This inflation of antegrade balloon anchored the retrograde guidewire and generated the strongest backup support for the retrograde passage of a balloon catheter.

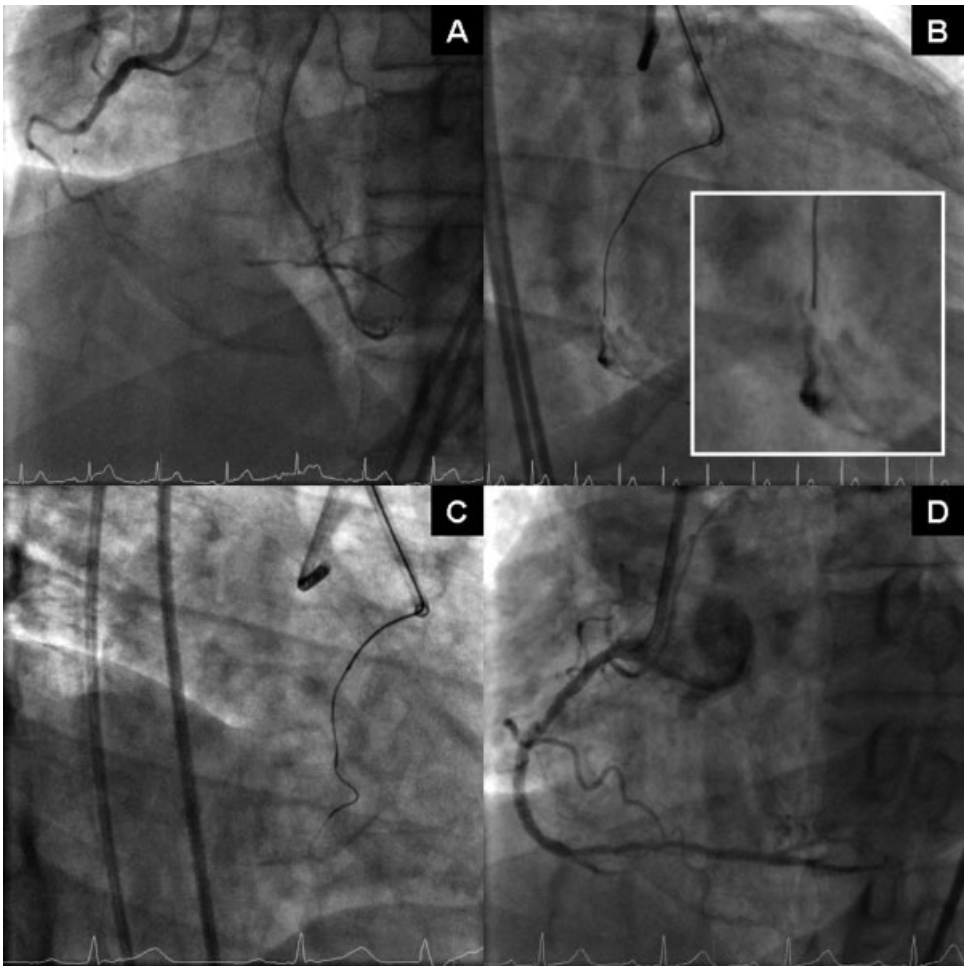

Fig. 4. An example of "Retrograde true lumen tracking" strategy. (A) A bilateral angiogram clearly shows a CTO lesion in mid RCA. (B) An antegrade guidewire (Miracle 3) clearly shows the discrepancy with the distal dye filling from the collateral route. White box is a magnified image. (C) A hydrophilic guidewire easily passes through the CTO lesion, which is inserted through the septal branch retrogradely. Following this, the same Miracle 3 guidewire easily passes through the lesion antegradely. The segment around the lesion shows a marked tortuousity. (D) Final angiogram.

Use of 5-French child guiding catheter. It is already reported that backup support can be increased by using a 5-French longer guiding catheter through a 6-French guiding catheter [8]. This technique can be used through a 7-French guiding catheter.

Statistical Tests

Data were collected and analyzed by using Access® 2003 (Microsoft, USA) and Statistica® 6.1 (Statsoft, USA) running on Windows-XP® (Microsoft, USA). Data were expressed as mean value ± SD. Comparison of categorical variables between equivalent groups were calculated by χ^2 test. P value < 0.05 was considered statistically significant.

RESULTS

Patient and Lesion Demographics

Forty-five patients included 38 males and 7 females, respectively, and their average age was 64 ± 10 years old. The target PCI was done after one or two previous failed attempt(s) in 39 and 3 patients, respectively. Six, 16, and 23 patients had triple-, double-, and single-vessel disease, respectively. The target CTO lesions were distributed among left anterior descending artery (LAD) in 11 patients (24%), left circumflex artery (LCX) in 3 patients (7%) and right coronary artery (RCA) in 31 patients (69%), respectively. The duration of occlusion was 5.4 ± 2.8 (1.0–15.0) years. The target CTO lesions showed the tapered end in 7 (16%), were located at the branching point in 24 (53%), and had fluoroscopically visible calcification in 14 lesions (31%). The length of the occlusion was 37 ± 19 mm.

Strategies and Techniques (Fig. 6)

Among several collateral routes, septal branch, apical, and left atrial routes were chosen in 42 (93%), 2 (4%), and 1 (2%) patients, respectively. The retrograde guide-

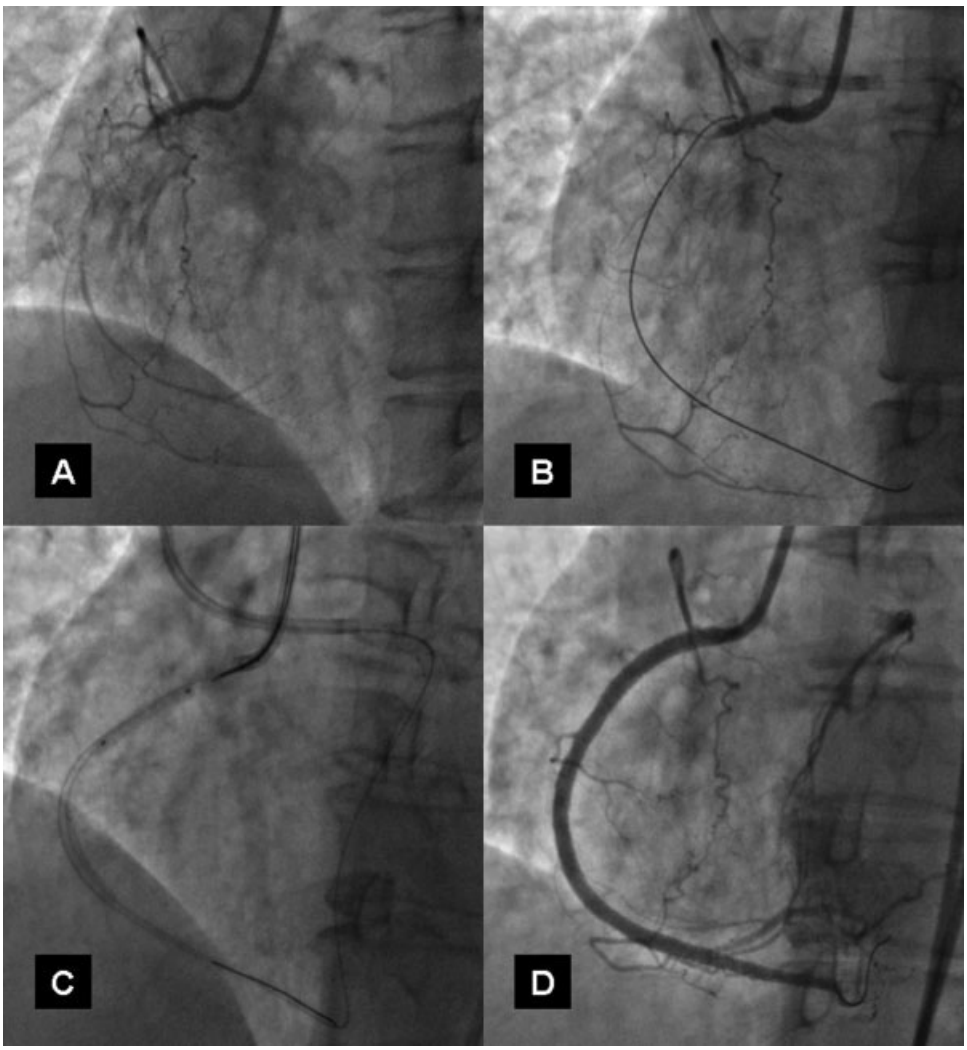

Fig. 5. An example of "Catching the retrograde guidewire" strategy. (A) Control angiogram. (B) A retrograde guidewire Miracle 3, which is introduced through a septal artery, passes through the CTO lesion and passes into the subintimal space at the proximal segment. (C) The Miracle 3 guidewire is successfully introduced into the proximal guiding catheter passing through the subintimal space of the proximal RCA and exchanged with a 300-CM Rotafloppy® guidewire. Then a 2.5-mm balloon is introduced antegradely over this long guidewire. Now, the balloon is inflated in the CTO lesion. (D) Final angiogram.

wires could be successfully passed through the collateral channels into the target artery distal to the CTO lesion in 37 patients (82%), among who success of PCI was achieved in 31 patients (84%). Thus, the PCI success rate by pure retrograde approach was 69% (31 of 45 patients). In 8 patients with failed retrograde guidewire passage, PCI success was achieved in 7 patients via the antegrade route. Thus, success of PCI was finally achieved in 38 among all of the 45 patients (84%), including 35 out of 42 patients with previous failed attempts (83%) and 3 patients at the first attempt.

The success rate of guidewire passage through the collateral channels was not different among patients with the target lesion in the LAD, LCX, and RCA (73, 67, and 87%, respectively; $P > 0.05$). The values of LCX and RCA were also not significantly different ($P = 0.340$). Septal dilatation by balloon catheters was done in 20 of 42 patients (48%) through the septal branch route. Among 37 patients with successful guidewire passage, ''Kissing guidewire,'' ''Just landmark,'' ''CART'', ''Reverse true lumen tracking'', ''Proximal true lumen puncture,'' and ''Catching the retrograde guidewire'' strategies were used in 1 (3%), 12 (32%), 10 (27%), 1 (3%), 11 (30%), and 2 (5%) patients, respectively. The final success of PCI was achieved in 31 (84%) of these 37 patients, and not achieved in the remaining 6 patients. The reasons for failure in these 6 patients included: (1) the lesion was too hard to pene-

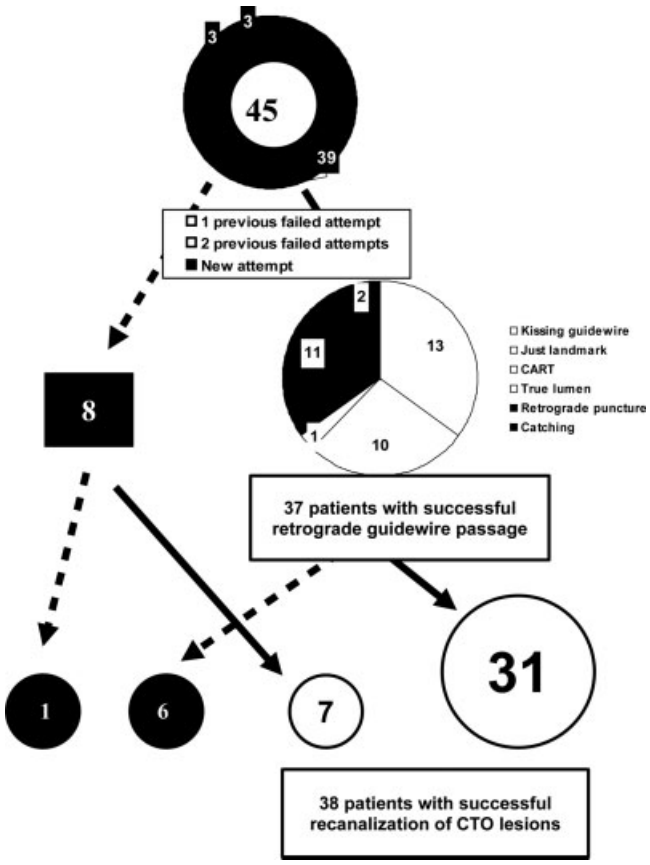

Fig. 6. Patient flow diagram. Forty-five patients were investigated. In 37 patients, a retrograde guidewire was successfully passed into the target artery distal to the CTO lesion. In 38 patients, successful recanalization was achieved. Solid arrow shows "success," and dashed arrow "failure."

trate for any guidewires even combined with different adjunctive techniques (4 patients), (2) the guidewire passage was blocked by the deformed stent strut within in-stent chronic occlusion (1 patient), and (3) the procedure through the collateral route could not be continued due to severe ST elevation of unknown cause in the region unrelated to PCI (1 patient).

Regarding the adjunctive techniques, anchoring, coaxial anchoring, or reverse anchoring balloon technique and the use of 5-French child guiding catheter were used in 4, 4, 7 and 2 patients, respectively.

Complications (Table I)

Dissection of the target artery or minor perforation and/or dissection of septal artery due to guidewire tip were observed in 6 patients (13%) and none of these patients developed any ischemia. No patients developed complications due to septal artery dilatation. Ischemia in the region supplied through the very tortuous epicardial collateral artery was observed in 1 patient after crossing a guidewire and a balloon (Fig. 2). Severe ST elevation of unknown cause in the region unrelated to PCI occurred in 1 patient as described before.

One patient had ventricular fibrillation due to wedge injection of contrast dye into RCA through the antegrade guiding catheter and was treated by DC cardioversion. One patient developed acute heart failure due to acute aortic regurgitation due to the transient deformity of aortic valve caused by the use of the left Amplatz guiding catheter for antegrade approach, which was easily corrected by adjusting the catheter position. One patient developed hemopericardium after the successful passage of the antegrade guidewire, which was sealed by using spring-coil embolization. All of these three complications were directly caused by an antegrade approach rather than the retrograde approach, and all of them were completely recovered.

One patient had the dissection of the ostium of the collateral-donor coronary artery, which was induced by the tip of the left Amplatz guiding catheter and treated by the implantation of a stent without any signs of ischemia (Fig. 7).

No patients suffered subsequent myocardial infarction, cerebral accidents, or death. No patient needed emergency bypass surgery.

Procedure Parameters

The data for fluoroscopy time, the amount of contrast dye, etc could be retrieved from 18 patients, who were treated in the author's hospital. The total procedure and fluoroscopy time, the amount of contrast utilized and total radiation doses were 89.1 ± 32.9 (35–165) min, 26.9 ± 10.6 (7.7–49) min, 234.1 ± 66.7 (150–385) ml, and 166.3 ± 88.8 (29–354) mGy per square centimeters, respectively.

DISCUSSION

Several new devices have been developed to improve the success rate of PCI in CTO lesions, but their contribution has been less than expected [9]. The introduction of guidewires specifically designed for CTO lesions such as tapered-tip type or sophisticated techniques such as double guidewire technique have improved the success rate [5]. However, it still requires much improvement even if PCI is performed by skillful operators. Thus, PCI for CTO lesions is currently one of ''the last frontiers'' in coronary intervention [10]. Retrograde approach is strongly expected to improve the success rate in PCI for CTO lesions. The results in this article show that the final success rate reached 83% even in the patients with previous failed attempts. While we did not specifically examine the success rate of a second antegrade approach to the

TABLE I. Complications

Complications	No. of cases	Caused by	Sequel and/or treatment
Dissection of the target artery	1	A tip of the retrograde guidewire	No residual ischemia
Minor perforation of septal artery	1	A tip of the retrograde guidewire	No hemopericardium
Dissection of septal artery	4	A tip of the retrograde guidewire	No residual ischemia
Transient ischemia in the target region	1	False spasm of the tortuous epicardial collateral artery by guidewire and balloon catheter insertion	No residual ischemia
Transient ST elevation in the region unrelated to PCI	1	Unknown	No residual ischemia
Ventricular fibrillation	1	Wedge injection of dye into the right coronary artery	Cardioverted to sinus rhythm
Acute heart failure	1	Acute aortic regurgitation from deformity of the valve from the use of the left Amplatz guiding catheter	Completely recovered by adjusting the position of the guiding catheter
Hemopericardium	1	A tip of the antegrade guidewire after successful ''Just landmark'' strategy	Pericardiocentesis and spring coil embolization of the perforated artery
Dissection of the ostium of the collateral-donor coronary artery	1	Injury of the ostium of the right coronary artery by the a tip of the left Amplatz guiding catheter	Treated by stent implantation

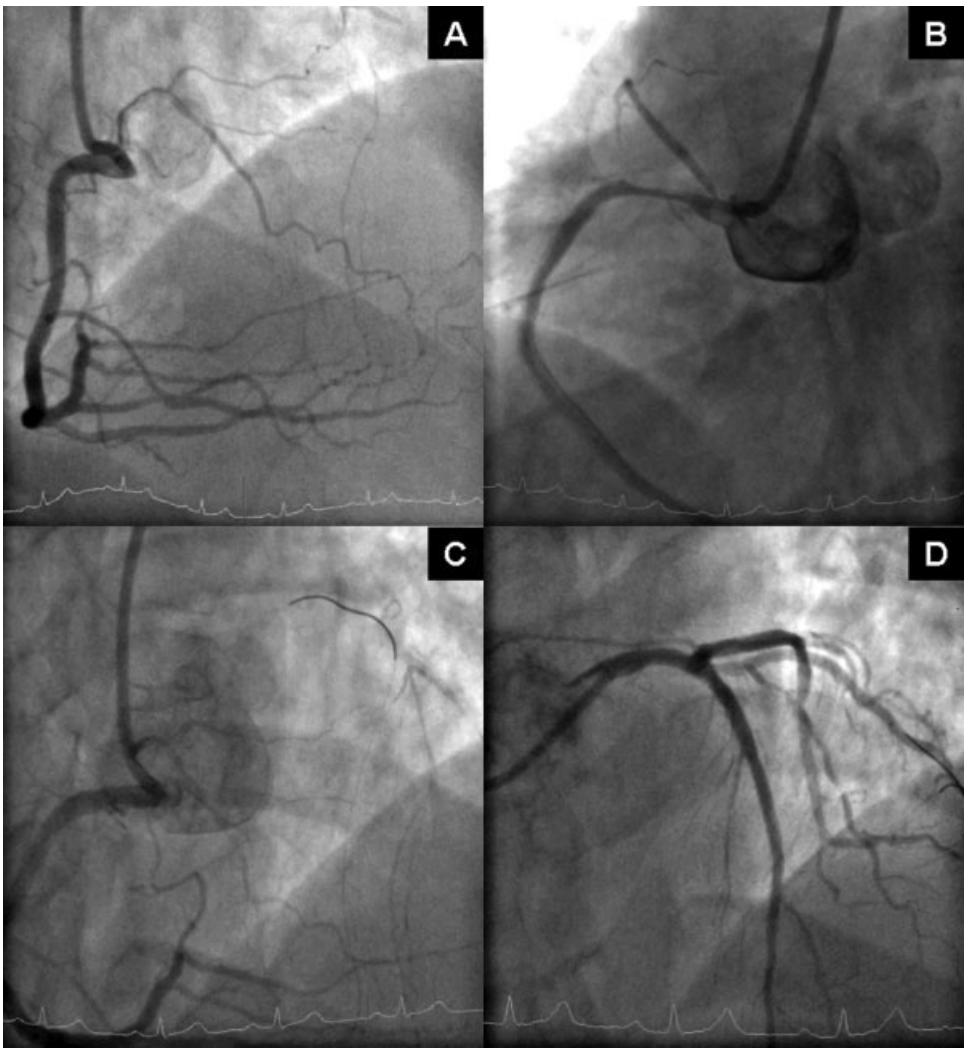

Fig. 7. A case with ostial dissection of a donor artery induced by a retrograde guiding catheter. (A) Control angiogram of a patient with a CTO lesion in proximal LAD taken by a 90-CM left Amplatz guiding catheter for retrograde access. (B) Because the proximal part of RCA dissects and becomes narrowed, the guiding catheter is temporarily changed to a Judkins type. A stent placement is done immediately. (C) After stent implantation in the proximal RCA, a hydrophilic guidewire is successfully passed through the septal artery into LAD distal to the CTO lesion. (D) Final angiogram.

CTO, the retrograde approach may improve the final success rate of PCI in CTO lesions.

Why does the retrograde approach work even after previous antegrade approach failed? Several reasons can be proposed. Firstly, previous failed attempts of antegrade approach induce intimal dissection, and as a result the anatomy becomes more difficult on future occasions for further antegrade attempts. Secondly, the distal cap of the CTO lesions is hypothesized to be softer than the proximal cap [11]. A Miracle 3 guidewire worked effectively from a retrograde route in 22 of 37 patients, although stiffer guidewires such as Conquest-Pro or Conquest-Pro 12 were necessary in the remaining patients. This finding shows the hypothesis earlier is true only to some extent. Thirdly, the entry point into the CTO lesions, which is inferred from the angiographic appearance, is sometimes wrong. In this situation, a Miracle 3 guidewire can easily pass through the lesion into the proximal true lumen from a retrograde approach. The case in Fig. 8 is a good example.

Septal branch route was chosen in 93% of the patients. Since the epicardial connections are highly dependent on the anatomical variation of each patient, this route is considered the most useful among different possible routes irrespective of the target lesion location [12]. Coronary collateral circulation might be present even if no visible collaterals can be detected angiographically [13]. In fact, a hydrophilic guidewire can be passed through such an angiographically invisible septal connection, as it occurred in 2 of 45 patients. Thus, as long as the septal artery is chosen for the retrograde route, the attempts to pass a hydrophilic guidewire through invisible routes might be justified. When the visible septal connection cannot be detected, the endhole injection of dye through a microcatheter in the septal branch may show a connection. However, the author did this on only a few cases because of the increased time if took to perform, and due to the risk of inducing septal branch dissection from forceful dye injection and the reinsertion of a guidewire.

The author has no conclusive data regarding the number of patients who have adequate collaterals for performing the retrograde technique. However, the author attempted it in 45 among 220 patients (20%) in the study period.

Several strategies in a retrograde approach have been proposed. ''Just landmark'' strategy can save the amount of contrast dye used and may promote the successful antegrade guidewire passage [14,15]. In fact, this strategy was used in 32% of the patients with successful retrograde guidewire passage. The fact that the author could clearly and continuously identify the target was considered to promote the successful antegrade guidewire passage, although the success might be achieved only because it was done on a second attempt. ''Kissing guidewire'' strategy can be considered a special version of ''Just landmark'' strategy. The usefulness of CART technique was also proposed in a small number of patients [6]. ''Retrograde proximal true lumen puncture'' strategy was also reported in the patient with a CTO lesion in the anomalous-origin RCA [16]. ''Catching the retrograde guidewire'' strategy was also reported in 2 patients [11]. ''Retrograde true lumen tracking'' strategy was proposed first in this article. Adjunctive techniques such as anchoring, co-axial anchoring, or reverse anchoring balloon technique and the use of a 5-French child guiding catheter were used in 17 patients (38%). Thus, a retrograde approach requires a combination of techniques, which have to be chosen on an individual basis according to the patient condition.

Retrograde approach is an emerging technique for CTO lesions. It might potentially be accompanied with several unexpected complications which do not happen during PCI for CTO lesions by using conventional techniques. First, this approach needs the insertion of a guiding catheter into the collateral-donor coronary artery. Diminished flow or occlusion in this artery due to thrombus formation may result in life-threatening ischemic complications. Adequate anti-coagulation therapy during PCI is therefore essential. Second, dissection of the proximal part of the donor artery may be life-threatening, and if it is observed, it should be immediately treated by placing stents across it (Fig. 7). Third, there is a risk that ischemia might be induced temporarily because the collateral route might be occluded by catheters during the procedure (Fig. 2). Fortunately, ischemia due to this reason has not been observed during the procedures in any of the patients. Fourth, any damage to the collateral routes caused during the procedures may result in the exacerbation of ischemia. In this series, 6 patients had minor intimal dissection and/or perforation of septal or target artery due to a guidewire tip. These patients fortunately did not develop any ischemic sequels. However, there is a case report in which a patient suffered from a complication of septum hematoma and myocardial infarction after successful guidewire passage through the septal artery [14]. In order to reduce this occurrence, excessive forceful attempts to cross a hydrophilic guidewire or a catheter through septal branch should be avoided. This case is a clear warning message not to take the retrograde approach too easily, although septal dilatation with low pressure has been reported to be safe in a small number of patient series [6].

Retrograde approach obviously requires high-class or special devices such as good microcatheters, hydrophilic and CTO guidewires, Tornus, good low-profile

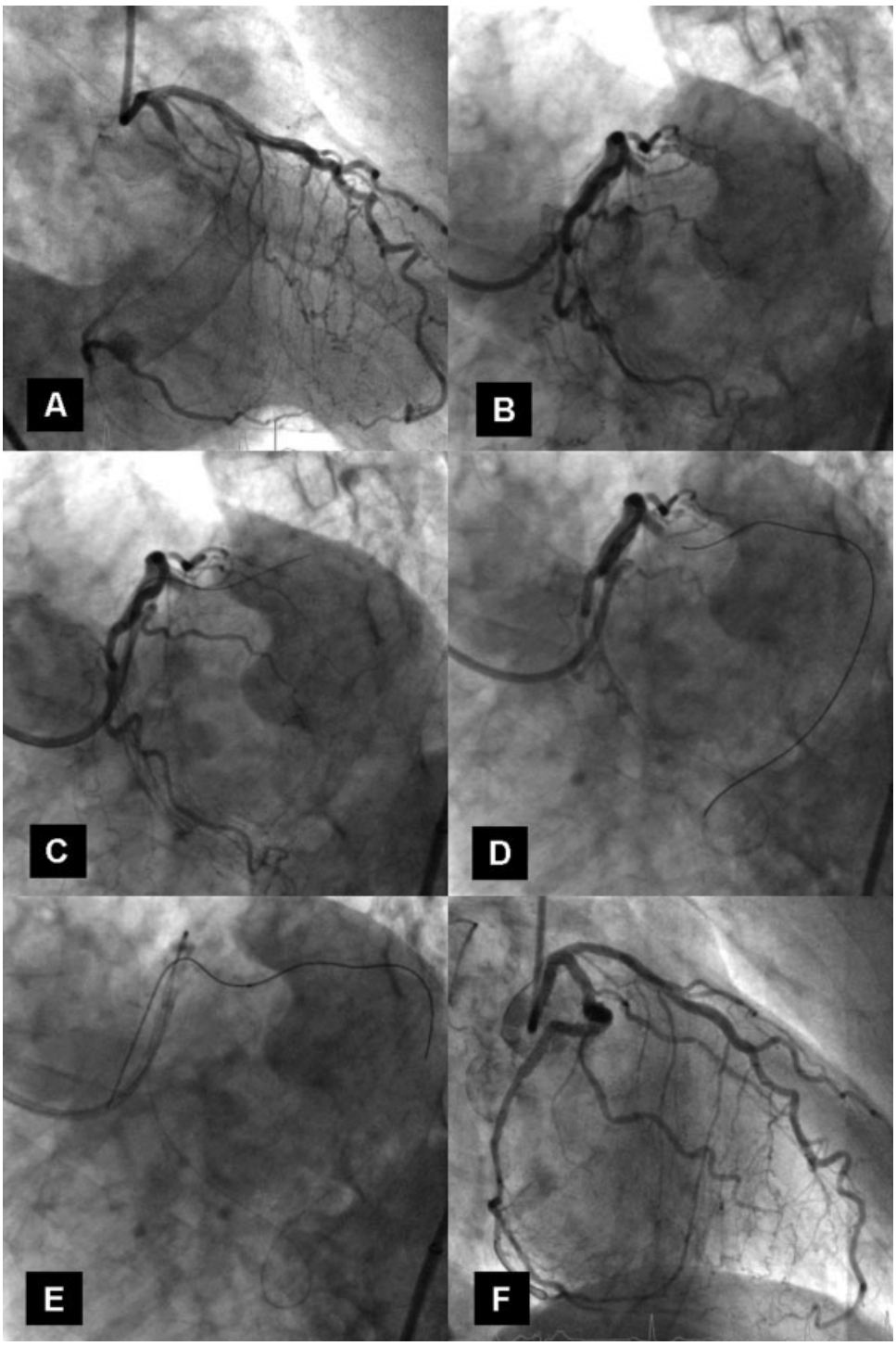

Fig. 8. A case with a CTO lesion in plroximal LCX. (A, B) Control angiogram. (C) An antegrade guidewire (Conquest-Pro 12) is advanced into the subintimal space distal to the CTO lesion. (D, E) A retrograde guidewire (Miracle 3) is relatively easily passed through the CTO lesion into the proximal true lumen. Note the difference of the guidewire route between C and D/E. (F) Final angiogram.

OTW balloons, or short guiding catheters. However, it must be emphasized that regular guiding catheters can be used if long-shaft balloons and/or long microcatheters are also employed. This approach should be done exclusively by highly-experienced operators, since it requires a combination of different techniques. Much more sophistication is necessary, before a retrograde approach is widely performed.

STUDY LIMITATIONS

There are several limitations in this study. First, this study is a retrospective observational study. The most scientific way to demonstrate the efficacy of newly developed treatments is to conduct a prospective randomized trial. However, it is practically difficult to achieve it in the field where interventional devices and techniques are rapidly improving and changing. In this kind of situation, a retrospective study is reasonable compromise. Second, the number of cases was as small, only 45 patients were included in this study. However, the experiences over 1 year in different countries can be considered enough for generalization of the author's experiences into various patients across racial differences. Third, the success in angioplasty is highly dependent on the operators' experience. Since all procedures described in this article were accomplished by only a single, highly experienced operator, the results may not be applicable for less-experienced operators. However, proper education will ultimately improve the general techniques. Fourthly, the patients in this study were highly selected ones, as most of them were chosen due to failed previous attempts at PCI. Lastly, the ideas, results, considerations, or opinions are solely those of the author. Despite these limitations, it can be concluded that a retrograde approach with different strategies mainly through septal arteries can provide a high success rate of 83% in patients with previous failed attempts without serious complications directly related to it in PCI for CTO lesions. More experiences of this technique and its refinement are required for further improvement.

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