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Review Article

Application of Intravascular Ultrasound in the Era of Optical Coherence Tomography

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Abstract

Intravascular imaging has advanced our understanding of in vivo path physiology 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 25 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.

Keywords: *Intravascular ultrasound; Optical coherence tomography; Coronary atherosclerosis; Progression-regression; Drug-eluting stent; Vulnerable plaque; Biodegradable vascular scaffold*

Introduction

More than 25 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 path physiology 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 optimization of coronary stenting with short-and long-term follow up. The omnipresence of OCT questions if IVUS has a future in OCT era.

Plaque Characterization

Arterial morphology could be better delineated by OCT due to its superior resolution. OCT is more accurate than IVUS in measuring intima media thickness, intimal hyperplasia, and external and internal elastic lamina [2,3]. OCT and not IVUS 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 micro-structures and tissue adjacent to calcium, OCT is superior to both grayscale and radiofrequency IVUS in characterizing plaque [10]. Full visualization of large plaques is precluded because of its limited depth of penetration (Figure 1). IVUS, however, can accurately quantify large lipid pool and see the entire vessel wall, even in presence of large plaque burden [4,11].

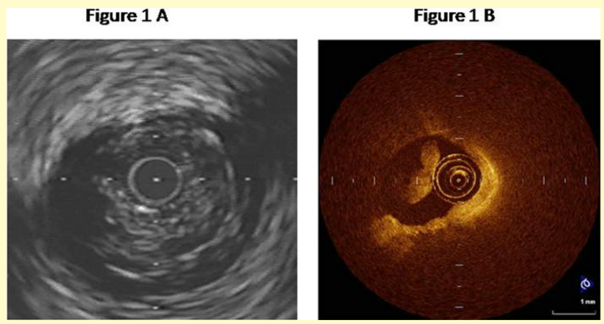

Figure 1: *(A): Suspicion of thrombus in IVUS (B): Clearly visible thrombus in OCT that precludes plaque characterization*

OCT is superior to IVUS in visualizing thin fibrous cap and its composition influencing cap stability [2,12]. It can visualize and qualify intracoronary thrombus as white or red [4]. Due to its depth of resolution, IVUS can assess plaque burden and vessel remodeling (component of vulnerability), whereas OCT cannot [13].

Vessel Size

Due to limited penetration, OCT cannot detail the whole vessel structure as compared to IVUS [14]. OCT measured reference lumen diameters are almost identical to those measured with IVUS [15].

Optimization 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 [15,16].

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 [17]. Unlike IVUS OCT can also be used for qualitative assessment of neointimal coverage (to determine if it is homogenous, heterogenous, or layered) [18].

Biodegradable Vascular Scaffold (BVS)

Because of translucency and radioluceny, visualization of BVS is difficult with traditional imaging modalities. OCT has the potential to quantitatively assess strut thickness and biodegradation making it an ideal imaging modality for monitoring these stents. This modality precisely characterizes stent apposition and strut coverage and demonstrates structural changes in the bioresorbable DES over time [19].

Future of IVUS in OCT era

OCT-"the new kid on the block"- still has to prove its value. Because of shallower penetration, OCT may not be able to visualize the whole vessel structures, including external elastic lumina, especially in presence of heavy lipid-rich plaque burden. It is inferior to IVUS in assessment vascular remodeling, and progression-regression trials [1]. However, OCT is able to depict and measure clearly thin cap fibro atheroma prone to rupture rather than IVUS. On the other hand, radiofrequency (RF) IVUS provides quantification of different plaque components which are displayed in simply color-coded images. The interpretation of OCT images is more difficult. Differentiation of lipidic and calcified plaques may be quite challenging with OCT [1].

Another drawback of this modality is the need to replace the coronary blood pool with contrast. The clinical value of higher the higher resolution images in guiding decision-making are still unclear [20]. Many experts agree to usefulness of IVUS guidance during stenting of bifurcations, left main, long lesions, small vessels, and in diabetes [21]. Forward looking IVUS may improve the ease and success of PCI in coronary chronic total occlusion in the near future [22]. IVUS guided DES stenting has been shown to reduce late stent thrombosis and other major adverse cardiac events as well as the need for repeat revascularization [23]. Even if OCT is likely to take over some of the current indications of IVUS, it (IVUS) still has a future.

Conclusion

In an era of more complex PCI, it remains an important armamentarium for the modern-day interventional cardiologist. OCT has limitations (penetration, true vessel sizing, assessment of plaque burden, etc) and really does not add important information. A good IVUS study provides all the information needed to optimize stenting. OCT only will have a niche role. There is simply not enough data to say for sure and clinical implications need to be determined. In the era of OCT, IVUS is still necessary to characterize and measure plaque burden, assess vessel remodeling, and view deep vascular structures. In fact, both the modalities are good in their own ways. They are complementary rather than competitive. Knowing the pitfalls of each technique is crucial to select the appropriate modality for each individual patient Considering advantages and limitations of both RF IVUS and OCT, their combined use may be suggested at least for certain indications.

Bibliography

1. Dash D., *et al*. "An update on clinical applications of intravascular ultrasound". *Journal of Cardiovascular Diseases & Diagnosis* 3 (2015): 4.
2. Jang I., *et al*. "Visualization of coronary atherosclerotic plaques in patients using optical coherence tomography: comparison with intravascular ultrasound". *Journal of the American College of Cardiology* 39.4 (2002): 604-609.
3. Kume T., *et al*. "Assessment of coronary intima-media thickness by optical coherence tomography: comparison with intravascular ultrasound". *Circulation Journal* 69.8 (2005): 903-907.
4. Kubo T., *et al*. "Assessment of culprit lesion morphology in acute myocardial infarction: ability of optical coherence tomography compared with intravascular ultrasound and coronary angioscopy". *Journal of the American College of Cardiology* 50.10 (2007): 933-939.
5. Murashige A., *et al*. "Detection of lipid-laden atherosclerotic plaque by wavelet analysis of radiofrequency intravascular ultrasound signals: *in vitro* validation and preliminary *in vivo* application". *Journal of the American College of Cardiology* 45.12 (2005): 1954-1960.
6. Nair A., *et al*. "Assessing spectral algorithms to predict atherosclerotic plaque composition with normalized and raw intravascular ultrasound data". *Ultrasound in Medicine & Biology* 27.10 (2001): 1319-1331.
7. Nair A., *et al*. "Coronary plaque classification with intravascular ultrasound radiofrequency data analysis". *Circulation* 106.17 (2002): 2200-2206.
8. Kawasaki M., *et al*. "*In vivo* quantitative tissue characterization of human coronary arterial plaques by use of integrated backscatter intravascular ultrasound and comparison with angioscopic findings". *Circulation* 105.21 (2002): 2487-2492.
9. Kawasaki M., *et al*. "Volumetric quantitative analysis of tissue characteristics of coronary plaques after statin therapy using three dimensional integrated backscatter intravascular ultrasound". *Journal of the American College of Cardiology* 45.12 (2005): 1946-1953.
10. Yabushita H., *et al*. "Characterization of human atherosclerosis by optical coherence tomography". *Circulation* 106.13 (2002): 1640-1645.
11. Kume T., *et al*. "Assessment of coronary arterial plaque by optical coherence tomography". *Journal of the American College of Cardiology* 97.8 (2006): 1172-1175.

12. Kawasaki M., *et al*. "Tissue characterization of coronary plaques and assessment of thickness of fibrous cap using integrated backscatter intravascular ultrasound: comparison with histology and optical coherence tomography". *Circulation Journal* 74.12 (2010): 2641-2648.
13. Kume T., *et al*. "Frequency and spatial distribution of thin-cap fibroatheroma assessed by 3-vessel intravascular ultrasound and optical coherence tomography: an ex vivo validation and an initial in vivo feasibility study". *Circulation Journal* 73 (2009): 1086-1091.
14. Yamaguchi T., *et al*. "Safety and feasibility of an intravascular optical coherence tomography image wire system in the clinical setting". *American Journal of Cardiology* 101.5 (2008): 562-567.
15. Kawamori H., *et al*. "The ability of optical coherence tomography to monitor percutaneous coronary intervention: detailed comparison with intravascular ultrasound". *Journal of Invasive Cardiology* 22.11 (2010): 541–545.
16. Bouma BE., *et al*. "Evaluation of intracoronary stenting by intravascular optical coherence tomography". *Heart* 89.3 (2003): 317–320.
17. Matsumoto D., *et al*. "Neointimal coverage of sirolimus-eluting stents at 6-month follow-up: evaluated by optical coherence tomography". *European Heart Journal* 28.8 (2007): 961–967.
18. Gonzalo N., *et al*. "Optical coherence tomography patterns of stent restenosis". *American Heart Journal* 158.2 (2009): 284-293.
19. Ormiston JA., *et al*. "A bioabsorbable everolimus-eluting coronary stent system for patients with single de novo coronary artery lesions (ABSORB): a prospective open-label trial". *Lancet* 371.9616 (2008): 899-907.
20. Meneveau N., *et al*. "Does optical coherence tomography optimize results of stenting? Rationale and study design". *American Heart Journal* 168.2 (2014): 75–81.
21. Minz GS., *et al*. "Atherosclerosis in angiographically "normal" coronary artery reference segments: an intravascular ultrasound study with clinical correlations". *Journal of the American College of Cardiology* 25.7 (1995): 1479-1485.
22. Dash D and Li Li. "Intravascular ultrasound guided percutaneous coronary intervention for chronic total occlusion". *Current Cardiology Reviews* (2015).

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