Correction of Stent Distortion and Overhanging Stent Struts during Left Main Bifurcation Stenting by Selective Distal Stent Cell Re-Wiring: A Novel Guidewire Approach

Mahmoud Sabbah,1,2 Kazushige Kadota,2 Yasushi Fuku2 and Kazuaki Mitsudo2

Stent malapposition and overhanging struts in front of the side branch (SB) ostium are not uncommon following bifurcation stenting that might lead to stent thrombosis. We herein present 2 cases, in which optical frequency domain imaging and intravascular ultrasound effectively revealed stent malapposition and overhanging struts inside the ostium of the SB following left main coronary artery stenting. Therefore, we introduced a novel technique for rectification of these incidental findings by selective SB re-wiring through the most distal stent cell with the adjunctive help of a double lumen microcatheter.

Key Words: Distal stent strut • Left main bifurcation • Overhanging struts • Side branch re-crossing • Stent optimization

INTRODUCTION

It is not uncommon to find stent malapposition and overhanging stent struts in front of the side branch (SB) ostium following bifurcation stenting1 that could result in stent thrombosis.2 However, selective SB recrossing through the distal strut of the deployed main vessel stent is associated with better kissing balloon inflation (KBI) results and might prevent stent distortion.3,4 We present 2 cases, in which intravascular ultrasound (IVUS) and optical frequency domain imaging (OFDI) effectively showed stent distortion and overhanging struts inside the ostium of the SB following left main coronary artery (LMCA) bifurcation stenting. We therefore introduced a novel technique for rectification of these incidental findings by selective SB re-wiring through the most distal stent cell with the adjunctive help of a double lumen microcatheter.

CASE REPORT

Patient 1

A 63-year-old man had a history of hypertension and prior myocardial infarction. Due to recurrent chest pain with minimal effort, he was referred to our hospital for recanalization of the left circumflex artery (LCX) chronic total occlusion (Figure 1. I). After successful wiring and balloon angioplasty, a Nobori 3.5 mm × 24 mm stent (Terumo Corp., Tokyo, Japan) was deployed in the distal left main trunk (LMT) to the proximal LCX followed by a successful final KBI with good final angiographic pictures (Figure 1. II). However, IVUS showed malapposition and distortion of the proximal LMT stent with overhanging struts inside the ostium of the left anterior...
descending artery (LAD) (Figure 1. IV).

Patient 2
A 55-year-old man with a history of hypertension and dyslipidemia was admitted to our hospital because of increasing chest pain in the last month. Two years earlier, percutaneous coronary intervention (PCI) had been performed, in which a Nobori 3.5 mm × 24 mm stent was deployed in the proximal segment of the LAD. The patient’s current coronary angiography revealed 85% stenosis at osteoproximal LAD extending to the proximal edge of the old stent (Figure 1A). Following successful wiring and scoring balloon dilatation, a new Nobori stent 3.5 mm × 14 mm was deployed in LMT into the proximal LAD and overlapped with the old one. Despite excellent angiographic results (Figure 1B), OFDI revealed stent malapposition and overhanging of the proximal stent struts inside the LCX ostium (Figure 1D and D’).

We therefore, devised a novel technique aimed to achieve a final stent optimization and resolve the problem of the floating stent struts towards the SB ostium, by deliberate guidewire (GW) recrossing through the distal cell of the deployed LMCA stent using a Crusade double-lumen microcatheter (Kaneka Corporation, Osaka, Japan). The technique is described as follows: (also see: Figure 2):

- The Crusade microcatheter is smoothly advanced over the previously placed SB wire to reach the site of the bifurcation, while keeping the wire in place.
- The new GW is then negotiated while keeping its tip continuously touching the carina of the bifurcation (Figure 2A).
- After the new GW catches the ostium, the Crusade catheter is slid towards the SB ostium. Any resistance suggests that it is catching in the distal stent cell close to the carina, i.e. the carina cell, and floating struts have trapped the microcatheter from further advancement (Figure 2D). At the same time, the guiding catheter will move backwards disengaging from the coronary ostium. The GW can then be safely advanced, ensuring capture of the appropriate stent cell.
- In contrast, if the catheter moves freely, it suggests that the guidewire has crossed through the same stent cell (Figure 2C).
- An intracoronary imaging assessment is strongly re-

Figure 1. Angiographic, intravascular ultrasound (IVUS), and optical frequency domain imaging (OFDI) images of patient 1 (I to V), and patient 2 (A to E). Patient 1, (I) Bilateral angiographic injection, right anterior oblique view with caudal angulation shows, total occlusion of the left circumflex artery (LCX) with retrograde filling by collaterals from the right coronary artery. (II) After successful recanalization and deployment of Nobori 3.5 mm × 24 mm stent in the left main coronary artery crossed to LCX [notice the first kissing balloon inflation (KBI) in the small inset]. (III) Final excellent angiographic results after guidewire crossing through the distal stent cell [notice the wire negotiation with help of Crusade double lumen microcatheter (small inset)]. (IV) IVUS image shows overhanging stent struts (yellow arrows) in the mainstream of the ostium of the left anterior descending artery (LAD). (V) After successful rewiring through the distal stent cells, IVUS image from the same correspond area shows widely patent LAD ostium with no over-hanging struts. Patient 2, (A) Angiogram of the left coronary system in right anterior oblique view with caudal angulation shows tight focal 85% in stent restenosis very close to bifurcation of LAD with ramus intermedius branch and left main coronary artery. (B) Good angiographic results after deployment of a Nobori 3.5 mm × 24 in left main coronary artery crossed to proximal LAD. (C) Final excellent angiographic results after KBI carried out in after guidewire crossing through the distal stent cell. (D) Malapposition and floating stent struts in the mainstream of left main artery against the ostium LCX (yellow arrow in D and arrowhead in D’). (E) Well opposed stent and clear LCX ostium after Kissing balloon inflation (KBI). Note the shadow of the floating struts in longitudinal view in D’ (yellow arrowhead) that was cleared after effective kissing balloon inflation in E’.
commended following the KBT to confirm that a proper stent apposition has been achieved.

Following confirmation of GW recrossing through the distal cell, KBI was performed using the same balloons (Figure 2E). Finally, IVUS in the first case and OFDI in the second case consistently showed a properly apposed LMCA stent and clear side branch ostium with no visible overhanging struts (Figure 1V and E).

DISCUSSION

A final KBI has been associated with better acute and long term results following bifurcation stenting. However, bench test results showed that, even after the KBI, stent distortion and malapposition still occur with all stent designs and with all bifurcation strategies, that may potentiate stent thrombosis, as a result of disturbed flow around the unopposed and floating non-endothelialized struts. These findings however, could only be disclosed by either IVUS or optical coherence tomography (OCT). Tyczynski et al. showed that OCT depicts 42.9% of strut malapposition that occur in the bifurcation sub-segment, most frequently close to the ostia of the side branch. Moreover, patients who were treated using OCT-guided SB recrossing had a significantly lower number of malapposed stent struts.

In our two patients, both IVUS and OFDI effectively and clearly depicted the malapposed segment of the LM stent and the protruded proximal strut inside the ostium of the SB, despite the excellent angiographic results. Given the limitations of OFDI (availability, cost and increased contrast use), we believe that both tools are extremely helpful during complex PCI procedures. This is particularly apparent following LMCA, as floating non-endothelialized struts inside the mainstream of the vessel would lead to flow disturbance with a higher risk of devastating stent thrombosis which may lead to sudden cardiac death. Therefore, operators should be attentive to detect these potentially risky events, especially during LMCA interventions regardless of the angiographic results.

On the other hand, a KBI can provide optimal SB scaffolding when care is taken to properly rewire the SB following main vessel stenting. Moreover, bench testing has shown that a wire crossing through the cell closest to the carina provides better scaffolding than a proximal crossing. Therefore, in the described cases, proximal stent malapposition and protrusion of the proximal strut towards the ostium of the SB might occur as a result of inappropriate site designation for KBI following GW crossing through non-distal stent cell. Thus, operators should check the appropriate GW recrossing site to achieve the optimum KBI results. However, deliberate GW recrossing through the distal stent cell remains technically difficult, even for experienced operators. Therefore, a specifically designed double lumen microcatheter (Crusade) can be beneficially utilized to facilitate re-wiring through the deployed MV stent, and hopefully point to the appropriate recrossing cell. In addition, when stent distortion and floating strut inside the SB ostium was detected by IVUS or OCT as a result of balloon angioplasty through the proximal cell, the Crusade microcatheter could assist the interventionalist to rewire into the distal cell of the stent thus ensuring the proper SB ostial scaffoldings and preventing stent malapposition.

Operators usually have limited control over the GW recrossing site, and they often focus on rewireing the SB

**Figure 2.** Distal cell Re-crossing (Novel Technique). (A) Using a Crusade catheter, The new guidewire (GW) (blue color) was negotiated while keeping its tip continuously touching the carina of the bifurcation and keeping the previously placed side branch (SB) wire (green color) in place. (B) Once the new GW is capturing the ostium, the Crusade catheter is slid towards the SB ostium. (Blue color). (C) If the catheter moves freely, it suggests that the guidewire has crossed through the same stent cell. (D) Any resistance suggests that it is catching in the distal stent cell close to the carina, and the floating struts have trapped the microcatheter from further advancement. (E) Final kissing balloon technique through the proximal stent cell. (F) Final image with widely patent SB ostium.
regardless of where they should recross. Different SB re-wiring techniques have been previously described.8,9 However, to the best of our knowledge, a special technique for selective distal cell recrossing has not been reported. Most recently, Okamura et al.,10 utilized specifically designed offline three-dimensional OCT software to re-direct the side branch GW towards the distal cell of the jailed main vessel strut. They showed that 3-D OCT may help to achieve distal rewiring and favourable stent positioning against the side branch ostium, leading to reduction in stent malapposition. In contrast, the presented technique is simple, practical and does not need special skills. In addition, its favorable results were immediately obtained following kissing balloon angioplasty through the distal stent cell in spite of using the same balloons. These optimized results were consistently confirmed by IVUS in the first case and OFDI in the second case. Therefore, obtaining a favorable result after bifurcation stenting may depend on the kissing site, and it would be better for the operators to cognitively select where they should kiss. Furthermore, even for those who aim only for the SB rewiring and in non-LMCA bifurcation lesions, we found that this double lumen microcatheter was helpful for this purpose even for the extremely angulated SB.

Nevertheless, we found that the markers of anticipated success were, the tactile sensation of resistance during the microcatheter advancement with a subsequent backward movement of the guiding catheter, disengaging it from the coronary ostium. Therefore, the clinical implication of the introduced technique is that it reliably helps operators to manipulate the second wire to pass through the proper cell with knowledge of the jailing configuration. Moreover, when both the distal re-wiring and favorable strut configuration are achieved, SB dilatation can reduce the floating struts, ensuring optimal result after kissing balloon angioplasty. However, due to the limited number of patients studied, it remains unclear whether this technique is appropriate for all bifurcation lesions with different technical complexities and different takeoff angles. In fact, 8 to 10 cases have been successfully done using the described technique, with the 3- and 8-month clinical and angiographic follow up benchmarks reached with no adverse events noted. Nevertheless, whether the introduced technique really makes better outcome remains in doubt, and further robust clinical experiences and follow-up of the performed cases are warranted.

In summary, the presented cases highlighted the effective role of the intracoronary imaging tools (IVUS and OCT) in optimizing the final kissing balloon results; and the double lumen microcatheter (Crusade) could helpfully assist GW recrossing through the distal stent strut, hence optimizes the SB ostial scaffolding.

CONFLICT OF INTEREST

The authors report no conflicts of interest regarding the content herein.

REFERENCES


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