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What you should know about OCT assessment

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Part 1 – Macular scan

In the first of three articles discussing what to look for when using an OCT, **Dr Rachel Hiscox** discusses scanning of the macula. Module C38457, one point for OOs and independent prescribers

Optical coherence tomography (OCT) is a non-invasive, non-contact, transpupillary imaging technique able to produce high-resolution images detailing the 3D structure of the eye, from the anterior segment to the posterior pole. With use of OCT growing in the primary eye care setting, this series of articles will discuss macular, disc and anterior OCT imaging in turn, breaking down and reviewing all the information you obtain from most commercially available OCTs. This first article in the series will review macular OCT scans.

Background

Since OCT was first demonstrated in 1991,[1] it has rapidly evolved as the only non-invasive diagnostic technique able to provide images of the retinal microstructure. OCT generates cross-sectional or three-dimensional images by utilising low coherence interferometry to detect and measure the depth and magnitude of back scattered (reflected) light.[2] A two-dimensional, cross-sectional retinal image is produced as the light source scans across the retina, stacking and aligning consecutive axial-scans (A-scans) side by side to produce a two-dimensional transverse-scan (B-scan).[3] Eye movements are corrected by digital processing (cross-correlation scan registration) to align the A-scans, and digital smoothing techniques are used to further reduce image noise.[4] The image produced resembles that of a histological section, with contrast produced by differences in the refractive index and scattering properties of the different retinal layers. Consecutive B-scans can then be aligned to produce a 3D cross-section of the retina.

When to use a macular OCT scan

The 3D macular cube scan is probably the most popular OCT scan protocol used. Covering the whole of the macular region, and typically consisting of over 30,000 A-scans, this scan gives high enough resolution to view all the retinal layers, while still being able to be captured in most commercially available equipment in just a couple of seconds, meaning patient comfort is maximised. Macular OCT is now an invaluable tool within hospitals for monitoring wet age-related macular degeneration (AMD) and has become the most commonly used diagnostic test to aid in treatment decisions. In community optometry this is also one of the biggest uses of OCT, allowing differentiation between wet and dry AMD, therefore avoiding unnecessary referrals. However, the benefits of macular OCT do not stop at AMD detection and monitoring. They also include identification of persistent vitreomacular traction and epiretinal membranes which may explain a slight reduction in vision which may have gone undiagnosed without the use of OCT; diagnosis of conditions such as central serous retinopathy (CSR); early detection of diabetic maculopathy and screening for macular oedema post cataract surgery.

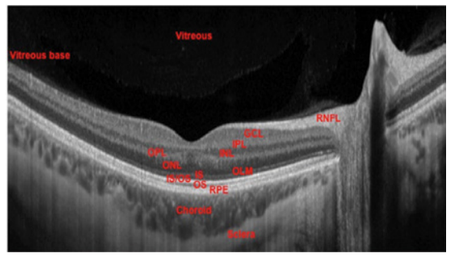

Figure 1 A healthy retinal OCT B-scan showing the macula and optic nerve. RNFL, retinal nerve fibre layer; GCL, ganglion cell layer; IPL, inner-plexiform layer; INL, inner-nuclear layer; OPL, outer-plexiform layer; ONL, outer-nuclear layer; OLM, outer-limiting membrane; IS, photoreceptor inner-segment; IS/OS, inner-segment outer-segment junction; OS, photoreceptor outer-segment; RPE, retinal pigment epithelium

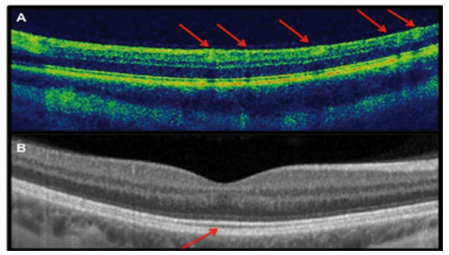

Figure 2 Artefacts in OCT scans. (A) The red arrows show the location of blood vessels, which block the infrared signal and cause shadows to fall underneath them. (B) The red arrow shows the area of photoreceptor outer segment elongation which is seen under the foveola zone

In addition to 3D macular scanning, additional macular scan protocols can provide further information on the macular region. Five-line cross scans, which take five horizontal and five vertical scans multiple times and overlap the images to create a smoother image are very useful if you require better definition of the different retinal layers, in order to determine where a defect lies. Overlaying multiple scans is very beneficial in eyes where the signal strength is poor eg in eyes with cataract, as this will boost the signal and allow a higher image quality.

What does a macular OCT scan look like?

A healthy macular greyscale OCT B-scan is shown in Figure 1, with the different retinal layers identified. Differentiation of the retinal layers is possible due to their varying scattering properties and differences in optical densities. With a colour image, large reflections are depicted by warm colours (yellow to red), while smaller reflections are depicted by cooler colours (blue to green). Images in greyscale utilise brighter shading in place of warmer colours. As the vitreous is not very dense, it appears black. Similarly, if fluid is present this will also appear black. Conversely, structures including the RNFL and RPE are much more dense, therefore they appear brighter (or red in a colour image).

When new to interpreting OCT images, a couple of normal anatomical features can cause concern. Firstly, because blood vessels are highly reflective, they cause a shadow to fall underneath them in the OCT scan due to blocking of the infrared OCT signal (Figure 2A). This can also occur with dense vitreous floaters, which will cast a shadow across all retinal layers of the OCT scan. Secondly, as you move over the foveal region of an OCT scan, the outer segments of photoreceptors appear to become oedematous (Figure 2B). This will cause obvious concern to those new to OCT interpretation; however, this is a normal feature of the fovea, representing the elongation of cone photoreceptors to enable closer packing and hence provide high visual acuity.

3D macular scan components

● Shadowgram

The shadowgram is a very useful element of the macular OCT scan output, and should always be checked first when analysing macular data, as it offers a quick way to determine scan quality over the whole scan area. The shadowgram is a surface image of all of the aligned B-scans. Anything that blocks light in an OCT scan will appear as a shadow, while the deeper the light penetrates, the brighter the area will appear. Figure 3 depicts three shadowgrams.

● Temperature thickness plot

The temperature thickness plot gives a representation of the retinal thickness over the scan area, with thicker areas appearing as warmer colours, and thinner areas as cooler colours. Observation of the temperature thickness plot provides a quick method for establishing whether the retinal architecture is normal over the macular region, as seen in Figure 4A. Identification of the abnormality must then be determined by observing the B-scans.

● Normative comparison – ETDRS

OCT has become increasingly popular for real-time quantitative evaluation of retinal thickness, due to its ability to detect the inner and outer retinal boundaries to a high degree of accuracy, automatically producing a retinal thickness value. However, different OCT instruments give different measures of retinal thickness. The main cause of this disparity is likely to be due to instruments employing different automated segmentation protocols, and defining retinal thickness using different retinal boundaries. However, while this is an important source of variability, instruments that use identical boundaries still measure retinal thickness differences.[5,6] For this reason, retinal thickness values are not interchangeable between different OCT machines.

Retinal thickness varies over the macular region, being thinnest in the central foveola. Average retinal thickness has been reported to be between 222±16µm [7] and 260±12.2µm [8] for the central area of the ETDRS grid, as measured on Topcon OCT instruments. As seen by the relatively high standard deviations, there is a wide range of retinal thicknesses in the normal population. Retinal thickness is reported to vary according to several factors including age (decreasing retinal thickness with increasing age),[9] axial length (decreasing retinal thickness with increasing axial length),[9,10] ethnicity (thinner in patients of African descent) and gender (thinner in women).[9,10,11]

Macular thickness is most commonly analysed and presented on the Early Treatment Diabetic Retinopathy Screening Study (ETDRS) grid, where the patient's retinal thickness is compared to that of a normative database and classified as 'within normal limits', 'borderline' or 'outside normal limits'. Because of the numerous factors which can affect macular thickness the classifications should only be taken as an indicator of the probability of there being a retinal abnormality, indicating what the practitioner should expect to see when they view the B-scans. For example, if the ETDRS grid shows an orange or pink region (representing borderline thickening or outside ▶

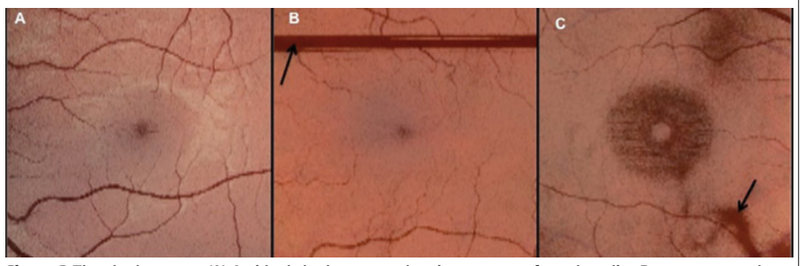

Figure 3 The shadowgram. (A) An ideal shadowgram, showing capture of good quality B-scans across the whole scan area. (B) The black arrow points to a horizontal black line which indicates missing B-scan data, caused by a patient blink. (C) The black arrow points to a shadow, which in this case is likely to indicate blocking of the OCT signal by a vitreous floater

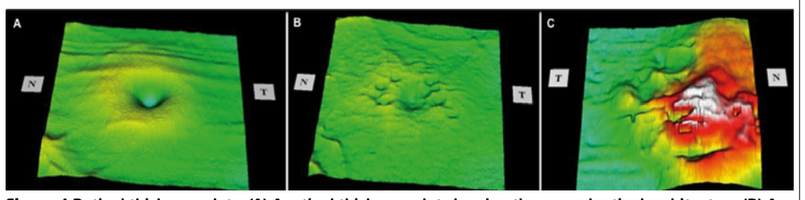

Figure 4 Retinal thickness plots. (A) A retinal thickness plot showing the normal retinal architecture (B) A retinal thickness plot showing multiple 'pits', characteristic of drusen. (C) A retinal thickness plot showing severe retinal thickening nasally with wet AMD as the most likely cause

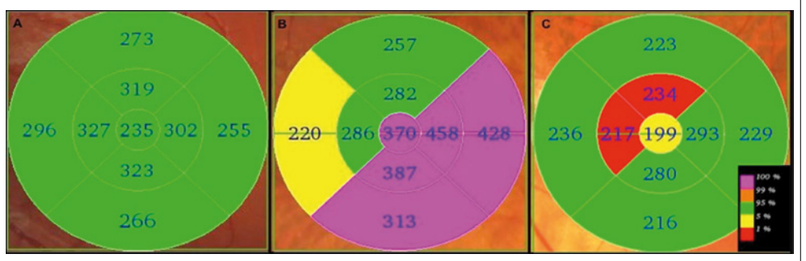

Figure 5 ETDRS thickness grids. (A) Retinal thickness falls within the middle 90 per cent of the normative population for all areas of the ETDRS grid. (B) Retinal thickness is considered outside normal limits in the pink areas, as it falls within the top 1 per cent of the normative population. (C) Retinal thickness is considered borderline in the central area of the ETDRS grid where it appears yellow, falling within the bottom 5 per cent of the normal population, whereas the red area is considered outside normal limits, falling within the bottom 1 per cent of the normative population

normal limits thickening, respectively), the practitioner should be looking for conditions which can cause retinal thickening, most commonly oedema in wet AMD.

● B-scan analysis

Viewing the shadowgram, temperature thickness plot and ETDRS grid are very useful, but individual B-scans provide the most information to the practitioner. Therefore, no macular analysis is complete without viewing each B-scan in turn. Subtle defects (including early signs of wet AMD) may be missed if each B-scan is not studied as they may not be evident in the temperature thickness plot or ETDRS grid.

With AMD being the principal cause of irreversible blindness among those aged over 65 years in the West,[12-14] it is not surprising that signs of both wet and dry AMD are among the most common abnormalities viewed in macular scans. Dry AMD, characterised by drusen within the macular region, is the most common type, accounting for up to 90 per cent of all cases of AMD.[15] On OCT examination, drusen appear as focal, hyper-reflective elevations of the RPE, disrupting the typically straight and smooth RPE (Figure 6A).

Development of choroidal neovascularisation (CNV) is the hallmark of wet AMD, a stage found in approximately 10 per cent of all AMD cases.[15] CNV on OCT examination typically presents as increased reflectivity of the RPE, often associated with irregular RPE elevation (Figure 6B). Leakage of these new blood vessels causes development of fluid, which appears as dark spaces within the B-scan. Fluid may be classified as intra-retinal when it is found above the photoreceptors, sub-retinal when it forms below the photoreceptors but above the RPE (Figure 6B), or sub-RPE, when it forms below the RPE. In cystoid macular oedema, a condition which is also associated with diabetes and branch retinal vein occlusion, intra-retinal fluid forms characteristic cystic spaces (Figure 6D).

Signs of persistent vitreomacular traction is another common observation in macular OCT scans (Figure 6C). Where vitreomacular traction is seen as a thin, moderately reflective band which is pulling on the retina in an incomplete v-shaped posterior vitreous detachment (PVD). As OCT has enabled practitioners to view the interaction between the retina and vitreous for the first time, it often causes most questions with regards to best patient management. If the patient is relatively asymptomatic and vitreoretinal traction is a chance finding, patients should be advised regarding self-monitoring with an Amsler grid,[16] and reviewed to see if spontaneous resolution occurs. However, it has been reported that spontaneous resolution only occurs in approximately 10 per cent of patients.[17] If vitreoretinal traction has resulted in significantly reduced vision, referral should be made to ophthalmology for consideration for treatment with vitrectomy or ocriplasmin.[16]

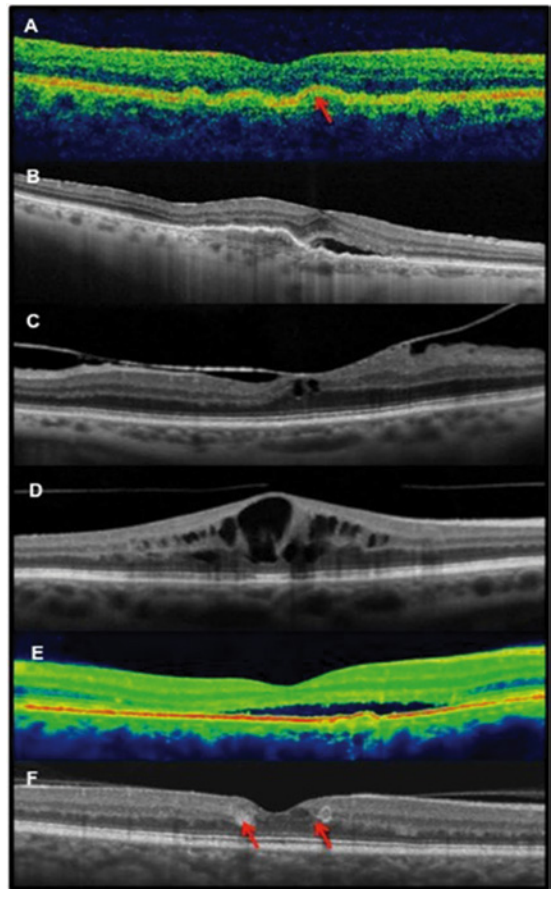

Figure 6 OCT B-scans showing (A) drusen (red arrow); (B) wet AMD with subretinal oedema; (C) vitreomacular traction; (D) cystoid macula oedema secondary to BRVO; (E) sub-retinal oedema in CSR; (F) exudates (red arrows) in diabetic maculopathy

● Part 2 will look at the scanning of the optic disc.

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