Country	CET/CPD information	Audience	Competencies	MCQs
UK	This article offers 1 non-interactive CET point (C-73782)	General Optical Council – Approved CET For Optometrists General Optical Council – Approved CET For Dispensing Opticians	STANDARDS OF PRACTICE OCULAR EXAMINATION STANDARDS OF PRACTICE	6
ROI	All articles are CPD accredited in the Republic of Ireland			6

Essentials of OCT

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Outline

OCT is a medical imaging technique that is now comprehensively used by ophthalmologists and optometrists to acquire high resolution images of the anterior segment and retina. This article is the first in a series that aims to provide the reader with an understanding of the use of this technique in clinical practice.

About the authors

William is dual qualified as a dispensing optician and optometrist as wells as clinical director of Lok Optometric Consultants Ltd, a company which develops and delivers training materials for optical conferences. He qualified as a dispensing optician in October 2005, an optometrist in August 2010 and was awarded independent prescriber status in June 2014. William has considerable experience of developing and delivering CET peer discussion sessions at regional and national training events.

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For 'non-interactive' CET you have to pass (>60%) a six-question multiple-choice quiz.

The learning objectives for this article are:

2.7.5 Optometrists will have an understanding of when assessment of retinal structures using OCT is useful for clinical decision-making

3.1.3 Optometrists will have an evidence-based understanding of the principles of use of OCT to assess various structures within the retina

2.2.2 Dispensing opticians will have an understanding of the application of OCT for assessment of the retina so that they can provide information in a supporting role to reassure patients and provide information about the procedure within their scope of practice.

Introduction

Optical coherence tomography (OCT) is a non-invasive medical imaging technique that uses light to capture high resolution, three-dimensional images from within the optical biological tissue. It enables sub-surface images of translucent or opaque materials to be obtained at a resolution equivalent to a low-power microscope. OCT is an echo technique, similar to ultrasound imaging, and can, therefore, also be known as an optical ultrasound as the imaging reflections from within the tissue provide cross-sectional images.1

The key benefits of OCT are:

- Live sub-surface images at microscopic resolution
- Instant, direct imaging of tissue morphology
- No preparation of the sample or patient
- No ionising radiation

As OCT is based on light rather than sound or radio frequency, it can deliver high resolution images. A light beam is directed at the surface of the tissue of interest; the small proportion of light that is reflected back is collated, enabling image generation. It should be noted that most light is not reflected, but rather is scattered off at wide angles. In conventional imaging, this diffusely scattered light contributes to background noise, which in turn obscures the image. However, in OCT, a technique called interferometry records the optical path length of all received photons allowing for the rejection of most photons that scatter before detection. This ensures the generation of clear 3D images by discarding background signals while gathering light directly reflected from the surfaces of interest.

OCT imaging is limited to 1 to 2mm below the surface in biological tissue; at greater depths the proportion of light that is reflected without scattering is too small to be detected. No special preparation of the patient is required. It is also important to note that eye-safe near-infrared light is used and, therefore, no damage to the eye is likely.

Layers of the retina

In an OCT image, the ten distinct retinal layers can be identified[2] (Figure 1) (from nearest to the vitreous body to furthest away):

1. Inner limiting membrane – basement membrane elaborated by Müller cells
2. Retinal nerve fibre layer (RNFL) – axons of the ganglion cell nuclei
3. Ganglion cell layer – nuclei of ganglion cells, the axons of which become the optic nerve fibres for messages and some displaced amacrine cells[3]
4. Inner plexiform layer – the synapse between the bipolar cell axons and the dendrites of the ganglion and amacrine cells[3]
5. Inner nuclear layer – the nuclei and surrounding cell bodies of the amacrine cells, bipolar cells and horizontal cells[3]
6. Outer plexiform layer – projections of rods and cones ending in the rod spherule and cone pedicle, respectively[3]
7. Outer nuclear layer – cell bodies of rods and cones
8. External limiting membrane – layer that separates the inner segment portions of the photoreceptors from their cell nucleus
9. Photoreceptor layer – layer of rod cells and cone cells
10. Retinal pigment epithelium - single layer of cuboidal cells

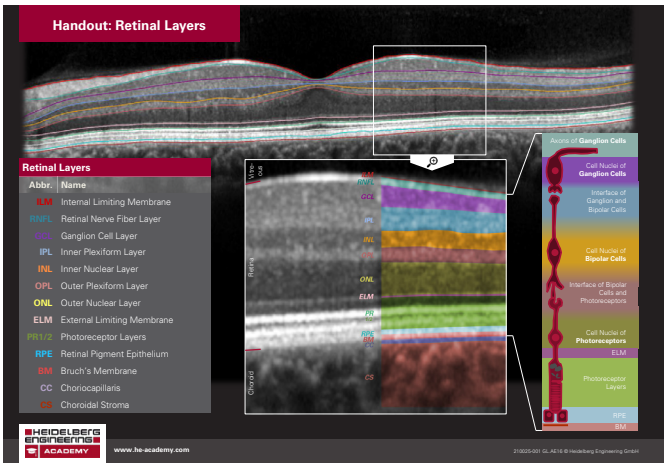

Figure 1: OCT scan depicting the different layers of the retina

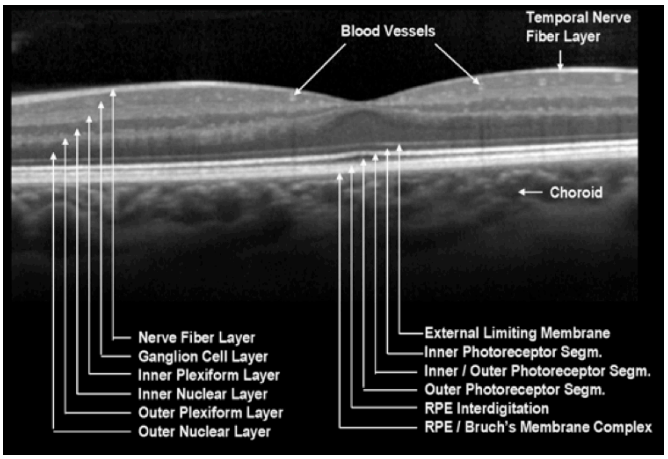

Figure 2: OCT image of retinal layers

Theory

OCT is based on low-coherence interferometry in which the light source is split between that entering the eye and a reference path.[4–6] In OCT, this interference is shortened to micrometres, due to the use of light sources that emit light over a broad range of frequencies (i.e. broad bandwidth light sources). Light with broad bandwidths can be generated by using super luminescent diodes or femtosecond lasers (i.e. lasers with extremely short pulses). An example of a broad bandwidth source with lower power is white light. The optical setup consists of an interferometer with a low coherence and a broad bandwidth light source. OCT images are generated by measuring the echo time lag and the intensity of back-scattered light. Because of the extremely high speed of light, optical echoes cannot be measured by direct electronic detection.

Light in an OCT system is broken into two arms:

- A sample beam (containing the item of interest)
- A reference beam (usually a mirror)

The combination of reflected light from the sample beam and reference light from the reference beam gives rise to an interference pattern, but only if light from both beams has travelled the same optical distance and thus matches the coherence length of the light source. Areas of the sample that reflect a lot of light will create greater interference than areas that do not. Any light that is outside the short coherence length will not interfere. This reflectivity profile is called an A-scan and contains information about the spatial dimensions and location of structures within the item of interest. A cross-sectional tomography (B-scan) may be attained by laterally combining a series of these axial depth scans (A-scan).

OCT combines lots of A-scans to build B-scan images; B-scans are subsequently used to produce 3D maps or cubes. For example, the Retina Scan Duo takes up to 53,000 A-scans per second to produce a B-scan. It uses up to 1024 vertical and horizontal B-scans to make a 3D map.

A-scan

A single depth profile (one-dimensional) scan is called an A-scan. In OCT, A-scan can also be taken as the abbreviation for axial scan, representing the reflected optical amplitude along a single axis of light propagation. A-scans identify boundary locations as the intensity peaks in each scan and link the feature points to form a smooth and continuous boundary.

B-scan

A sequence of A-scans across the structure in question allows a cross-sectional reconstruction of a plane through the anterior or posterior segment of the eye (two-dimensional) this is known as a B-scan. A B-scan, therefore, refers to the cross-sectional image where the amplitudes of reflections are represented in a greyscale or a false-colour scale. A B-scan produces high-resolution images and can be beneficial in assessing the retina in more detail (Figure 3). The amplified resolution allows subtle fluctuations in reflectivity to be seen more definitively. The number of B-scans per frame can be used to provide an indication about the image quality. The more B-scans averaged, the better quality the image is supposed to be, but an increased number of scans will slow down the acquisition process and the resulting data may become prone to noise due to eye movements. A B-scan can also be known as a line scan and can be positioned anywhere across the fundus including the macula.

Figure 3: High resolution B-scans of the retina

C-scan (En Face)

A C-scan refers to a section across structures at an equal optical delay. In the eye, the C-scan also conveniently corresponds to the coronal section. A C-scan image from an OCT can also be called a 'phase fundus image'. The image is like that of a fundus camera image, only it is not in colour.

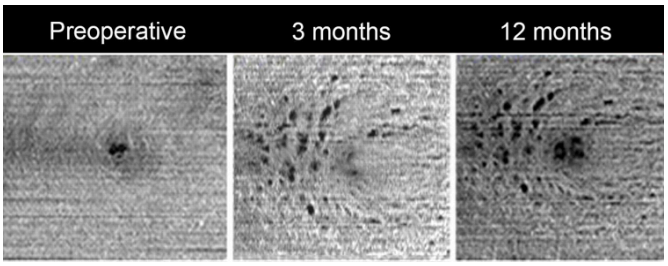

Figure 4: C-scans of a patient who underwent pars plana vitrectomy for a full thickness macular hole. Scans were performed before surgery and 3 and 12 months post-surgery.

Scan types

An OCT can provide many different outputs depending on what type of scan is required. The different scans include:

- Raster scan
- 3D scan
- Radial line scan
- Thickness map
- RNFL scan
- Macula single line scan

Raster scan

A raster scan describes the pattern of scan lines a particular test uses. For example, there could be a horizontal raster or a vertical raster. The spacing between the scan lines can be varied although, obviously, if they are spaced too far apart then there is more chance to miss a lesion.

Some machines have raster patterns that are closer together at the fovea and further apart the further away from the fovea you scan. Often, they will carry out more A-scans along the foveal lines to give a more detailed image of the tissue.

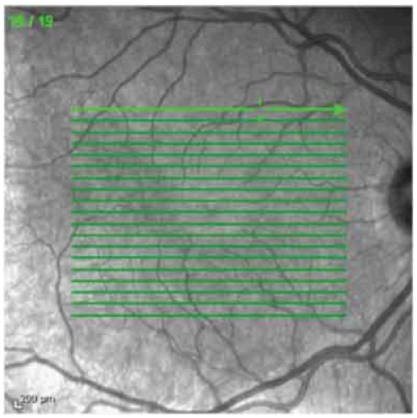

Figure 5: A raster scan

Volume scan (3D scan)

A volume scan is built of up of multiple B-scans (Figure 6). It is a series of horizontal and vertical raster scans combined to create a cube of images. Volume scans allow for a more extensive area of the retina to be scanned without the patient having to change their fixation. This is ideal when screening for abnormalities, or to build up an overall impression of an area of interest. 3D volume datasets can be viewed as orthogonal cross-sectional planes and volume renderings.

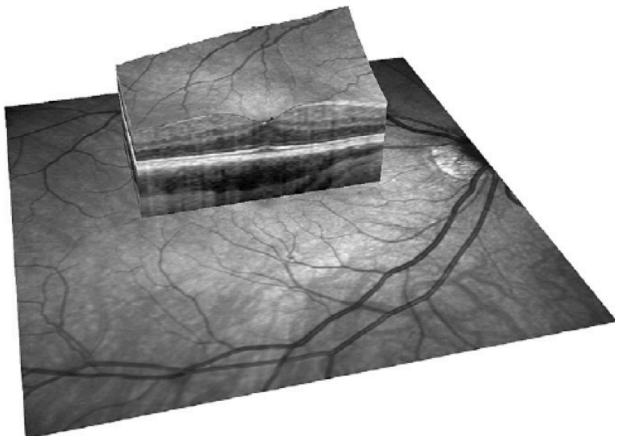

Figure 6: A volume scan of the retina

Radial line scan

A radial line scan directs the OCT beam radially, providing images that are displayed in a "radar-like" circular plot. These images have the highest definition when the probe is introduced within a small-diameter lumen. When a large-diameter lumen is scanned, the OCT images become progressively coarser due to the increase in pixel spacing derived from the increased distance between the probe and the tissue.

A radial line scan takes a series of 6–12 radial line scans through the macula. The advantages of a radial line scan include:

- A larger area of the macula scanned than in a single line scan
- Maintains a high resolution
- Relatively short scanning time

The disadvantages of a radial line scan include:

- Potential for lesions to be missed as there is a greater distance between the scan lines in the parafoveal area
- Decreased accuracy of thickness values

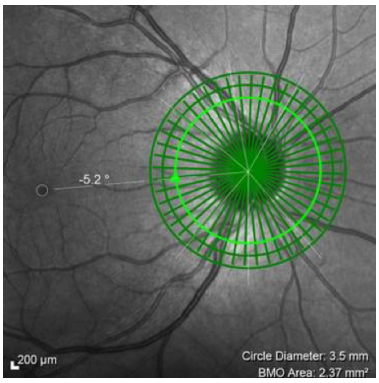

Figure 7: Radial line scan

Thickness map

Retinal thickness maps (Figure 8) can be generated to provide quantitative data around a specific area of interest. These are displayed as colour maps. The warmer colours are indicative of increased retinal thickness, while cooler colours represent thinner areas. A thickness map can be useful in identifying the degree of diffuse thickening of the retina. OCT imaging techniques can be used to generate thickness maps of a three-layer complex consisting of:

- Nerve fibre layer
- Ganglion cell layer
- Inner plexiform layer

This then allows the assessment of numerous non-glaucomatous optic neuropathies to be made.

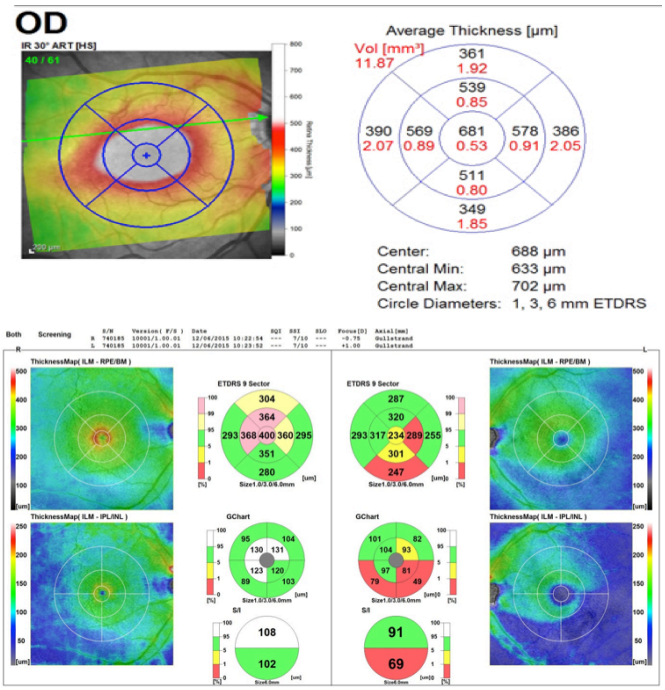

Figure 8: Thickness maps of the retina

RNFL scan

The RNFL is the anatomical structure affected in glaucoma. It is a relatively highly scattering layer compared to the vitreous and the subjacent retinal structures. Due to the cylindrical nature of the nerve fibres, the strength of the backscattered signal from the RNFL is expected to be strongly dependent on the incident angle of the light.

The RNFL scan is a circular scan centred on the optic nerve head. It allows the shape of the optic nerve head to be imaged and the RNFL thickness to be assessed (Figure 9). The scan first displays the RNFL thickness profile at the temporal region, then the superior region, then the nasal region, then the inferior region and finally back to the temporal region.

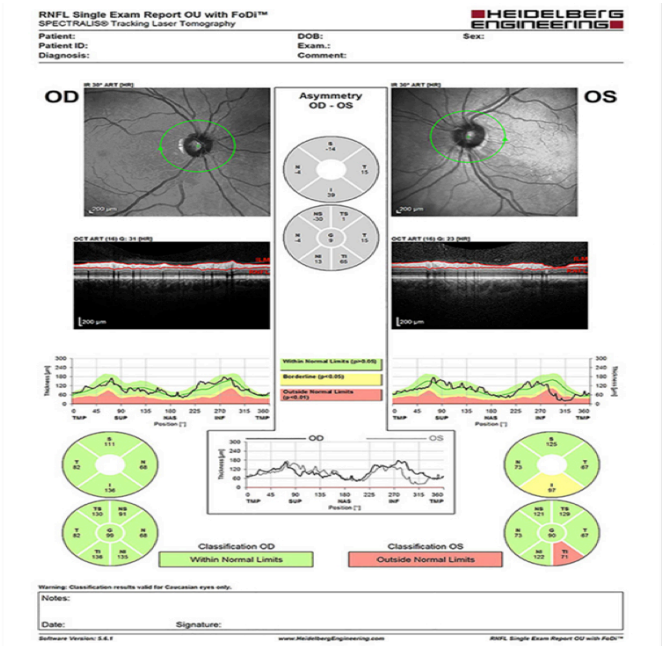

Figure 9: A RNFL scan of the optic nerve head

Macula single line scan

A macula single line scan yields high-resolution images of the macula.

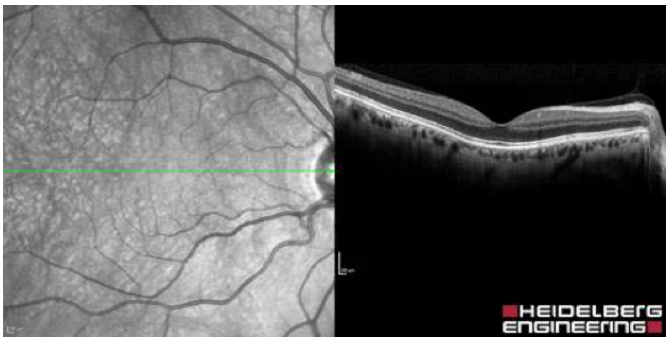

Figure 10

Image presentation

It is possible to view OCT images with different colour schemes. For clinical use, black-on-white (Figure 11A) and white-on-black (Figure 11B) are most commonly used. Changing the colour scheme does not change the information displayed in the image; however, it is sometimes helpful to reverse the contrast to highlight areas of interest. Pseudocolour images are also available (Figure 11C)

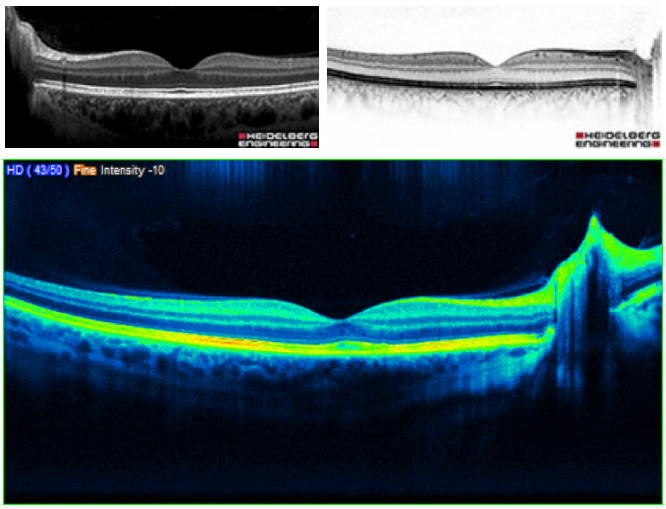

Figure 11: OCT colour schemes. A: OCT image on a black background. Here, hyperrefelective layers appear white and hyporeflective layers appear black. B: OCT on a white background. Hyperrefelective layers=black; hyporeflective layers=white C: Pseudocolour image.

Summary

OCT is a medical imaging technique that is now comprehensively used by ophthalmologists and optometrists to acquire high resolution images of the anterior segment and retina. Due to its cross-sectional capabilities, OCT can deliver a direct method of assessing axonal integrity in multiple sclerosis[7] and glaucoma.[8] OCT is also an appropriate method to assess macular degeneration,[9] and is considered to be the new standard for the assessment of diabetic macular oedema.[10] Furthermore, recent advancements in OCT devices have been developed to also perform angiography; this has led to the use of OCTs to assess retinal microvasculature pathology in diseases such as glaucoma and diabetic retinopathy.

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