



Optical coherence tomography: an arrow in our quiver

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“3D optical coherence tomography-based calculation of local endothelial shear stress in combination with anatomic plaque characteristics such as fibrous cap thickness and lipid core size may facilitate the early identification and prompt treatment of high-risk plaques.”

The rapid advances in the diagnosis of coronary artery disease during the second half of the 20th century may be fairly attributed to the introduction of new imaging techniques. Noninvasive techniques have great specificity and sensitivity for the identification of flow-limiting lesions. It is, however, the non-flow-limiting lesions with a large lipid burden and severe inflammation (i.e., high-risk plaque) that are responsible for the majority of acute coronary syndromes [1,2]. These high-risk lesions are mostly identified with invasive imaging modalities. The era of invasive coronary imaging has enormously expanded over the last 10 years with the development of novel imaging techniques, enabling us to understand the complex aspects of the natural history of coronary artery disease while creating new therapeutic opportunities. Optical coherence tomography (OCT) has been an emerging and a quite promising invasive technique with a unique ability to visualize microstructural changes of the intima [3].

How it works

OCT is a catheter-based, low-coherence interferometric technique utilizing near-infrared electromagnetic radiation that originates from a fiberoptic core. The technique is based on the calculation of the echo time delay of laser light waves that are reflected from biological tissues [4]. OCT provides real-time high-resolution 2D cross-sectional images of coronary arteries with an axial resolution of 10–15 μm and a lateral resolution of 20–40 μm .

There are two types of OCT – time-domain OCT and frequency-domain OCT – representing the first and second generation of OCT, respectively. Frequency-domain OCT allows faster and better signal acquisition compared with time-domain OCT. A typical OCT pullback at a speed of 20–40 mm/s with a frame rate of approximately 100–200 frames/s has the potential of scanning nearly 60 mm of coronary arteries in less than 5 s. Such a rapid pullback eliminates the need for balloon occlusion and minimizes the amount of saline or contrast flush required for the removal of red blood cells, resulting in reduced risk of myocardial ischemia and clearer images [5].

What has OCT got to offer us?

OCT is the only clinically available technique capable of depicting the arterial lumen and intima with high resolution. Studies have shown the ability of OCT to assess the presence of thrombus, plaque rupture, plaque neovascularization and, most importantly, high-risk plaque characteristics, such as lipid-rich necrotic core and the presence of macrophages in a thin fibrous cap [3,6–10]. Furthermore, the use of OCT in post-stent implantation has allowed the early identification of stent malapposition, lumen dissection, stent protrusion and neointimal hyperplasia [11–13]. In addition, OCT has provided important insights into late drug-eluting stent thrombosis [14].

KEYWORDS: atherosclerosis • optical coherence tomography • vulnerable plaque

Relative limitations

Although OCT is a powerful modality for the imaging of coronary arteries, it has several limitations. Poor tissue penetration is the most important one. The penetration's depth is largely dependent on the tissue characteristics. Lipid-rich plaques and thrombus attenuate OCT signal, thereby diminishing our ability to evaluate the arterial wall beyond the internal elastic lamina [4]. Sharing common disadvantages with other intravascular techniques, the OCT requires total clearance of red blood cells for fine-quality image acquisition. The relatively high cost of the procedure along, with the limited reproducibility and subjectivity in the interpretation of the results, are additional limitations. Multicenter OCT studies are now underway and they are anticipated for the formulation of consensus statements concerning the integration of OCT into diagnostic and therapeutic guidelines.

What is there to come?

Recently developed techniques related to OCT include polarization-sensitive OCT, a method providing a quantitative measure of birefringence. Birefringence constitutes a tissue property related to macromolecules and proteins, such as actin and collagen. Collagen depletion in the intima overlying a lipid-laden core is a critical component of plaque vulnerability [15]. Pilot human studies are currently underway in the area of ophthalmology, testing the polarization-sensitive OCT [16,17]. The application of this new technique in cardiovascular medicine appears to be quite challenging.

Geometrically correct 3D OCT is a novel imaging tool providing accurate 3D representation of coronary arteries in space by fusion of OCT and biplane angiography [18]. The technique allows analysis of plaque anatomic characteristics, including fibrous cap thickness and lipid core size, as well as functional characteristics, including vascular remodeling and assessment of local endothelial shear stress. Studies have shown that low endothelial shear stress leads to atherogenesis and high-risk plaque development [19–21]. 3D OCT-based calculation of local endothelial shear stress in combination with anatomic plaque characteristics such as fibrous cap thickness and lipid core size

may facilitate the early identification and prompt treatment of high-risk plaques.

Micro-OCT is another recently developed OCT-related modality. Micro-OCT utilizes a very broad-bandwidth light source and common-domain OCT technology to provide images with 1- μ m axial resolution and 2- μ m lateral resolution. Understanding of the mechanisms involved in the formation and potential rupture of vulnerable plaque requires deeper tissue penetration in the cellular and subcellular level, and micro-OCT appears to have the potential to shed light towards this direction [22]. Currently, micro-OCT is exclusively applied on an experimental level; its clinical application, however, will most likely expand our understanding of the vulnerable plaque pathophysiology.

“...rigorous clinical research is needed to show that the appropriate use of this method can further improve patient outcomes.”

A combination of OCT with other interventional and non-interventional modalities comprises another fascinating perspective creating new opportunities of local interventions for the management of coronary artery disease.

In conclusion, OCT has been an ‘arrow in our diagnostic quiver’ opening new perspectives in the diagnosis and management of coronary artery disease. However, whether this new tool has a role in reducing cardiovascular morbidity and mortality is unclear. As with every new diagnostic tool, rigorous clinical research is needed to show that the appropriate use of this method can further improve patient outcomes.

Financial & competing interests disclosure

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