Chapter 10
Optical Coherence Tomography: Basic Principles of Image Acquisition

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ABSTRACT
This chapter is devoted to the description of the basic principles of data acquisition of the Optical Coherence Tomography imaging technique. The physical mechanisms of the tissue optics are detailed, while the architecture of the OCT system is provided, emphasizing on both the TD-OCT and FD-OCT. Then, after discussing about the OCT image resolution, a parametric comparison of OCT with regard to IVUS imaging technique is attempted. Finally, the limitations of the technique are described, along with the safety of its application to the clinical practice.

INSIGHTS INTO THE PRINCIPLES OF OCT IMAGING

Introduction
Optical Coherence Tomography (OCT) (Huang et al., 1991) is a new imaging modality which produces high resolution tomographic images of the internal vessel microstructure. The concept of OCT imaging is based on measuring the echo time delay and the magnitude of backscattered light. OCT can be applied to a variety of applications with special focus on medical applications. A major advantage of OCT is the high transversal resolution. OCT is used in three fields of medical optical imaging:

- In macroscopic imaging of structures where the structures can be identified with naked eye,
Optical Coherence Tomography

- In microscopic imaging by magnifying the image up to the limits of microscopic resolution,
- In endoscopic imaging where low and medium magnification is used.

OCT enables real-time visualization of tissue making it a powerful imaging tool for medical applications. OCT could be used in the following clinical situations:

- If standard excisional biopsy is not possible such as in coronary arteries and nervous tissues or in the eye,
- If sampling errors affect standard excisional biopsy. For diagnosing many diseases including cancer, excisional biopsy after which histopathology is performed are the standard applied techniques. However, in such a sampling procedure as biopsy, if a lesion is not included in the sample then we might obtain a false-negative result. OCT is being evaluated in order to improve the accuracy of excisional biopsies to increase the number of samples that include lesions,
- And to guide interventional procedures. OCT has the ability to see beneath the tissue surface, enabling guidance and assessment of microsurgical procedures.

Basic Tissue Optics

For the correct interpretation of OCT images, a general understanding of some basic optical properties of tissue is crucial. Absorption and scattering are two basic optical properties of living tissues. The absorption coefficient $\mu_a \,[m^{-1}]$ is defined as the probability of absorption of a photon at an infinitesimal distance $\Delta d$ when the photon propagates over the infinitesimal distance. This probability is $\mu_a$ times the distance $\Delta d$. In other words, for an absorption event the mean free path is $\frac{1}{\mu_a}$. Similarly with the definition of the absorption coefficient, the scattering coefficient $\mu_s$ is the probability of scattering of a photon at an infinitesimal distance $\Delta d$. This probability is $\mu_s$ times the distance $\Delta d$. When single scattered photons are detected in OCT, the relevant light from the source that is collected by the interferometer detector travels in the tissue a distance $2d$. This distance is the sum of two distances. The first distance is the distance in the tissue from the source to the point where the light is backscattered or reflected. The second distance is the distance from the point where the light is backscattered or reflected to the detector. These two distances are equal and the light is attenuated twice over that distance. Lambert–Beer’s law describes the light attenuation in a non-scattering media:

$$I(d) = I_0 e^{-\mu_a d} \quad (1)$$

where $I(d)$ denotes the intensity at a distance $d$ and $I_0$ denotes the light intensity incident on the tissue. Lambert–Beer’s law is used to calculate the total attenuation, using the total attenuation coefficient $\mu_t \,(\mu_t = \mu_a + \mu_s)$ instead of $\mu_a$.

The OCT System

The aim of the OCT technique is to measure the echo time delay of light using interferometric techniques (Rollins & Izatt, 1999). By using interferometric techniques the tissue backscattered light signal is correlated with the light which has traveled a reference path length that is already known. The use of interferometry techniques to determine the echo time delay of light is crucial since the speed of light is faster than the speed of sound. Using interferometry both the magnitude of backscattering light properties and the echo time delay can be measured. A frequent detection method used is the Michelson interferometer, which applies a scanning reference delay arm (Kersey, Marrone, & Davis, 1991). OCT uses interferometric techniques to perform
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