Beyond Stent Sizing and Optimization: Update of Clinical Optical Coherence Tomography for PCI – A Review Article

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Abstract

Compared to intravascular ultrasound (IVUS), optical coherence tomography (OCT) offers higher resolution, clearer definition of plaque character and neointima imaging, along with the capability of calcification penetration. Hence OCT guidance offers some advantages for the management of certain specific lesions, such as intermediate lesions, acute coronary syndrome, in-stent restenosis, calcified lesions, and bifurcation lesions. In this review article, we focus on clinical OCT application for the above lesions.

Keywords: optical coherence tomography, intermediate lesions, acute coronary syndrome, in-stent restenosis, calcified lesions, bifurcation

Introduction

Optical coherence tomography (OCT) is an intra-coronary imaging technique which can provide high resolution cross-sectional images of the coronary artery and is used to guide percutaneous intervention (PCI). PCI planning, selection of stent landing site and stent sizing become much easier and better with detailed vessel information, such as plaque characterization, lesion length and lumen diameter, as provided by OCT (Figure 1). Suboptimal stent deployment, which is associated with an increased risk of major cardiovascular event (MACE),[1] can also be detected and avoided (Figure 2). Many randomized controlled trials have revealed the superiority of OCT-guided- over angiography-guided PCI,[2,3] and the non-inferiority of OCT-guided- vs. intravascular ultrasound (IVUS) guided PCI.[4,5] Furthermore, recent evidence suggests that OCT may be superior to IVUS for intermediate lesions, acute coronary syndrome (ACS), in-stent restenosis (ISR), calcified lesions and bifurcation lesions. In this review article, beyond stent sizing and optimization, we discuss updates regarding the above special clinical utilization of coronary OCT.

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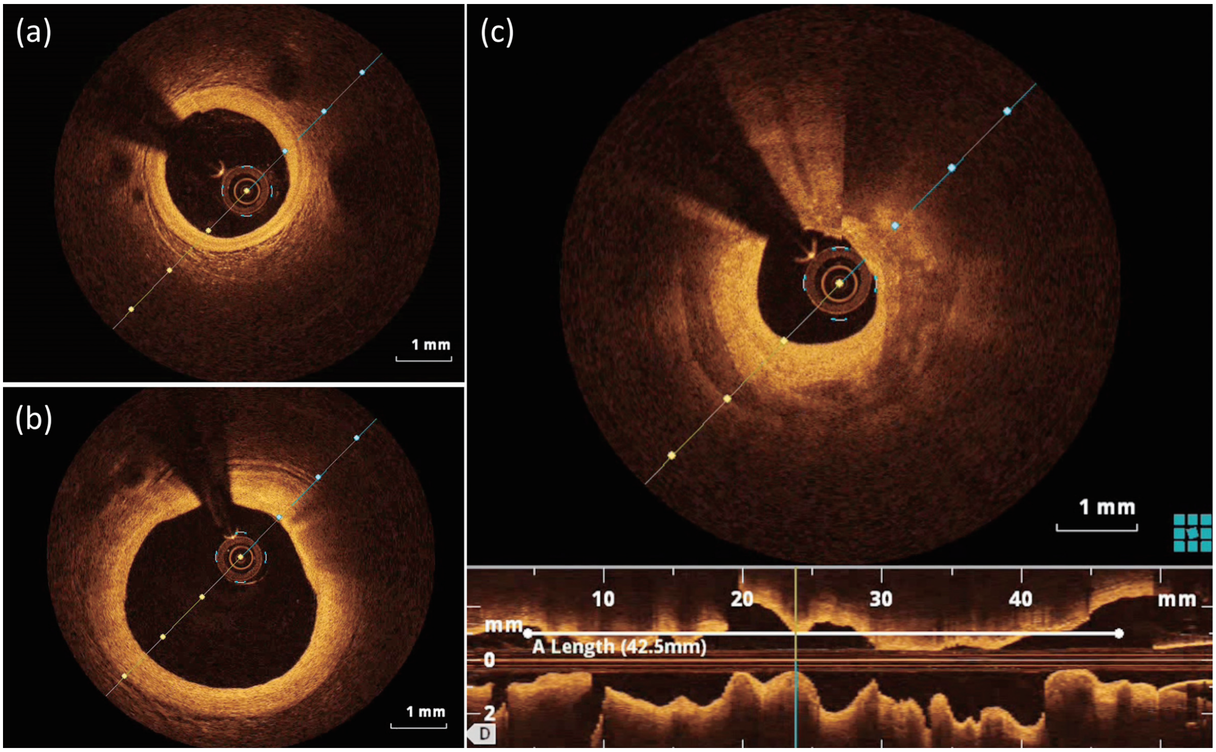

Figure 1. An example of Optical coherence tomography (OCT) guided PCI.
(a) Distal reference: a normal vessel, which was an optimal stent landing site without plaque. Mostly, stent size was chosen according to the EEL or lumen diameter of the distal reference. (b) Proximal reference: here was a suboptimal but acceptable stent landing site with relative smaller lipid arc. Risk of stent edge restenosis is lowest if stent edge segment at normal vessel, secondly at fribrous/calcified plaque(plaque burden <50%), highest at lipid plaque.[17] However, if it is not possible to avoid landing stent at lipid plaque, at least stent should be landed at lipid plaque burden <50% and arc <180°. (c) Lesion site: the characterization can be identified easily by OCT. In this case, calcified plaque with calcium angle >180° and thickness >0.5 mm were showed. Besides, stent length could be decided easily according the length from distal to proximal reference at the "long-view" of OCT.

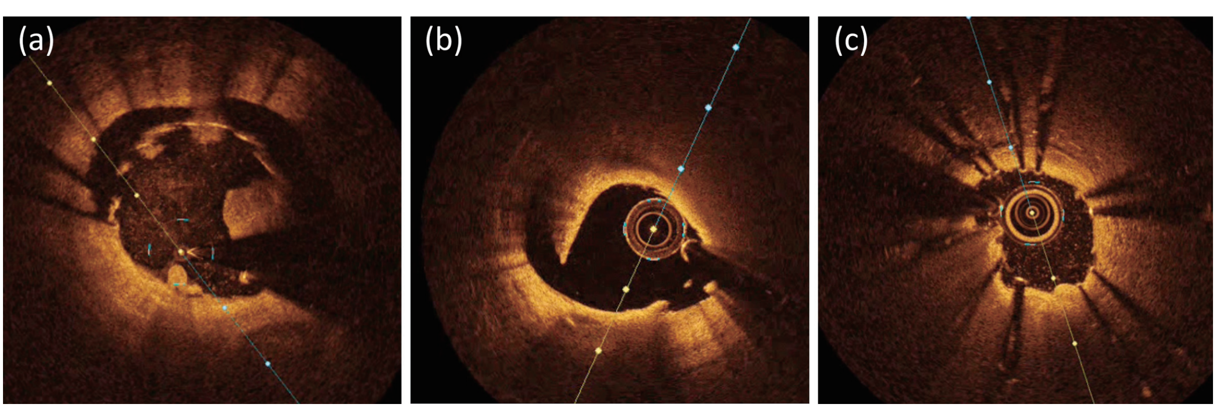

Figure 2. OCT images of suboptimal stent deployment.
(a) Stent malapposition (axial distance >0.4 mm, length >1 mm). (b) Stent edge dissection (not limited to intima, arc >60°, length >2 mm). (c) Stent under expansion (MSA <4.5 mm^2, or <80% average reference lumen area).

Intermediate lesion

For intermediate coronary lesions, fractional flow reserve (FFR) has been the worldwide accepted, undisputed gold standard to decide whether to conduct PCI or not. However, the application of adenosine, risk of vascular injury by the pressure wire and increased procedure time are of concern. Mismatches between ischemic symptoms and FFR results have also been noted in some patients.

An interesting trial, the FROZA (FFR or OCT Guidance to Revascularize Intermediate Coronary Stenosis Using Angioplasty) trial[6] by Burzotta F, et al. was published in 2020. The trial was designed as a head-to-head comparison of outcomes between OCT- (n = 174) and FFR- (n = 176) guided PCI for intermediate lesions. The PCI criteria for OCT guidance were area stenosis (AS) < 75%, or AS between 50% and 75%, with either minimal lumen area < 2.5 mm^2 or plaque rupture. Although the PCI rate, cost and total contrast amount were less in the FFR arm, MACE and significant angina at 13 months post-op were significantly reduced (8.0% vs. 14.8%; p = 0.048) in the OCT arm. It has been hypothesized that OCT can reveal the vulnerability of the intermediate lesion, which is related to adverse clinical outcomes. Additionally, target vessel failure (TVF) rate was also less common in the OCT arm (2.3% vs. 7.4% with TVF; p = 0.027). Based on the results of the FROZA trial, OCT guidance to revascularize intermediate coronary stenosis (Figure 3) could be a viable alternative choice.

Acute coronary syndrome

In acute coronary syndrome, the goal of PCI is to identify and treat the culprit lesion efficiently. However, in some acute coronary syndrome (ACS) cases, especially multi-vessel disease or non-ST elevation myocardial infarction (NSTEMI)-ACS, the culprit vessel or lesion is difficult to localize with coronary angiography and electrocardiogram only. This is where OCT assessment can play an important role in ACS. ACS is mainly attributed to three pathologic conditions: plaque rupture, plaque erosion or calcified nodule[7] with thrombus formation and blood stasis (Figure 4), requiring different treatment for each condition. Due to the high resolution of OCT (about 10 times that of IVUS), the location and morphology of the culprit lesion can be identified easily and accurately.

In a 3-vessel OCT study,[8] Koji Kato et al. found that the vulnerability of non-culprit lesions is higher in patients with ACS than in those without ACS. Under OCT imaging, these hidden, vulnerable and relatively vulnerable plaques can be precisely located and identified (Figure 5). The risk of slow flow, no flow, peri-procedural myocardial infarction and recurrent MI could be decreased if existence and location of unstable lesions are identified before undertaking culprit or non-culprit lesion PCI.

In-stent restenosis

OCT appears to be effective for evaluating neointima of in-stent restenosis (ISR). Previous ex-vivo histopathology studies have reported that neointimal tissue morphologies can be characterized well with OCT.[9] Briefly, the character of neointima can be classified into 3 types: homogeneous, heterogeneous and layered (Figure 6). The homogeneous type is composed of smooth muscle cells with collagen fibers. The composition of the heterogeneous type is proteoglycan-rich myxomatous matrix and calcium deposition. The layered type is similar to neo-atherosclerosis and composed of foam cell accumulation or large fibro-atheroma/necrotic core.

More importantly, Takeshi Tada, et al. reported that different types of neointima showed different responses to PCI.[10] Homogeneous type ISR (high backscatter and non-lipid rich) respond most favorably to paclitaxel-coated balloon (PCB) dilatation, compared with POBA. Based on re-ISR and target lesion revascularization (TLR)

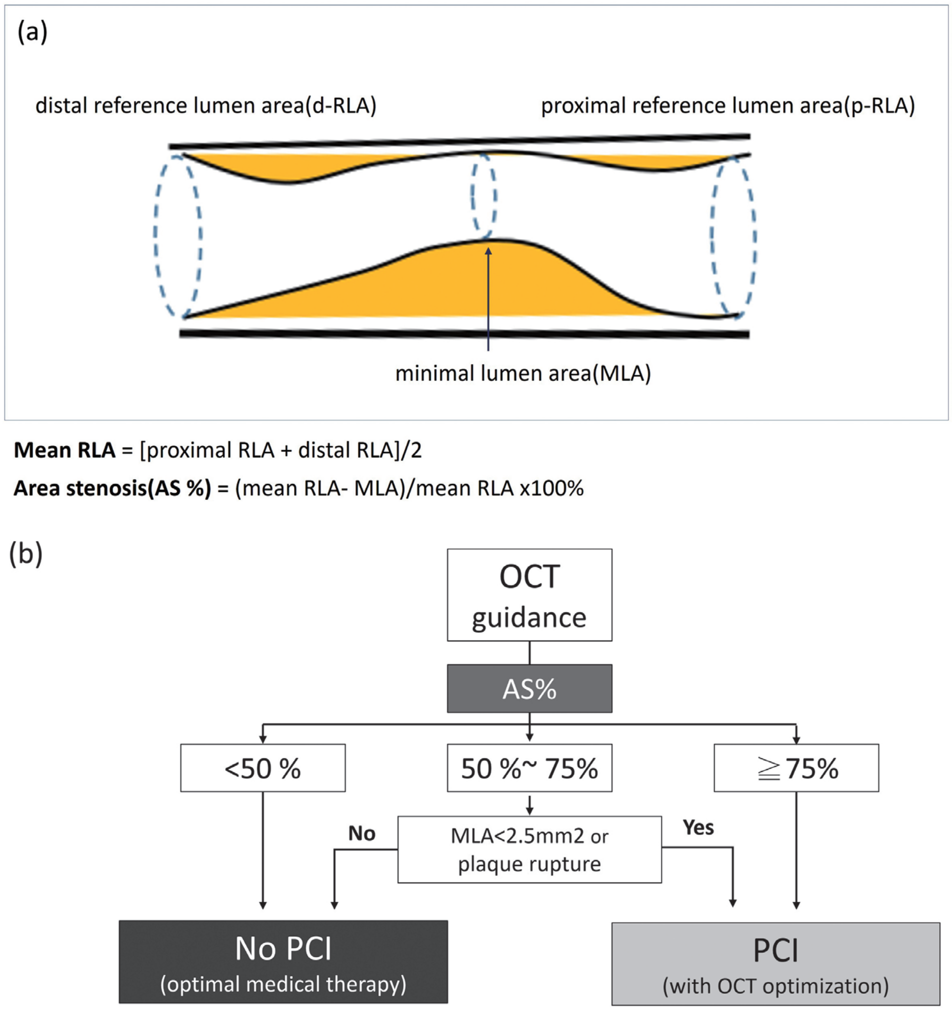

Figure 3. OCT guided management of angiographically intermediate lesion.
(a) Measurement of area stenosis %. (b) Flowchart of OCT guidance for intermediate lesion.

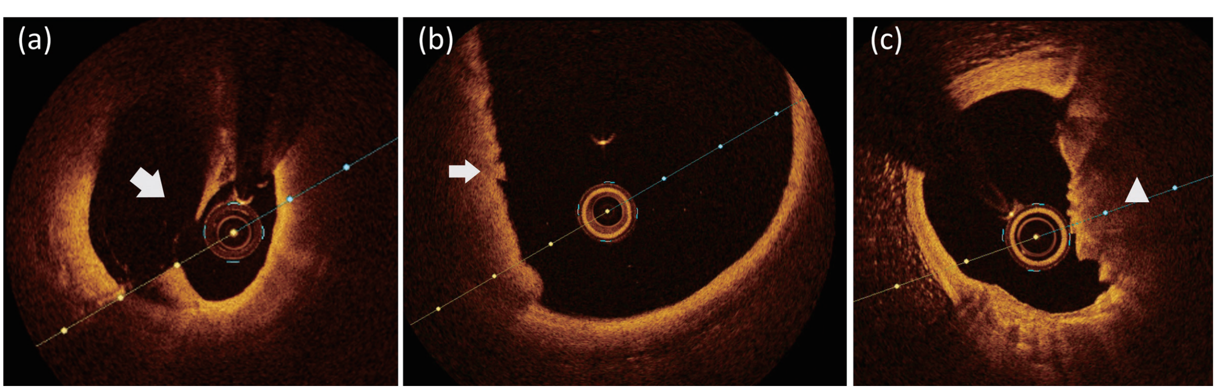

Figure 4. OCT images of ACS.
(a) Plaque rupture. (b) Plaque erosion with some white thrombus on the irregular luminal surface. (c) Calcified nodule.

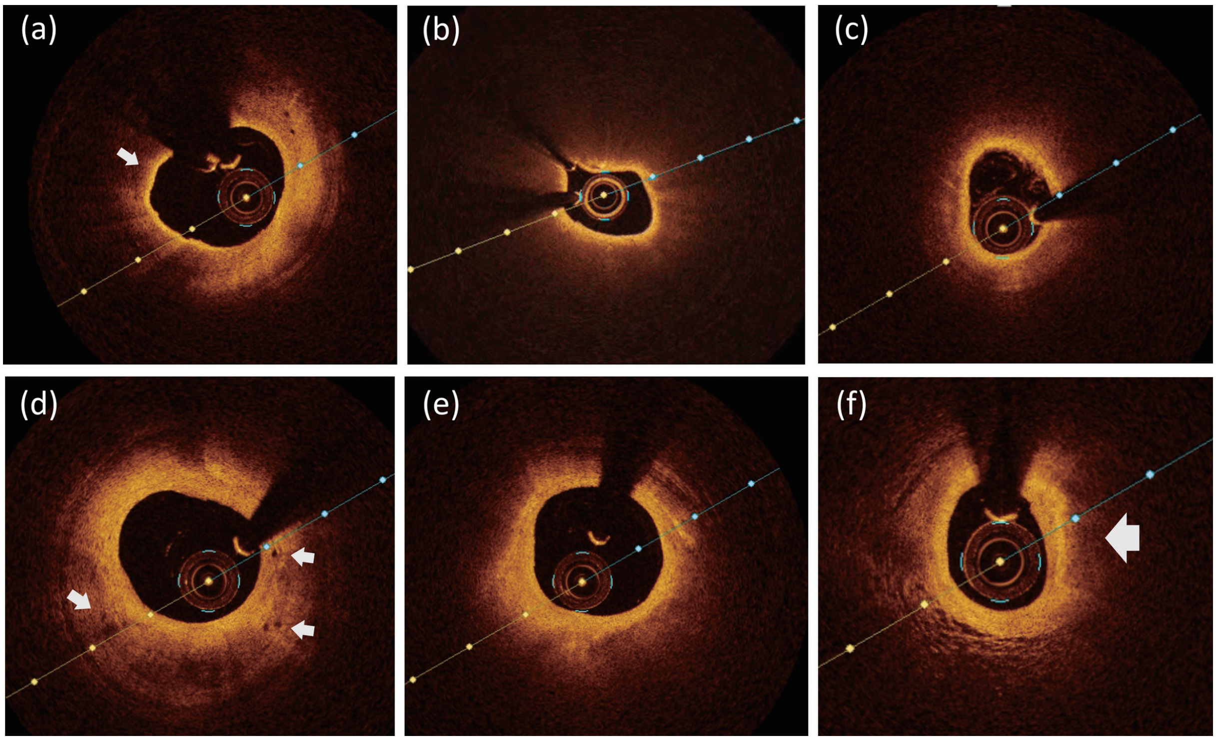

Figure 5. Vulnerable OCT characters.
(a) Thin-cap fbroatheroma (TCFA) with thin fibrous cap (<65 μm). (b) TCFA with a large necrotic core. (c) Large lipid pool. (d) neoangiogenesis (vasa vasorum). (e) Lipid plaque with activated macrophages (bright spots in fibrous cap with black-tail). (f) Cholesterol crystal.

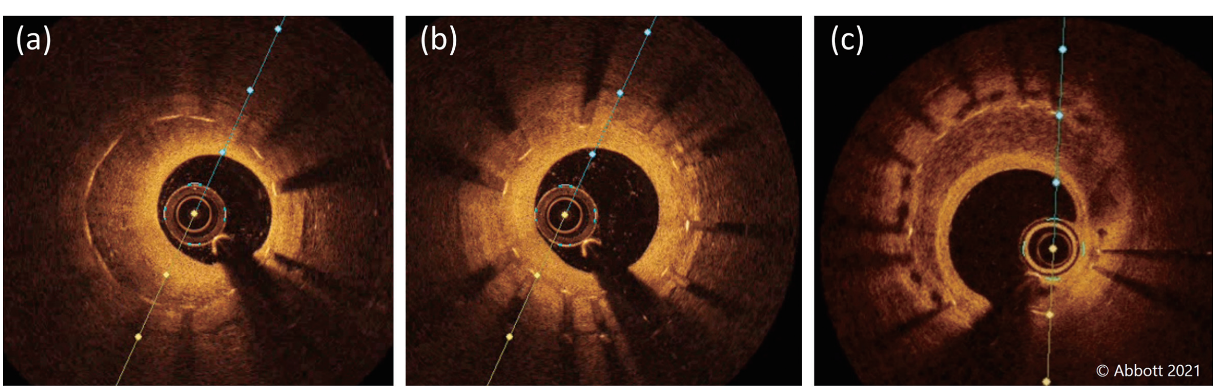

Figure 6. Major types of neointima.
(a) Layered type(with attenuation). (b) Homogeneous type. (c) Heterogeneous type (without attenuation).

rates, PCB dilatation also has a similar effect to the above drug-eluting stent (DES) implantation in homogeneous type ISR. For heterogeneous type ISR, although different treatments showed no statistically significant difference in re-ISR and TLR rates, the efficacy of POBA and DES does seem to be better than PCB. In layered-type ISR, re-ISR and TLR rates were significantly higher in the POBA group than in the DES and PCB group. As stated above, OCT imaging of ISR morphology is indeed necessary for decision-making when treating ISR. Based on the OCT assessment, we can choose the most appropriate PCI type for the patient.

Calcified lesions

For calcified lesions, especially superficial calcified lesions, the greatest advantage of OCT is the capability of calcification penetration. Because ultrasound signals are reflected by calcification, the morphology behind the calcium cannot be assessed with IVUS. Recently, a novel and reliable IVUS calcium score has been developed,[11] which can help to predict stent expansion with IVUS. (The IVUS Ca score covers 4 items: arc > 270˚ with lesion length > 5 mm, 360˚ calcification, calcified nodule and vessel diameter < 3.5 mm. If the IVUS Ca score is more than 2 points, the risk of stent under-expansion increases.) However, it would be more convenient to have OCT evaluation when dealing with calcified lesions because it allows easy assessment of the diameter of the external elastic membrane and calcification thickness. Additionally, rotablation atherectomy (RA) is a useful, commonly used tool for calcified lesions, and Norihiro Kobayashi et al. found that OCT-guided RA for calcified coronary lesions resulted in a larger percent stent expansion, compared to IVUS-guided RA.[12]

By current evidence, OCT can reveal detailed calcium and vessel characteristics. Hence we can follow the steps below to manage calcified lesions with OCT. First, after pre-procedural OCT evaluation, stent expansion can be predicted based on OCT calcium score[13] (Figure 7). Second, if lesion modification is indicated, the size of the rotablation burr can be precisely determined based on the true vessel size (burr-to-artery ratio of 0.4-0.6).[14] Third, after RA, OCT is an ideal method to determine the endpoint of RA before stent implantation. Based on residual calcium thickness, the need for burr up-sizing and the final burr size can be recognized. Maejima et al. reported an OCT trial wherein calcium fracture by balloon angioplasty was facilitated if residual calcium thickness <670 μm and calcium arc > 227° after RA.[15]

Bifurcation lesions

Intra-coronary imaging, by both IVUS and OCT, is indispensable for guiding coronary bifurcation intervention. The interventionist is unlikely to be able to understand lesion distribution, accurately size or check the positioning of stents in bifurcation lesions under angiography guidance only. The advantages of

Maximum Calcium angle >180˚	**2 points**
Calcium length > 5 mm	**1 point**
Maximum calcium thickness > 0.5mm	**1 point**
4 points → Poor stent expansion	

Figure 7. OCT-based calcium score.

OCT-guided bifurcation PCI are the ability to predict side branch compromise (SBC), reduce incomplete stent apposition, and facilitate wire re-crossing.

While doing main vessel provisional stenting, SBC (due to plaque or carina shift) is a serious complication that should be avoided. After pullback from the main vessel, SBC risk is expected to be high if there is a narrow carina tip angle (< 50°) and a short length from the proximal branching point to the carina tip (< 1.7 mm) under the L-mode view of OCT (Figure 8).[16] Based on this useful OCT predictor, jailed balloon technique or 2 stent strategy can be considered to avoid complications when there is a high probability of SBC.

Furthermore, although evidence of better clinical outcomes is still lacking, given the high-resolution and 3-dimensional mode of OCT, incomplete stent apposition and proximal cell wire re-crossing after provisional stenting can be avoided with OCT-guided bifurcation PCI. The stent strut and location of the guidewire can be seen clearly with OCT (Figure 9).

Conclusion

OCT is an ideal tool to guide PCI and is especially useful for intermediate lesions, acute coronary syndrome, in-stent restenosis, calcified lesions and bifurcation lesions. Last but not least, although it is basic and not emphasized in this review article, stent optimization remains very important and outcome-related when performing OCT-guided PCI.

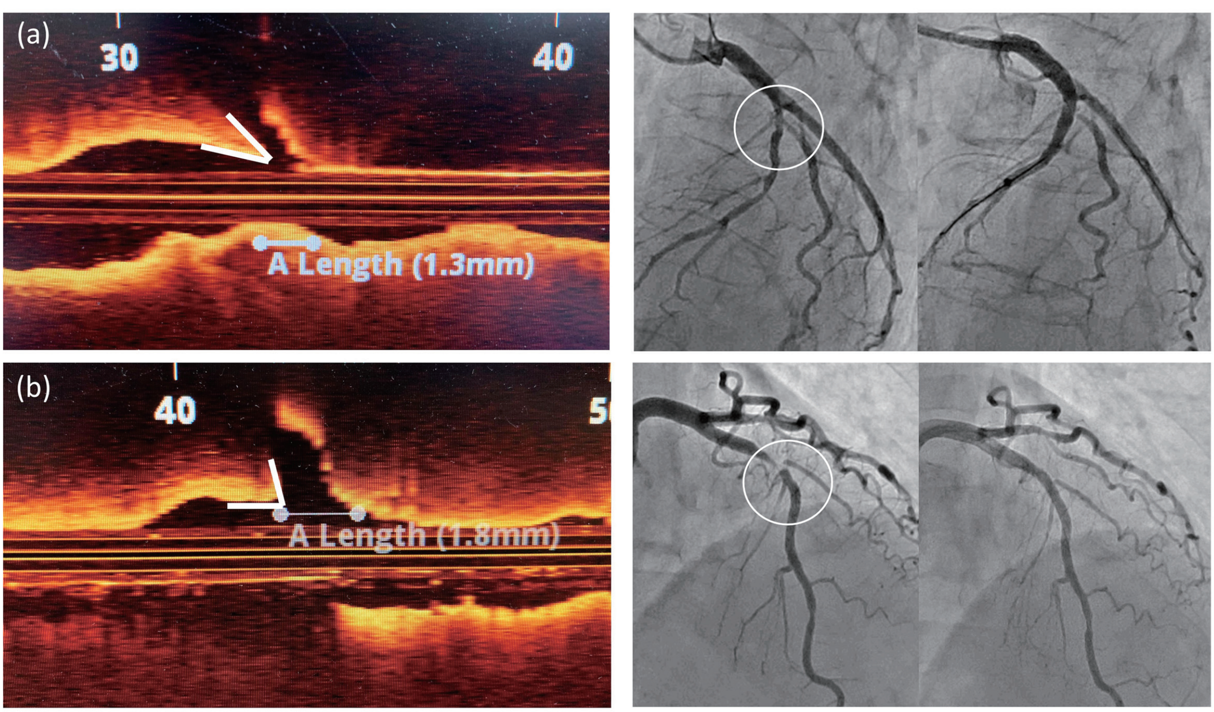

Figure 8. Case sharing- to predict side branch compromise (SBC) with OCT.
(a) In this case, carina tip angle <50° and length from the proximal branching point to the carina tip <1.7 mm. SBC with TIMI 2 flow was noted after stenting. (b) In another case, carina tip angle >50° and length from the proximal branching point to the carina tip >1.7 mm. No SBC with TIMI 3 flow was noted after stenting.

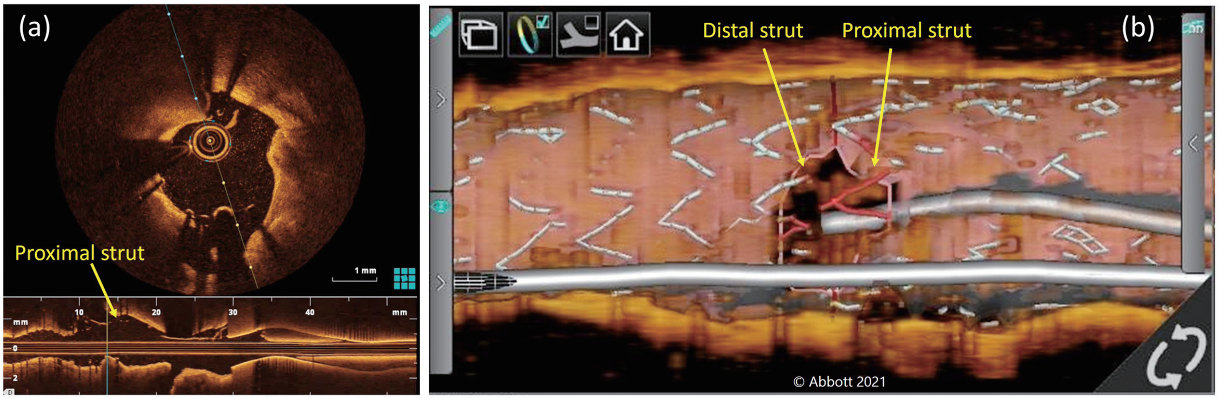

Figure 9. OCT assisted wire re-cross.
(a) Proximal cell wire re-cross was revealed by 2D OCT. (b) In another case, wire re-cross through the proximal strut was showed clearly by 3D OCT.

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