Fundamentals of Optical Coherence Tomography

Image Acquisition and Interpretation

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KEYWORDS

• Optical coherence tomography • Intracoronary imaging • Image interpretation • Vulnerable plaque

KEY POINTS

- Optical coherence tomography (OCT) is a catheter-based modality that enables in vivo imaging of coronary arteries with 10-fold improved resolution compared with intravascular ultrasonography.
- The high resolution of OCT imaging allows it to serve as an "optical biopsy," facilitating detailed plaque characterization and evaluation of features associated with plaque vulnerability.
- Limitations of OCT include its limited depth of penetration and the need to create a blood-free field during imaging.
- Improvements in image acquisition speed have enabled the translation of OCT from the research setting to clinical practice, and studies are now underway to evaluate OCT-guided decision making.

INTRODUCTION

Optical coherence tomography (OCT) is an emerging catheter-based intravascular imaging modality that enables high-resolution cross-sectional imaging of coronary arteries in vivo. By measuring the magnitude and time delay of backscattered light waves in a manner analogous to the use of sound waves in intravascular ultrasonography (IVUS) imaging, OCT produces images with 10-times improved resolution compared with IVUS.[1] OCT is widely used in ophthalmology for evaluation of the retina,[2] and its application to vascular imaging has enabled detailed plaque characterization,[3] opening up significant opportunities for application in both research and clinical settings.[4] This article introduces the basic principles of OCT image acquisition and interpretation for coronary arteries.

PRINCIPLES OF OPTICAL COHERENCE TOMOGRAPHY IMAGE ACQUISITION

The first generation of OCT platforms used a time domain (TD) detection system in which light from a broadband source with wavelengths centered on 1300 nm was directed at the tissue of interest. Determination of imaged tissue depth required a reference mirror to be moved back and forth, significantly limiting the speed of image acquisition.[3] The second generation of OCT platforms uses a technology called Fourier or frequency domain (FD) detection in which a monochromatic source emits light sweeping across a range of wavelengths between 1250

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and 1350 nm. Reflected light from various tissue depths can therefore be detected simultaneously, facilitating significantly faster image acquisition (Fig. 1).[5] The technical specifications of IVUS, TD-OCT, and FD-OCT imaging are compared in Table 1.

An important consideration in the use of OCT as an intravascular imaging modality is that blood must be cleared or flushed from the vessel lumen, because the backscatter of light by red blood cells precludes OCT imaging through a blood field.[6] Initially, blood clearance was accomplished using the occlusion technique, in which an occlusive balloon was inflated proximally to stop coronary blood flow, and saline or Ringer lactate was infused downstream to clear the vessel of blood during pullback imaging. Limitations to this technique include ischemia during balloon occlusion, potential damage to the vessel at the site of balloon occlusion, the need for multiple catheter exchanges, and the inability to image ostial lesions.[7] In addition, vessel dimensions measured on OCT images obtained with the occlusion technique may be artificially small because of reduced intracoronary pressure downstream from the occlusion balloon.[8,9] Improvements in image acquisition speed have enabled the use of a nonocclusion technique to clear blood from the vessel. In this technique, pullback imaging is performed with simultaneous infusion of saline or contrast through the guide catheter.[10]

At present, FD-OCT imaging is most commonly performed using the C7XR system (LightLab Imaging Inc/St. Jude Medical, Westford, MA). With this system, pullback imaging of up to 54 mm in length can be acquired in 2.7 seconds with 10 to 15 μm axial and 20 to 40 μm lateral resolution.[11] Newer FD-OCT systems such as the ILUMIEN and ILUMIEN OPTIS OCT Intravascular Imaging Systems (St. Jude Medical, St. Paul, MN) have recently become commercially available and are replacing the C7XR system, because they offer additional features to facilitate improved image acquisition and real-time interpretation, including faster pullback speed, longer pullback length, automated measurements,

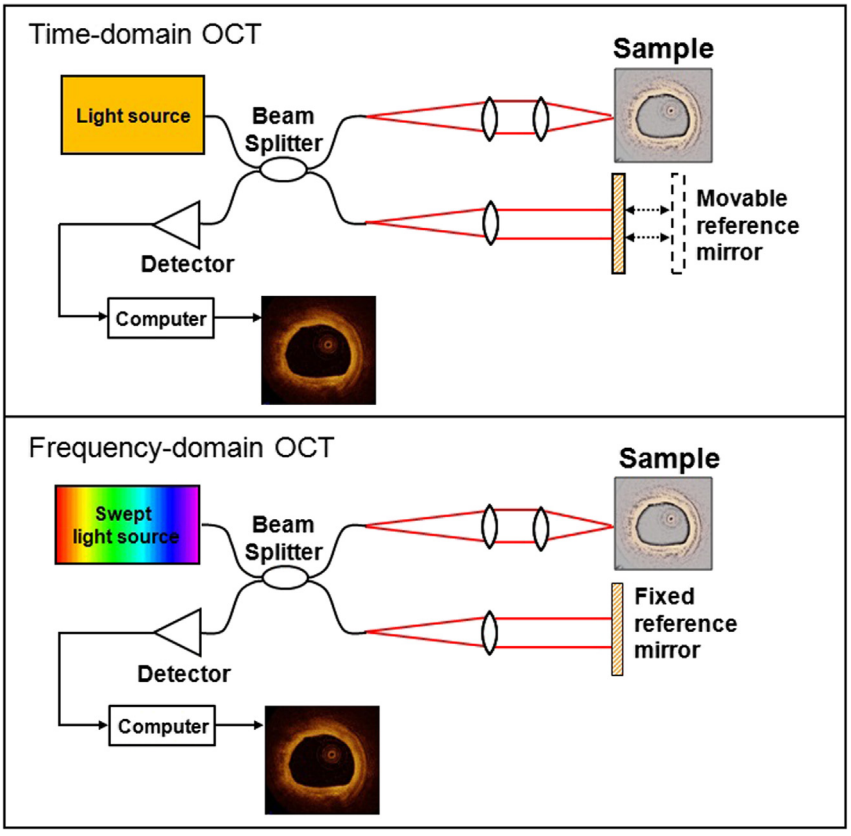

Fig. 1. TD-OCT and FD-OCT. (*From* Soeda T, Uemura S, Saito Y, et al. Optical coherence tomography and coronary plaque characterization. J Jpn Coron Assoc 2013;19(4):309; with permission.)