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Editorial

Three-dimensional reconstruction of optical coherence tomography for improving bifurcation stenting

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Coronary bifurcation lesions are encountered in approximately 15–20% of all percutaneous coronary interventions (PCIs) [1]. Bifurcation PCI has historically been associated with lower procedural success rates and higher long-term adverse event rates compared with PCI for non-bifurcation lesions. In the drug-eluting stent (DES) era, the clinical outcomes for bifurcation PCI have improved considerably [2]. However, bifurcation stenting is still technically challenging and associated with an increased risk of stent thrombosis [3]. The conventional coronary stent is a small mesh-patterned tube, usually linear in shape. To adapt the DES for morphological variation of bifurcation, various techniques have been developed [4]. Although a simple single stent technique has been generally recommended, a complex technique is occasionally required. However, it is not clear which technique is appropriate for each bifurcation lesion. Moreover, even when angiographic results after stent implantation are satisfactory at a glance, unapposed struts, which can potentially cause stent thrombosis, are unobservable with angiography and poorly visible with intravascular ultrasound (IVUS). In order to elucidate such interaction between stent and vessel wall in bifurcation stenting, many bench tests and computer simulations have been performed and useful findings have been reported. However, we could not understand them during procedures in each case.

Intravascular optical coherence tomography (OCT) is a light-based imaging modality, which provides high-resolution images of the coronary arteries. With its unrivaled high resolution (10–15 μm) compared with IVUS (100–150 μm), OCT can evaluate the interaction between the coronary artery and the implanted stent. Viceconte et al. reported that unapposed struts at side branch ostium were frequently observed after bifurcation stenting and that the prevalence of unapposed struts in a two stent technique was significantly greater than that in a single stent technique [5]. Recently developed optical frequency domain imaging (OFDI) and Fourier/frequency-domain OCT (FD-OCT) systems can obtain cross-sectional OCT images of the coronary artery at much faster frame rates and pullback speeds than previously possible. Thus, three-dimensional (3D) reconstruction of OCT/OFDI pullback has become available without motion artifact. The first publication regarding clinical application of 3D-OCT/OFDI was reported by Tearney et al. [6]. They showed the 3D-OFDI image of human coronary arteries with tissue characterization and visualization of a metallic stent.

For bifurcation, there is difficulty in fully understanding its complex anatomy and the interaction between an implanted stent and the vessel wall by angiography and/or 2D imaging alone. For example, how an implanted stent is jailing the side branch ostium, where the second guidewire crosses into the side branch, or how a stent is distorted after side branch dilatation. 3D reconstruction of OCT/OFDI images facilitates the understanding of these questions [7]. The ILUMIEN OPTIS™ FD-OCT system (St. Jude Medical, St Paul, MN, USA) is equipped with a 3D rendering package. This instant 3D reconstruction can provide two types of 3D view (lumen view or navigation view) immediately after OCT acquisition. Lumen view shows the volumetric reconstruction of lumen, similar to 3D angiography. Thus, it facilitates the understanding of the overall bifurcation anatomy and luminal narrowing. Previous bench tests demonstrated that stent distortion developed after side branch dilation. However, subsequent kissing balloon inflation resolved the distortion. The present case report by Koiwaya [8] showed that instant 3D reconstruction of lumen derived by OCT pullback was useful to recognize this phenomenon during procedures. They deployed the DES crossing over the left circumflex (LCx) coronary artery to treat the severe stenosis of the proximal left anterior descending (LAD) coronary artery. After dilation of LCx, a cross-sectional OCT and its instant 3D reconstruction clearly revealed stent distortion with malapposed struts at the opposite site of side branch ostium. Furthermore, kissing balloon inflation resolved the stent distortion with the disappearance of the stent malapposition. They confirmed these phenomena with a contrast between OCT and macroscopic images in the coronary bifurcation model. Instant 3D reconstruction of OCT may be useful to optimize bifurcation treatment. However, 3D reconstruction of intracoronary imaging differs from the real structure as it centers on the catheter pathway within the coronary artery. When a vessel is tortuous or angulated, 3D images are also distorted. Further studies are necessary to investigate whether it is consistently useful for treatment of other bifurcation lesions.

Another potential utility of 3D-OCT/OFDI is the evaluation of overhanging struts in front of side branch orifice after crossover stenting, which is completely missed by angiography and even IVUS. Serial change of overhanging bioresorbable scaffold in front of

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diagonal branch was assessed by 3D reconstruction of OCT images obtained from the main vessel. In this case, overhanging scaffolds were resorbed and a membranous new carina was created at 2 years after the index procedure [9]. Foin et al. demonstrated by 3D-OCT that a thick rim of neointimal proliferation can develop at the ostium of side branches jailed by bare-metal stent [10]. Moreover, we showed the same phenomenon at the side branch ostium after sirolimus-eluting stent (Cypher; Cordis, Johnson&Johnson, Miami, FL, USA) implantation [11]. These reports suggest that deployment of a stent in a bifurcation main branch without opening the struts at the side branch ostium may facilitate focal restenosis.

Another application of 3D-OCT/OFDI is the guidance of rewiring the side branch. Before side branch dilatation, the distal rewiring through the jailing struts is recommended. Confirmation of distal rewiring by 2D OCT can reduce incomplete apposition at side branch orifice after kissing balloon inflation significantly in comparison with angio-guidance [12]. However, it is difficult to recognize the rewiring position with only 2D OCT. We evaluated the feasibility of using off-line 3D OCT reconstruction during a PCI procedure to confirm the rewiring position in 22 cases [13]. After OCT acquisition, raw data were transferred to the off-line workstation, where automatic stent strut detection and enhancement were performed. A 3D OCT reconstruction was completed within 10 min. The assessment of the side branch ostium by off-line 3D OCT was feasible in all but four cases, in which guidewire shadow artifacts, severe motion artifacts, or the presence of intraluminal thrombus prevented assessment. In 14 of the remaining 18 cases (77.8%), it was confirmed with off-line 3D OCT that the guidewire successfully passed through the most distal cell under the fluoroscopy. Second attempts were needed in three cases to take an optimal cell. According to the 3D assessment, malapposition in bifurcation lesions was influenced not only by the recrossing position of the guidewire, but also by the configuration of the jailing struts. More specifically, the presence of a longitudinal link between the crowns at the ostium was associated with more frequent malapposition compared to the cases without a longitudinal link. The study demonstrated the feasibility of 3D OCT imaging guidance during the procedures, but it should be noted that the 3D reconstruction was still conducted off-line.

Although it is considered that residual struts at side branch orifice and the accumulation of incomplete stent apposition could potentially cause adverse events, no definitive evidence that 3D-OCT/OFDI guidance improves clinical outcomes has been reported. However, we occasionally encounter the situation in which antiplatelet therapy must be discontinued due to unexpected surgical operation or bleeding complications. In this situation, if optimal bifurcation stenting (no stent deformation or distortion, sufficient stent expansion and no incomplete stent apposition) was performed under 3D-OCT/OFDI guidance, there might be less risk for stent thrombosis. Recently, a 3D reconstruction with automatic strut detection system has been released on the Terumo OFDI console (Terumo, Tokyo, Japan), and St. Jude Medical 3D reconstruction software will be upgraded to detect stent struts in the near future. These systems allow for observation of stent deformation or rewiring position immediately after OCT/OFDI acquisition during the PCI procedure. Clinical studies that investigate the usefulness of 3D-OCT/OFDI guidance for improving patient outcomes will be warranted.

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Takayuki Okamura (MD)*
Tatsuhiro Fujimura (MD)
Masafumi Yano (MD, FJCC)
Division of Cardiology, Department of Medicine and Clinical Science, Yamaguchi University Graduate School of Medicine, Ube, Japan

*Corresponding author at: 1-1-1 Minami-kogushi, Ube, Yamaguchi 755-8505, Japan. Tel.: +81 836 22 2248; fax: +81 836 22 2246
E-mail address: t-okamu@yamaguchi-u.ac.jp (T. Okamura).

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