

A Novel Guidewire Approach for Handling Acute-Angle Bifurcations: Reversed Guidewire Technique With Adjunctive Use of a Double-Lumen Microcatheter

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ABSTRACT: Guidewire manipulation to negotiate branches originating at an acute angle from the parent artery is a frequently encountered challenge by the interventional cardiologist in clinical practice. To date, several methods have been developed, but none of them has a definitive success rate. Here, we report a technique for negotiating extremely angulated vascular bifurcations, with which we have achieved a high rate of success in percutaneous coronary intervention. This technique involves combining a reversed guidewire technique with a double-lumen multifunctional probing microcatheter. We present the cases of 3 patients successfully treated using this technique.

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Percutaneous coronary intervention (PCI) involves a challenge to negotiate acute-angle bifurcations even for the considerably skilled interventionist, and significant angulations are a predictor of procedural failures and complications.^{1–3}

The Crusade catheter (Kaneka), a double-lumen multifunctional probing microcatheter, was designed with the express purpose of managing bifurcation lesions. A double-lumen is an effective structure for this purpose. The guidewire in the monorail lumen protruding from the end helps to stabilize the microcatheter, while the guidewire in the over-the-wire lumen protruding from the side hole can be directed toward the ostium of the intended branch. Thus, this device provides adjunctive support in getting catheters into the desired position.^{4,5} The double lumen additionally prevents entanglement of multiple guidewires.

However, there remain blood vessels with acute-angle bifurcations that are difficult to access even with this double-lumen microcatheter under conventional manipulation.

The reversed guidewire technique is a technique in which a distal wire shaft formed into a swan-neck shape is passed into an unintended vessel beyond a bifurcation,

followed by pull-back toward the bifurcation to engage the origin of the intended vessel. Further withdrawal of the wire shaft should cause the tip to advance deeper into the targeted vessel. The reversed guidewire technique was originally reported by Kawasaki et al, who successfully accessed the targeted vessel manually by forming a swan-neck shape in the distal tip of a guidewire.⁶ However, we show that the above method is not foolproof, either.

Here, we present a new technique that combines the reversed guidewire technique with a Crusade catheter, and we expect that this technique will increase the rate of access into vessels, particularly with a difficult anatomy. We describe the details of this technique, its usefulness, why it works, and when to employ it in clinical practice through the following case reports.

Case 1

A 72-year-old man with a history of coronary artery bypass grafting for myocardial infarction was brought to our hospital because of paroxysmal nocturnal dyspnea.

Angiography revealed that a Y-graft bypass from the ascending aorta to the posterolateral branch (PL) of the left circumflex artery (LCX) and to the first diagonal branch was patent (Figure 1A). On the other hand, pharmacological stress scintigraphy indicated that the anterior and lateral myocardial walls had obviously been exposed to ischemia, which suggested that the blood supply via the bypass graft was still insufficient. Therefore, we attempted PCI for the native coronary arteries, ie, the LCX ostium with subtotal occlusion and for the distal left main trunk (LMT) with 90% stenosis (Figure 1B).

An 8 Fr long-tip guiding catheter was inserted from the left femoral artery to the LMT. The distal LMT – proximal left anterior descending artery (LAD) had a thick, calcified deposit that was maximally rotablated using a 2.0 mm burr (Rotablator RotaLink Plus; Boston Scientific). To access the LCX ostium, a Fielder FC guidewire (Asahi Intecc) was used together with a Crusade catheter in a conventional manner. However, the guidewire tip immediately prolapsed into the unintended LAD no matter how many times we attempted to pass the wire through the origin of the intended LCX (Figure 1C), and thus we had to abort the conventional antegrade approach. Then, we attempted the retrograde approach via the bypass graft,⁷ but it was unsuccessful because of the extremely angulated anastomosis with the PL (Figures 1A and 1D).

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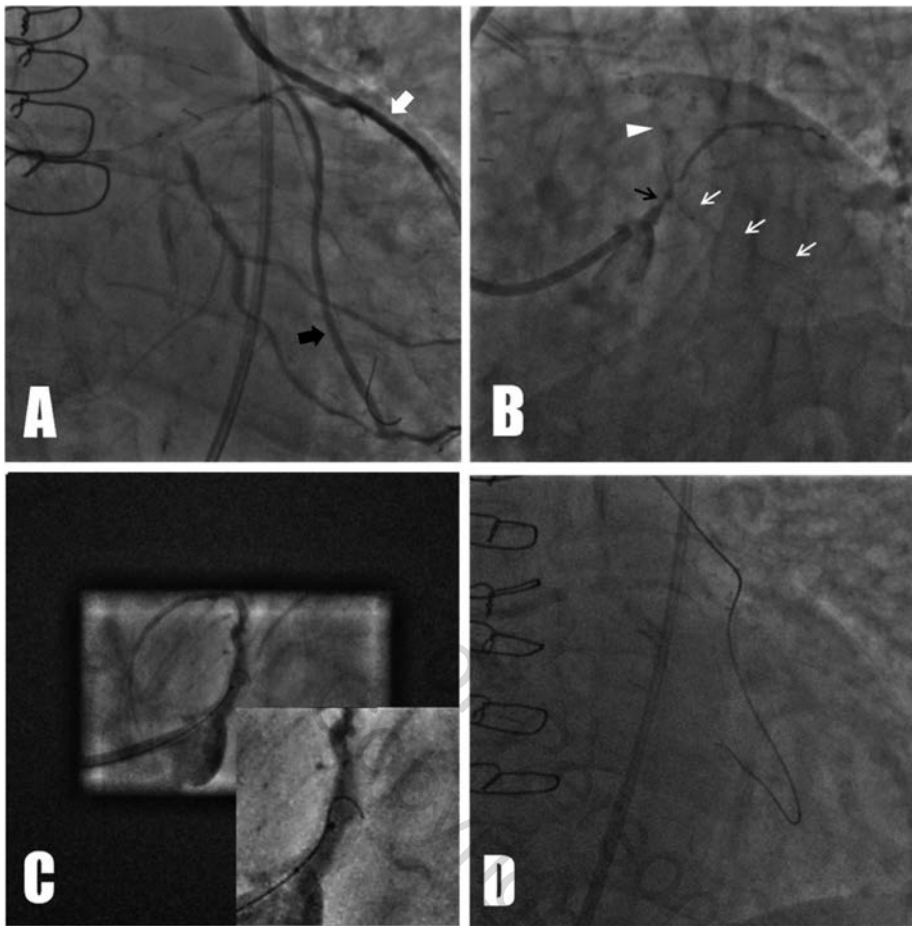


Figure 1. Procedural steps of intervention in Case 1 (the former). (A) A Y-graft from the ascending aorta to the first diagonal branch (thick white arrow) and to the left circumflex (LCX; thick black arrow). (B) The LCX is almost totally occluded at the ostium and is barely detected with a faint stain of contrast material (white arrows). In addition, a 90% stenosis is located at the distal left main trunk (LMT; black arrow). Flow competition between antegrade flow via the LMT and retrograde flow via the bypass graft is detected in the proximal left anterior descending (LAD; white arrowhead). (C) A Fielder FC wire with a conventional curve created at the tip in the over-the-wire lumen of a Crusade catheter. The tip barely engages the LCX ostium. However, pushing the shaft gently forward, the tip easily prolapses into the LAD. (D) Retrograde approach to the LCX via the bypass graft. Panels A and D, anteroposterior view; Panels B and C, left anterior oblique caudal view).

using a cutting balloon, a drug-eluting stent was deployed for the mid LCX. Two drug-eluting stents were placed to the span length of the mid LAD to the LMT ostium (traversing the LCX), ensuring that there was a slight overlap of 2 to 3 struts of the 2 stents. A Fielder FC wire was passed through a strut of the 2 stents and advanced to the distal end of the LCX with adjunctive use of the Crusade catheter, and kissing balloon inflation was applied (Figure 3E). All procedures were successfully completed without any complications (Figure 3F).

Case 2

A 79-year-old man, who had once undergone surgical repair of the thoracic aortic arch, was urgently admitted to our department for unstable angina pectoris. Coronary angiography showed severe multivessel stenosis (Figure 4).

A week after treatment for the right coronary artery, PCI was attempted for the LCX. A 7.5 Fr, sheathless, long-tip guiding catheter was inserted from the right radial artery and positioned at the origin of the LMT. A general coronary guidewire (Rinato; Asahi Intecc) traversed the lesions toward the PL. After inflation of a balloon (caliber, 2.5 mm), the flow in the posterior descending artery (PD) was nearly lost [Figures 5-(1)A and 5-(1)B]. To prevent the loss of flow in the PD, a Rinato wire in the PL

was withdrawn to the proximity of the PD ostium with an attempt to pass it into the PD using a conventional single-lumen microcatheter. However, the distal tip kept prolapsing into the unwanted PL despite multiple attempts to reshape the configuration of the tip. Similarly, guidewires were replaced multiple times with no success. Finally, we attempted the reversed guidewire technique using a Crusade catheter. The monorail lumen of the Crusade catheter was passed over the wire in the PL. The over-the-wire lumen held a Whisper LS wire formed into a swan-neck shape at the distal end [Figure 5-(1)C and Figure 5-(2)]. The tip easily engaged the origin and went into the deep branch with continuous withdrawal of the shaft until the hairpin-bend reached the bifurcation, as shown in Figures 5-(2)A through Figure 5-(2)C. Once the hairpin-bend point arrived at the bifurcation, a combination of gentle pushing and rotation of

Finally, we used a reversed guidewire technique. A hairpin-bend was formed in a Whisper LS wire (Abbott Vascular) at a point 3 cm from the distal tip (Figure 2A) and inserted in the over-the-wire lumen. The Whisper LS wire was passed via the Crusade catheter into the LAD beyond the bifurcation with the swan-neck shaped distal shaft protruding out of the side port (Figure 2B). Withdrawal of the wire toward the bifurcation with the Crusade catheter caused the Whisper LS wire tip to engage the ostium of the targeted LCX (Figures 2C, 2D, and 3A). When the wire was withdrawn further until the hairpin-bend reached the bifurcation point, the tip went deep into the LCX (Figures 2E, 3B, and 3C). At this point, a gentle forward force with adequate rotation of the shaft enabled distal advancement of the tip (Figure 2F). After the LCX ostium was rotablated using a 1.75 mm burr (Figure 3D) and dilated

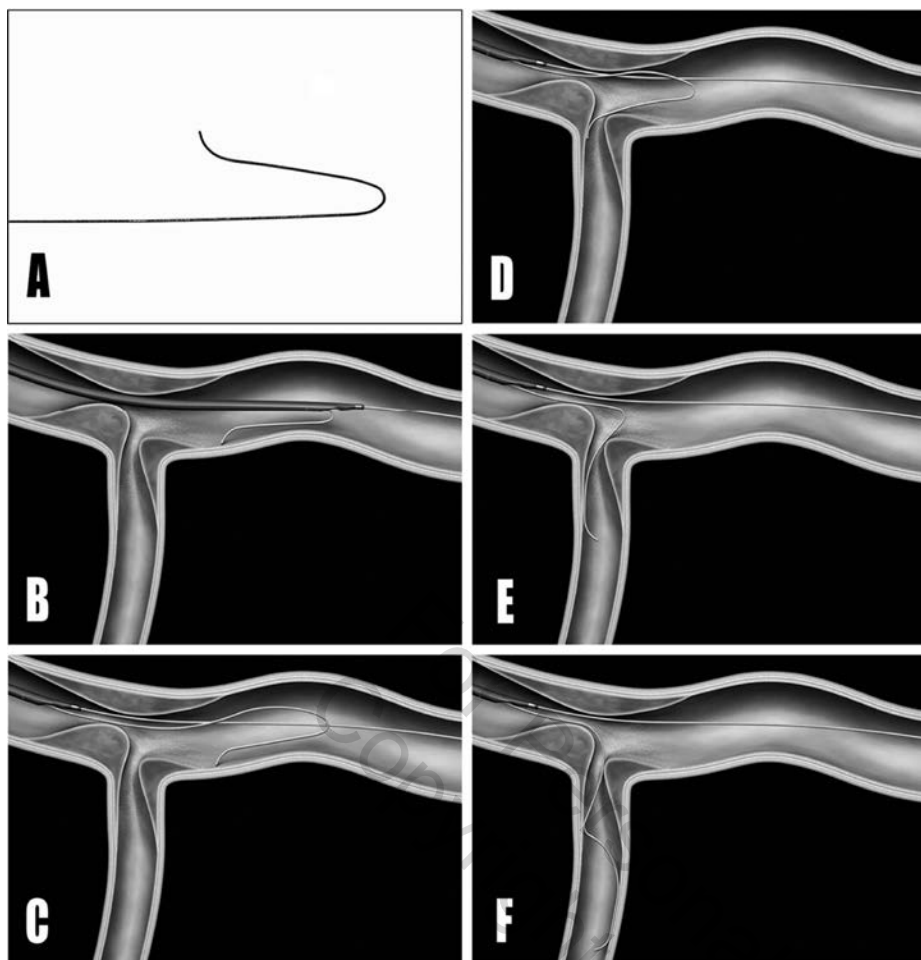


Figure 2. Reversed guidewire technique using the Crusade catheter. (A) A swan-neck shaped guidewire. A conventional curve formed at the tip and a hairpin-bend at a point 3 cm from the tip. (B) A guidewire for the unintended vessel in the monorail lumen fixes and stabilizes the microcatheter in place, while a guidewire for the intended vessel in the over-the-wire lumen comes out the side hole. The Crusade catheter helps the swan-neck shaped distal shaft cross the stenosis protruding from the side hole and enables advancement of this irregularly shaped shaft deep into the unintended vessel. (C, D) Withdrawing the swan-neck shaped wire while manipulating the tip engages the ostium of the intended branch. (E) Mere withdrawal of the shaft allows advancement of the tip deep into the vessel along with enlargement of the angle of the hairpin-bend. (F) After the hairpin-bend arrives at the bifurcation, application of a gentle forward force with appropriate rotation of the shaft takes the tip further into the intended branch.

the shaft sent the tip further into the distal PD to the end [Figures 5-(2)D and 5-(2)E]. Two drug-eluting stents were placed in the manner of T-stenting [Figures 5-(1)D and 5-(1)E]. After a hydrophilic-coated spring coil wire was fed through the over-the-wire lumen of the Crusade catheter and employed to recross the PD ostium from the inside of the stents [Figures 5-(1)F and 5-(3)], final kissing balloon inflation was accomplished [Figure 5-(1)G]. On the basis of intravascular ultrasound (IVUS) findings, additional stents were deployed to the distal PD [Figure 5-(1)H].

After 3 days, the very proximal LAD underwent directional coronary atherectomy and stent placement. Thus, we achieved complete revascularization with PCI.

Case 3

A 60-year-old man was admitted to our department because of deteriorating angina pectoris. Coronary angiography

revealed a 90% stenosis at the mid LAD [Figure 6-(1)A]. A 7 Fr, long-tip guiding catheter was inserted from the right femoral artery and positioned in the LMT. An IVUS catheter could not cross the lesion, which suggested the presence of a thick calcified layer in the lesion. Hence, rotational atherectomy was performed as the first step [Figure 6-(1)B]. At a very distal end of the stenosis, a large diagonal branch originated at an acute angle with respect to the LAD. Therefore, the reversed guidewire technique combined with a Crusade catheter was attempted from the beginning for securing the branch. The Whisper LS wire inserted in the over-the-wire lumen engaged the ostium and advanced into the branch without any difficulties [Figures 6-(1)C and 6-(2)]. After the bifurcation was predilated by kissing balloon inflation, a bare-metal stent was deployed at the parent artery, followed by high-pressure inflation using a non-compliant balloon. Thus, optimal stent expansion was obtained without loss of the diagonal branch [Figure 6-(1)D]. However, the coronary angiogram displayed a contrast material stain in the epicardium [Figure 6-(1)D], which suggested accidental coronary perforation by the Whisper LS wire. Fortunately, the leakage stopped when protamine sulfate, a heparin counter-actant, was administered.

Discussion

All 3 patients described above had coronary anatomy with acute-angle bifurcations. Conventional manipulation of guidewires failed to negotiate the origin of the intended branch in 2 patients and failure was anticipated before the procedure in 1 patient. However, the reversed guidewire technique with adjunctive use of a double-lumen microcatheter Crusade was successful in the cases of all 3 patients.

Vascular features suitable for the technique. The 3 patients had 2 features in common. First, each patient had stenosis immediately proximal to the bifurcation. Generally, the guidewire tip requires a large curve to negotiate an angulated branch ostium. However, preshaped large curves collapse and get straightened by the stenosis at the end, which hinders the ability of the curves to direct the

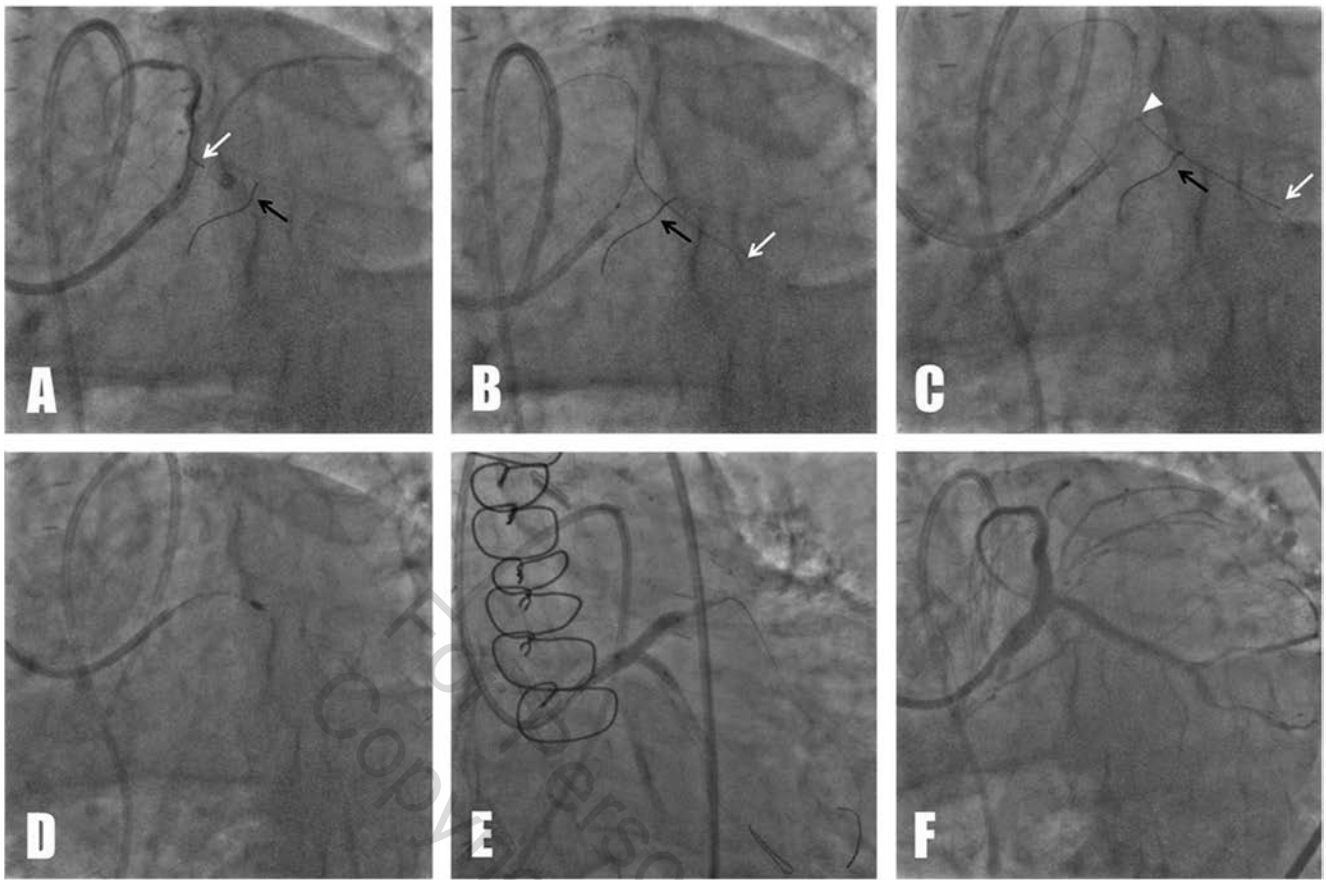


Figure 3. Procedural steps of intervention in Case 1 (the latter). (A-C) Accessing the targeted left circumflex (LCX) with reversed guidewire technique using a Crusade catheter: the white arrow represents a reversed wire tip for the intended LCX, and the black arrow, a wire tip in the unintended left anterior descending (LAD). A Whisper LS wire in the over-the-wire lumen of a Crusade catheter with a swan-neck shaped distal shaft protruding from a side hole is carried to the distal LAD. The LCX ostium is engaged using a reversed wire tip (A). As the shaft is withdrawn, the tip advances to the deep LCX (B). Once the hairpin-bend (white arrowhead) reaches the bifurcation, application of a gentle forward force with rotation of the shaft sends the tip further into the deep LCX (C). (D) Rotablation for the ostium to the mid LCX. (E) After dilation of the LCX lesion using a Flextome $3.25 \times 10 \text{ mm}^2$ cutting balloon (Boston Scientific) and stent ($3.5 \times 15 \text{ mm}^2$ PROMUS; Boston Scientific) deployment for the mid LCX, the left main trunk (LMT) to the LAD was treated using 2 stents ($3.0 \times 15 \text{ mm}^2$ and $3.5 \times 15 \text{ mm}^2$ PROMUS stents). Finally, a kissing balloon inflation was performed at the LMT bifurcation using a 3.5 mm stent-system balloon and a 3.5 mm non-compliant balloon for the LMT to proximal LAD and for LMT to the LCX, respectively. (F) Final angiogram. Panels A through D and F, left anterior oblique caudal view; Panel E, anteroposterior caudal view.

wire toward the desired branch. Even if the tip eventually engages the intended branch ostium, it tends to prolapse immediately into the unintended main vessel, because the relationship between the direction the tip is heading to and the force exerted on the proximal shaft by the operator's hand will necessarily be far from coaxial. In contrast, pulling a swan-neck shaped guidewire back from the distal toward the proximal direction in the parent vessel makes the angle obtuse from the direction that the tip is facing (Figures 2B, 2C, and 2D). Additionally, this enables the tip to avoid interference from the stenosis.

The second commonality was the fact that the Whisper LS was the guidewire that finally achieved advancement into the desired branch. The use of plastic-jacket hydrophilic wires is reasonable for this procedure, because they offer both good controllability for engaging the ostium of extremely angulated branches and better trackability for

advancement deep into the vessel because of lower resistance, even under conditions of poor pushability.

Tips of the technique. Once the tip engages the ostium of the branch, pulling the guidewire back forces the tip to advance into the distal vessel until the bend in the hairpin reaches the bifurcation (Figure 2E). After the hairpin-bend reaches the bifurcation, application of a gentle forward force with adequate rotation on the shaft allows the tip to advance further into the vessel (Figure 2F).

To create a swan-neck shape in the distal shaft, a conventional curve should be formed at the tip first. Then, a hairpin-bend needs to be shaped at an optimal distance from the end. If one makes this acute bend at a point far from the tip where the core of the guidewire is not tapered, there is a risk of erasing its shape memory. Conversely, if the point is too close to the tip, it becomes difficult to carry the tip into the distal targeted branch after the hairpin-bend

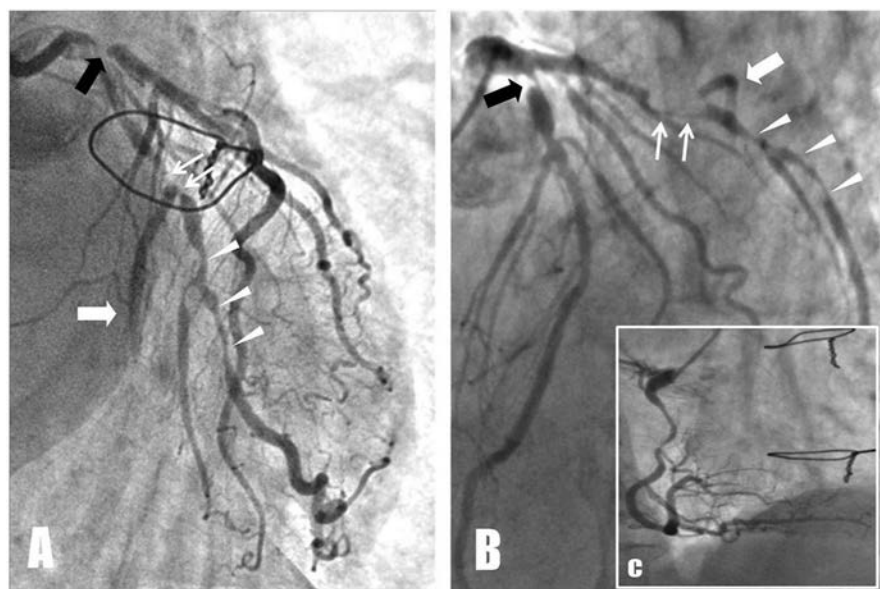


Figure 4. Coronary angiogram in Case 2. (A, B) Left coronary artery: an intense stenotic lesion traverses the mid LCX to the proximal posterolateral (PL) branch (thin white arrows) crossing the PD (thick white arrow). The posterior descending (PD) artery had TIMI 1 flow. A diffuse lesion in the further distal PL (arrowheads) had TIMI 2 flow. The left anterior descending (LAD) artery also had a critical stenosis at its take-off (thick black arrow). (C) A diffuse lesion in the right coronary artery. Panel A, right anterior oblique caudal view; Panel B, left anterior oblique cranial view; and Panel C, right anterior oblique view).

reaches the bifurcation. We propose forming the hairpin-bend 3 cm from the tip as an optimal distance on the basis of our experience (Figure 2A).

Advantages of the technique. Kawasaki et al succeeded in treating an ostial LAD, which bifurcated at an acute angle from the LMT, using a bare wire.⁶ Adjunctive use of a double-lumen catheter at the time of guidewire manipulation has some additional advantages as compared to the reversed guidewire technique alone. First, the former helps the hairpin-bent shaft to pass into the unintended vessel beyond the bifurcation with less interference from the stenosis. Further, the guidewire gains better back-up support toward the intended branch, as the catheter minimizes the sway of the shaft. Third, the present technique prevents entanglement of the wire shafts with one another. In the reversed guidewire technique, there are 3 wire shafts: a shaft distal to the hairpin-bend point of the wire for the intended vessel; a shaft proximal to the hairpin-bend point of the wire for the intended vessel; and a shaft required for the unintended vessel. Pulling the swan-neck shaped guidewire back to the bifurcation with torque to carry the tip to the targeted branch ostium in a crowded vessel is likely to induce shaft entanglement. Because a double-lumen microcatheter accommodates 2 of the 3 shafts separately in each lumen and leaves only the shaft distal to the bent point outside the catheter, using this device can prevent entanglement. Lastly, using the double-lumen microcatheter may decrease the risk of a swan-neck shaped wire getting stuck in a vessel, which is the greatest fear when utilizing the reversed bare guidewire operation.

commercially available. Third, the swan-neck portion of the wire may present difficulty in traversing the critical coronary stenosis. Furthermore, when stenotic lesions lie not only proximal but also distal to the bifurcation, this irregularly shaped wire could be difficult to manipulate, even after the swan-neck part passes into the distal main vessel. Lastly, because the shaft of the Crusade microcatheter has a thickness of 2.9 Fr, the use of this catheter is limited to patients with greater vascular luminal caliber. This microcatheter may not be able to pass through lesions with nearly critical stenosis, particularly if accompanied by a thick layer of calcification. Predilation using a small balloon or rotational atherectomy may be required as a pretreatment as described in Cases 2 and 3.

If another acute angle exists distal to the ostium of the targeted branch, other catheter-based systems such as a deflectable tip catheter may offer better navigation.⁹⁻¹¹ However, the deflectable tip catheter is not widely available in daily practice thus far. In addition, when performing kissing balloon inflation after stent placement for the parent vessel, a double-lumen structure is more advantageous than a deflectable tip (single lumen) because the wire has to cross into the branch through the stent cell facing the ostium from the side port, and there is no opportunity for the wire to pass into the branch inadvertently through cells further away.

In conclusion, despite some limitations, the reversed guidewire technique with adjunctive use of a double-lumen microcatheter leaves less to chance and may be a reliable way to treat patients with acute-angle bifurcations of the coronary anatomy.

Limitations. This technique does have limitations. First, the reversed guidewire has inferior torque performance compared to the technique using the conventional antegrade wire. Second, the reversed guidewire has a higher potential of causing vessel dissection. As stated above, the highly trackable performance of plastic-jacket hydrophilic guidewires is a favorable feature for this technique. However, this feature itself may sometimes damage vessels. Furthermore, coronary perforation is also a risk, similar to that we experienced in Case 3, because the guidewire tends to slip forward into the distal end of the vessel regardless of intention during withdrawal of the microcatheter. The Crusade catheter should be removed by the trapping technique (inflating a balloon inside the guiding catheter to fix the wire).⁸ However, this technique cannot be used in guiding catheters smaller than 7 Fr. Thus, it may be safer to choose at least a 7 Fr guiding catheter until a thinner trapping catheter becomes

Fig. 5-(1)

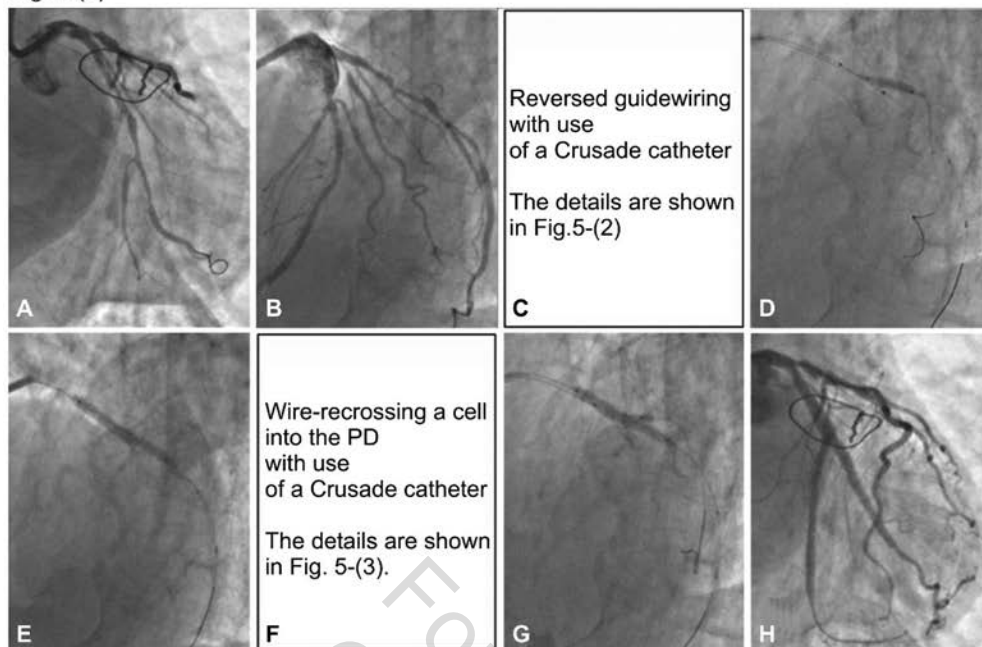


Fig. 5-(2)

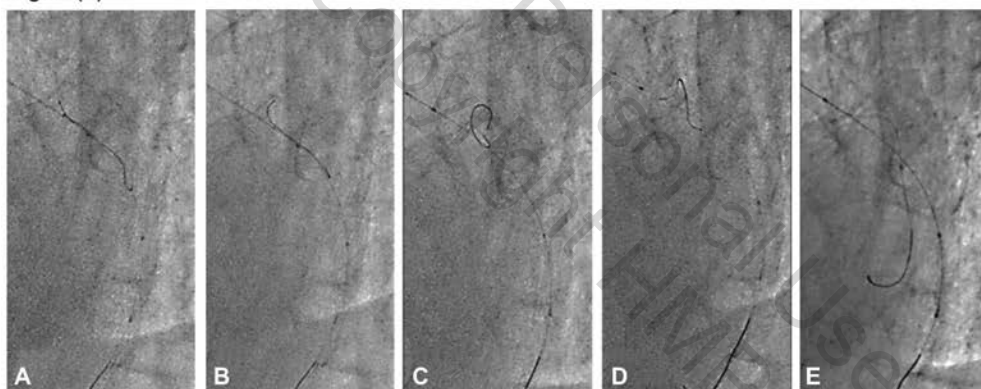


Fig. 5-(3)

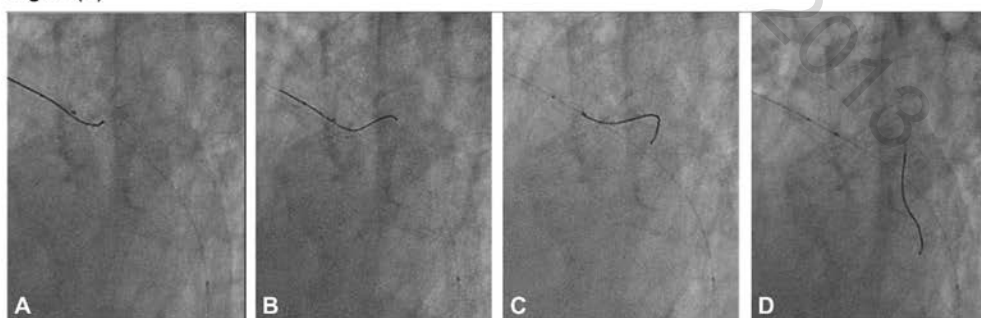


Figure 5. (1) Procedural steps of the intervention for the left circumflex (LCX) artery in Case 2. (A, B) After predilation for the mid LCX to the posterolateral (PL) branch, the posterior descending (PD) artery is pinched. (C) Reversed guidewire technique with adjunctive use of a Crusade micro-catheter. The details are shown in Figure 5-(2). (D, E) T-stenting using Cypher stents (Cordis; Johnson & Johnson). (F) A guidewire with conventionally shaped tip recrossing the jailed PD ostium also using a Crusade catheter. The details are shown in Figure 5-(3). (G) Kissing balloon inflation. (H) After Cypher stent deployment at the distal PD. Final angiogram. Panels A and H, right anterior oblique caudal view; Panels B, D, E and G, left anterior oblique cranial view).

(2) Reversed guidewire technique with adjunctive use of a Crusade catheter. (A) The tip captures the PD ostium on the way back from the proximal LCX. (B, C) Pulling only the shaft allows the tip to advance deep into the PD branch. (D, E) Once the hairpin-bend arrives at the bifurcation, gentle pushing of the shaft with appropriate rotation sends the tip further. Left anterior oblique cranial view.

(3) A Runthrough NS Floppy wire (Terumo) with a conventional tip form recrosses the jailed PD ostium in a Crusade catheter for kissing balloon inflation. Left anterior oblique cranial view.

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Fig. 6-(1)

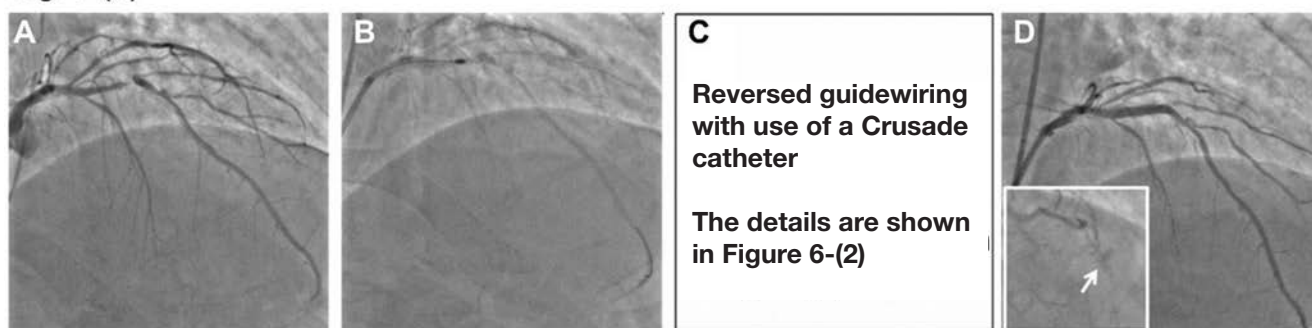


Fig. 6-(2)

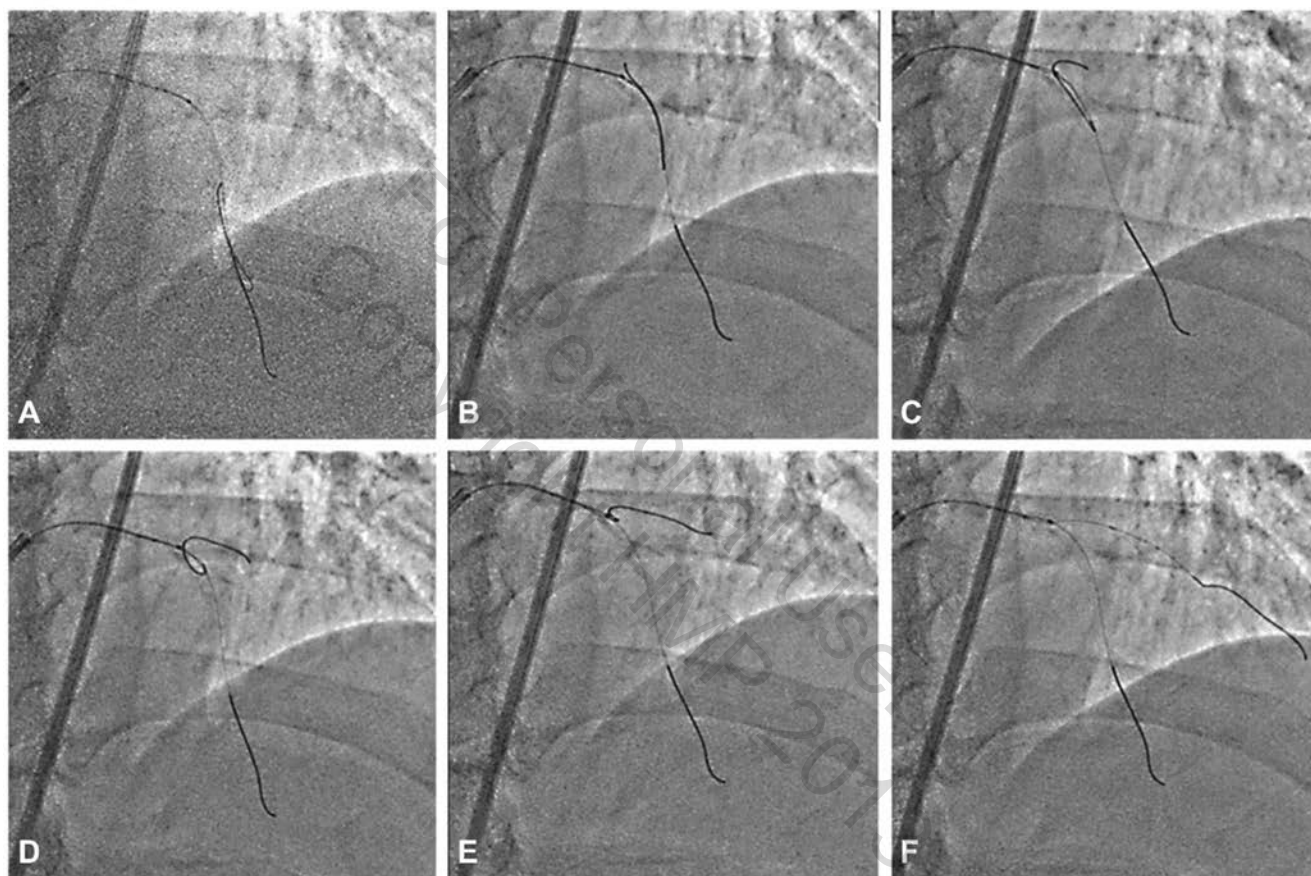


Figure 6. (1) Procedural steps for left anterior descending (LAD) intervention in Case 3. **(A)** A severe stenosis with calcification located at the mid LAD. A large diagonal branch originates immediately distal to the stenosis at acute ostial angle. **(B)** Rotablation for the mid LAD lesion (burr caliber, 1.75 mm). **(C)** Reversed guidewire technique using a Crusade catheter. The details are shown in Figure 6-(2). **(D)** Final angiogram: after predilation by kissing balloon inflation with 3.5 mm and 2.5 mm balloons into the LAD and the diagonal branch, respectively, a 3.5 × 18 mm² DRIVER stent (Medtronic Inc) is deployed at the parent artery followed by high-pressure inflation using a 3.75 mm non-compliant balloon. An optimal stent expansion is gained without the loss of the diagonal branch; however, a stain with contrast material at the distal end of the diagonal branch is suggestive of perforation made by the Whisper LS wire (arrow in the square). Right anterior oblique cranial view).

(2) Reversed guidewire technique with adjunctive use of a Crusade catheter. **(A)** A Whisper LS wire in the over-the-wire lumen of a Crusade catheter with protrusion of the swan-neck shaped distal shaft from a side hole is carried to the distal LAD. Then, a swan-neck shaped wire is withdrawn using a Crusade catheter toward the bifurcation. **(B)** The tip engages the ostium of the diagonal branch. **(C-E)** Mere withdrawal of the wire shaft causes the tip to go deep into the branch vessel smoothly until the hairpin-bend reaches the bifurcation. **(F)** Application of a gentle forward force with adequate rotation on the shaft advances the tip further. Right anterior oblique view.