1.1 Scanning principles

Optical coherence tomography (OCT) is a medical diagnostic imaging technology that captures micron resolution three-dimensional images. It is based on the principle of optical reflectometry, which involves the measurement of light back-scattering through transparent or semitransparent media such as biological tissues. It achieves this by measuring the intensity and the echo time delay of light that is scattered from the tissues of interest. Light from a broadband light source is broken into two arms, a reference arm and a sample arm that is reflected back from structures at various depths within the posterior pole of the eye.

There are two main ways in which the backscattered light can be detected:

- Time domain (TD) detection
- Fourier domain (FD) detection, which is further broken down into:
  - Spectral domain (SD)
  - Swept source (SS)

Time Domain OCT

In time domain OCT scanning, light from the reference arm and light reflected back from the sample undergo interference, and the interference over time is used to generate an A-scan depth resolved image of the retina at a single point. Moving the sample and the light source with respect to each other generates multiple A-scans that are combined into a cross-sectional linear image called the B-scan or line scan. Scanning speeds of TD-OCTs are typically around 400 A-scans/second. These older-generation machines are now rarely used in clinical practice.

Spectral Domain OCT

In this technology, the spectral interference pattern between the reference beam and the sample beam is dispersed by a spectrometer and collected simultaneously with an array detector. This simultaneous collection allows much faster scanning speeds than the traditional time domain devices where a mechanically moving interferometer gathers the data over time. An A-scan is then generated using an inverse Fourier transform on the simultaneously gathered data. Commercially available SD-OCT devices have scanning rates of 40,000–100,000 A-scans/second.

Higher scan speeds in the SD-OCT allow faster acquisition time, which minimizes the chance of eye movements during acquisition. Both hardware and software enhancements permit precise image registration, which allows for a more reliable comparison between visits. Faster acquisition speeds also mean a higher sampling density of the macula, minimizing the chances of missing pathology and allowing the production of three-dimensional OCT scans. The broader light sources of SD-OCT devices achieve a higher axial resolution than TD-OCT, providing better visualization of retinal anatomy. At present, there are eight commercial SD-OCT devices that are available in at least some, if not all, large international markets.

Swept Source OCT

In swept source (or optical frequency domain) OCT scanning, the light source is rapidly swept in wavelength and the spectral interference pattern is detected on a single or small number of receivers as a function of time. The spectral interference patterns obtained as a function of time then undergo a reverse Fourier transform to generate an A-scan image. Higher scanning speeds allow for denser sampling and better registration. Swept source OCT also has less sensitivity roll-off with depth, allowing for a better visualization of structures deep to the retina. At present, swept source OCT is not widely available commercially, with only two commercially available devices.

OCT Angiography

OCT angiography (OCTA) is an application of OCT that noninvasively visualizes the vascular layers of the retina. The microvasculature is not depicted in OCT images because it does not produce back-scatter distinct from its surrounding tissue. Instead, OCTA takes advantage of motion contrast between moving blood flow and the static retinal surroundings to visualize the vasculature. In sequentially repeated B-scans taken at the same position, the only differences, or decorrelation, in reflectivity come from sites of blood flow. Higher resolutions and scan speeds in contemporary OCT devices allow B-scans to be repeated fast enough to resolve the vasculature adequately.

OCTA devices use different algorithms to calculate motion contrast between repeated B-scans. Swept source OCTA offers less sensitivity loss with depth, which permits better visualization of the deeper vasculature of the choroid and choriocapillaris.