Use of Optical Coherence Tomography in Coronary Artery Disease: Review Article

Syed Mustajab Hasan, MD, Mohammed Faluk, MD, Jay D. Patel, DO, Ramy Abdelmaseih, MD, and Jigar Patel, MD

Abstract: Optical coherence tomography is a catheter-based imaging modality in heart catheterizations, which provides a significantly higher resolution of intravascular pathology by means of using light as opposed to ultrasound. The applications of this modality may include a detailed assessment of atherosclerotic plaques, stent evaluation including coverage and restenosis and percutaneous coronary intervention optimization. In this article, we provide a review of current literature highlighting the advantages and disadvantages of the use of optical coherence tomography in the catheterization lab. (Curr Probl Cardiol 2021;46:100597.)

Introduction

Radiographic coronary angiography, which uses contrast material at the time of cardiac catheterization, remains the preferred diagnostic test to assess the extent and severity of atherosclerotic changes in the coronary circulation to date. Decisions regarding revascularization are based on information obtained from coronary angiography as well as clinical correlations and other noninvasive findings. However, this approach can provide only information regarding the contour of vascular lumen and not the complete endothelial wall. It is also

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subject to performer bias, intraobserver and interobserver variability, which can lead to quantitative coronary angiography.[1–10] To overcome these limitations, it was reported that intravascular imaging techniques such as optical coherence tomography (OCT), intravascular ultrasound (IVUS), and coronary angioscopy can provide information above and beyond that of coronary angiography. In this review article, we will focus on OCT compared to other modalities and the evolution of its use.

Discussion

OCT is a novel invasive intravascular imaging modality that can be used in vivo to assess coronary arterial wall vasculature by using infrared light emission that can provide high resolution (in the range 15-20 microns) images. It can show all the 3 concentric layers of coronary artery by creating cross-sectional images of the coronary artery wall. This imaging modality is analogous to ultrasound but utilizes light instead of sound.[11–13] The 2 most commonly used intravascular catheter-based imaging modalities are IVUS and OCT. Since the first OCT intravascular imaging modalities were first introduced in Japan and the European Union in 2004 and then in the United States in 2009, its use has since grown very rapidly.[14–16] Since the introduction of percutaneous coronary artery intervention (PCI) in 1977, safety and efficacy outcomes of PCI have improved due to advancement in device technology, preprocedural adjunctive pharmacology and operator experience. Although, radiograph angiography is still the primary imaging modality of coronary artery atherosclerosis, addition of intravascular imaging modalities (OCT) may further improve PCI outcomes.[17] It has become an invaluable tool for guiding complex PCI.[18]

OCT Utility in Acute Coronary Syndromes

OCT can potentially be used to identify angiographically unclear lesions and assess stent failure. In acute coronary syndromes (ACS), optimal management usually relies on rapid treatment of culprit vessel. In most of the patients, culprit vessel can be localized with EKG or coronary angiography. However, sometimes it is challenging to identify the culprit lesion of some individuals, especially those with multivessel disease. Similarly, almost 15% of patients who are undergoing primary PCI for STEMI, angiography shows patency of infarct related with TIMI score 3 flow.[19] OCT can give accurate information of superficial plaque composition, identifies ruptured plaques, thrombosed lesions, and thus the culprit

lesion.[20] These characteristics make it the ideal imaging modality for defining the anatomic location of the culprit vessel/lesion or ruling out ACS (and defer unnecessary stenting). OCT can be used to evaluate the causes of stent failure in any given patients, differentiate mechanical stent failure: from impaired healing vs finally guide the treatment decision.[21]

OCT Utility for Stent Expansion Assessment

Stent expansion is the single most important parameter that has been associated with clinical outcomes.[22,23] It can be assessed by either using IVUS or OCT. Both of these intravascular modalities rely on lumen assessment quantification to optimize the expansion result. As reported by ILUMIEN II (an observation study of OCT in patients undergoing fractional flow reserve [FFR] and PCI), both OCT and IVUS guidance showed similar degree of stent expansion.[24] As also evident in ILUMIEN III: OPTIMIZE PCI[25] which is the first randomized, controlled, prospective multicenter trial conducted at 29 sites in 8 countries that compared OCT-guided PCI with IVUS-guided PCI and with angiography to guide coronary stent implantation and to assess whether OCT-based stent sizing strategy would result in a minimal stent area (MSA) similar to or better than that achieved with IVUS guidance and better than that achieved with angiography guidance alone. Four hundred and fifty patients were randomized (158 to OCT [35%], 146 to IVUS [32%], 146 to angiography [32%]) and 415 final OCT acquisitions were analyzed for the primary endpoint of Post-PCI MSA. OCT-guided PCI was safe and showed similar MSA and noninferiority compared to IVUS-guided PCI. Compared to angiography, OCT showed greater MSA but it did not reach statistical significance ($P = 0.12$), however this may be due to small sample size. In this study OCT-guided PCI showed fewer untreated major dissections and less major malposition compared to IVUS and angiography guided PCI. OCT-guided PCI also resulted in greater stent expansion and procedural success compared to angiography guided PCI.

Unlike IVUS that is essentially a poststent assessment/optimization tool, intravascular OCT is a periprocedural tool that can be used for superior plaque characterization, ACS differentiation from stable coronary artery disease, stent planning, and volumetric lumen segmentation for stent optimization.[18]

Benefits of OCT Over IVUS and Angioscopy

- Has the ability to give in greater detail the structure and extent of coronary artery disease.
- Has higher accuracy to detect early atherosclerosis, necrotic core, or lipid-rich tissues.[26,27]
- Has higher accuracy to detect intracoronary thrombi (difficult to differentiate thrombi blood filled lumen in IVUS[28] and visualize calcifications without blooming artifact. Due to its high sensitivity it can fulfill angiographic limitations in differentiating thrombus from calcifications and other etiologies of ambiguous radiolucency.[18]
- Due to high spatial resolution, OCT is the only technique able to detect eroded plaques.[29] It is considered the gold standard method for ruptured fibrous cap detection[30] and has twice the sensitivity of IVUS.
- Has good inter- and intraobserver agreement for visual plaque characterization.[31,32]
- In acute stent placement, it allows you to visualize in acutely stented vessels in greater detail and also identify periprocedural coronary artery trauma including coronary artery dissection than IVUS.[33]
- In long-term stent outcome, it can reliably detect and quantify early and thin layers of tissue coverage on stent struts, even in the drug-eluting stents with very thin layers of neointima, often below 80 μm in thickness unlike IVUS.[34]

Limitations of OCT

- Like IVUS, OCT is unable to accurately predict coronary physiology compared to the gold standard of FFR. Specifically in left main disease, FFR remains the primary metric for assessment.[35]
- Limitation in left main ostium characterization due to lack of consistent OCT imaging.[36]
- Far-field detection is limited with OCT. Current maximum tissue penetration is only 1.5-3 mm making it challenging to fully characterize an atheromatous plaque. IVUS, in contrast, can penetrate with a depth of up to 10 mm.[37]

Conclusion

The use of OCT can potentially expand to all coronary angiograms due its potential benefit in not only identifying key elements of intravascular lesions, but also due to its utility with more delicate devices such as bioresorbable vascular scaffolds. However, long-term clinical outcomes of OCT-guided stent implantation are not known yet. We are hoping that the ongoing ILUMIEN IV clinical trial that was initiated in March 2018 will give further directions for OCT utilization.

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