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Optical coherence tomography is a kid on the block: I would choose intravascular ultrasound

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ABSTRACT

Intravascular imaging has improved our understanding of in vivo pathophysiology of coronary artery disease (CAD) and predicted decision-making in percutaneous coronary intervention (PCI). Intravascular ultrasound (IVUS) has emerged as the first clinical imaging method contributing significantly to modern PCI techniques. This modality has outlived many other intravascular techniques 26 years after its inception. It has assisted us in understanding dynamics of atherosclerosis and provides several unique insights into plaque burden, remodeling, and restenosis. It is useful as an imaging endpoint in large progression-regression trial and as workhorse in many catheterization laboratories. IVUS guidance appears to be most beneficial in complex lesion subsets that are being treated with drug-eluting stents. The recent introduction of optical coherence tomography (OCT), a light based imaging technique, has further expanded this field because of its higher resolution and faster image acquisition. The omnipresence of OCT raises the question: Does IVUS have a role in the era of OCT? Whether OCT is superior to IVUS in routine clinical practice? Even if OCT is currently gaining clinical significance in detailed planning of interventional strategies and stent optimization in complex lesion subsets, it is the much younger technique and has to prove its worth. Nevertheless, undoubtedly IVUS plays significant role in studies on coronary atherosclerosis and for guidance of PCI. In fact, both the methods are complementary rather than competitive.

1. Introduction

More than 26 years after its inception, intravascular ultrasound (IVUS) is still alive and has outlived many intravascular techniques. IVUS has played a pivotal role in understanding the pathophysiology of coronary atherosclerosis and has facilitated the refinement of diagnostic and therapeutic strategies.[1] It assists in understanding of the dynamics of atherosclerosis because of its capability to depict the arterial wall and lumen of the coronary arteries across the full 360° circumference of the vessel. It is not only an established imaging endpoint in progression-regression trials, but also an important workhorse in many catheterization laboratories across the globe. The advent of drug-eluting stents (DES) expands the horizon of complex percutaneous coronary intervention (PCI) where in application of IVUS could be useful. Recently, the introduction of optical coherence tomography (OCT) with better resolution allows for increased ability to visualize vessel wall, characterize plaque, and assist with opimization of coronary stenting with short-and long-term follow up. The omnipresence of OCT questions if IVUS has a future in OCT era.

2. Plaque characterization

Arterial morphology could be better delineated by OCT due to its superior resolution (Table 1). OCT is more accurate than IVUS in measuring intima media thickness, intimal hyperplasia, and external and internal elastic lamina.[2,3] But it lacks depth of penetration to visualize the external elastic lamina in the presence of heavy plaque burden.[4] Plaque burden, an important predictor of clinical outcome, is more readily quantified with IVUS.

Newer applications such as integrated backscatter, wavelet analysis, and virtual histology, currently allow IVUS to characterize plaques as lipid, fibrous tissue, calcification, or necrotic core with high accuracy.[5–9] Because of its ability to visualize plaque microstructures and tissue adjacent to calcium, OCT is superior to both grayscale and radiofrequency IVUS in characterizing plaque.[10] This superiority is apparent while identifying lipid-rich plaques. However, full visualization of large plaques is precluded because of its limited depth of penetration (Fig. 1). IVUS, however, can accurately quantify large lipid pool and see the entire vessel wall, even in presence of large plaque burden.[4,11]

3. Plaque vulnerabilty

Identification of vulnerable plaque has emerged as a potential tool in preventing acute coronary syndromes. Pathologically vulnerable plaque has been characterized as hypocellular, lipid rich with necrotic core, and covered by a thin cap (<65 um). OCT is superior to IVUS in identifying features of vulnerability for plaque rupture including thin fibrous caps (Fig. 2), large lipid cores (Fig. 2), microchannels, macrophage infiltration, superficial spotty calcification, and cholesterol crystals.[2,12] It can visualize and qualify intracoronary thrombus as white or red.[4] OCT may misinterpret signal-poor regions in the deeper vessel wall as necrotic core that may can label plaque falsely as vulnerable.[13] It can interpret mural thrombi as lipid-rich fibroatheroma, due to smaller OCT single attenuation patterns produced by these two plaque components.

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Table 1
Comparative technical summary of Intravascular Ultrasound (IVUS) and Optical Coherence Tomography (OCT).

	OCT	IVUS
Technology	Near-infrared	Ultrasound
Axial resolution (um)	10–20	100–200
Lateral resolution (um)	20–90	200–300
Frame rate (frame per second)	100	30
Pull-back speed (mm/s)	1–20	0.5–1.0
Rotation speed (Hz)	16–160	30
Scan diameter-field of view(mm)	7–11	15
Tissue penetration (mm)	1–3	10
Image through blood field	No	Yes
Blood removal with contrast	Yes	No
Catheter size	3.2 Fr	3.5 Fr
Wavelength	10–40 MHz	1.3 um

Due to its depth of resolution, IVUS can assess plaque burden and vessel remodeling, whereas OCT cannot.[13]

4. Vessel sizing

Due to shallow penetration of OCT, there may be a limit in the detail of the whole vessel structure visualized as compared to IVUS imaging.[14] OCT measured reference lumen diameters are almost identical to those measured with IVUS.[15] OCT derived minimal lumen area (MLA) is smaller than IVUS.

5. Optimisation of PCI

OCT allows detailed evaluation of stent apposition and expansion. It detects stent edge dissection, tissue protrusion and incomplete stent apposition that may not be visualized by IVUS (Table 2).[15,16] Although, long-term clinical implications of these findings are unclear, the ability to visualize clearly these phenomena will motivate the researchers further to conduct more large, long-term prospective trials to study their impact on clinical outcomes.

6. Neointimal coverage

Strut coverage is an important surrogate risk factor for stent thrombosis. Most DES appeared uncovered by neointima in IVUS examination. The thickness and extent of neointimal coverage are difficult to be delineated by IVUS due to limited resolution. On the other hand, OCT clearly demonstrates both the coverage of individual struts and thickness of neointimal coverage (Table 2).[17] Unlike IVUS, OCT can also be used for qualitative assessment of neointimal coverage (to determine if it is homogenous, heterogeneous, or layered)[18] which could improve the understanding of the mechanism of in-stent restenosis. Histological validation of these measurements remains to be performed, and the long- term prognostic implications are unknown.

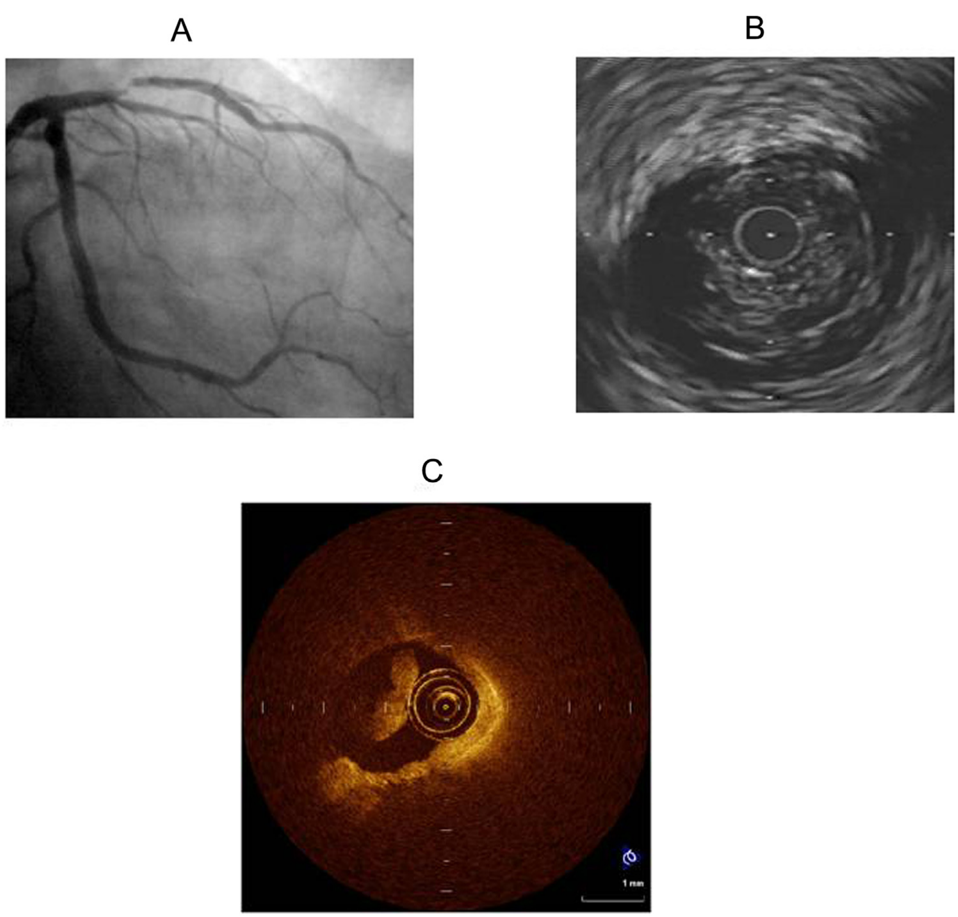

Fig. 1. A) 43 year old gentleman with non ST-elevation myocardial infarction depicting significant lesion in mid segment of left anterior descending artery. B) Suspicion of thrombus in IVUS intrrogation. C) Clearly visible thrombus in OCT that precludes plaque characterization.

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