Country	CET/CPD information	Audience	Competencies	MCQs
UK	This article offers 1 non-interactive CET point (C-73777)	General Optical Council Approved CET For Optometrists	STANDARDS OF PRACTICE; OCULAR EXAMINATION; OCULAR DISEASE	6
ROI	All articles are CPD accredited in the Republic of Ireland			6

OCT and Medical Retina

by **Jason Higginbotham** BSc(Hons) MCOptom FBDO

Outline

This article examines how clinicians can use OCT images relating to a range of retinal lesions to aid diagnosis and clinical decision making.

About the author

Jason Higginbotham is an Optometrist and Dispensing Optician with over 27 years' experience in the field. Jason achieved a high level of academic success before working in independent and multiple practices, owning his own practices, working in refractive laser, working in IOL clinics, working in hospital low vision clinics and in domiciliary optometry. Jason is currently undertaking an MSc in Optometry and is then proceeding to complete a taught PhD in Ophthalmology. After joining Birmingham Optical, Jason has been promoted to the position of Director of Medical and Education and has been providing training and CET lectures on a range of instruments and diagnostic techniques, including refractive laser, corneal surgery, OCT, dry eye assessment and other subjects. Jason has undergone extensive training with several manufacturers on numerous complex devices and is widely respected for his comprehensive training and CET sessions.

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The learning objectives for this article are:

2.7.2 Optometrists will have an enhanced understanding of the use of OCT for retinal assessment and diagnosis of a range of retinal abnormalities

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

6.1.5 Optometrists will have an enhanced understanding of the identification of a range of retinal abnormalities and conditions using OCT

Introduction

In Part 1, you will have learnt about the basic principles of OCT and looked at the various scan types. You should now recognise the retinal layers and normal anatomical features, and be able to understand retinal thickness maps. **It is very important to stress that learning what is normal is the best way to understand what is not.** Before examining specific retinal pathologies, we'll briefly revisit what a normal retinal B-scan looks like and what normative data tells us.

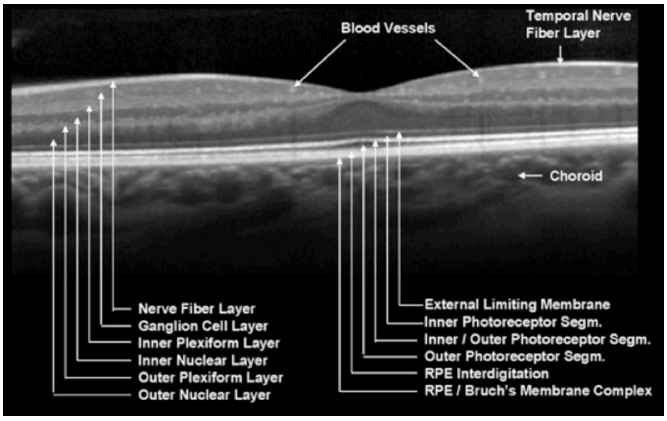
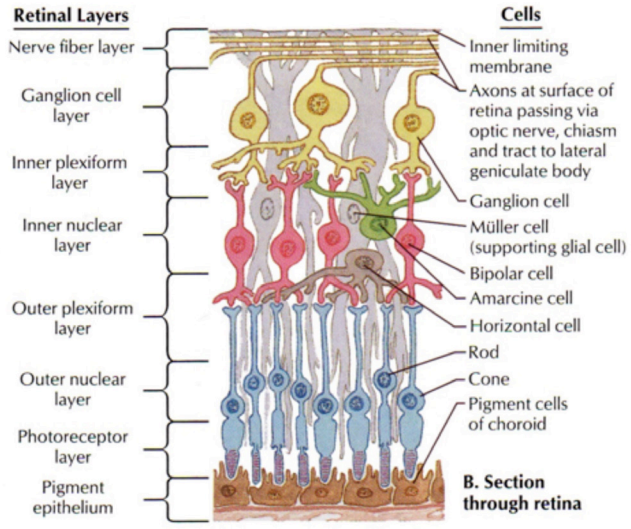


Figure 1: OCT image of retinal layers

In Figure 1, aside from the expected retinal layers, we can see the external limiting membrane (ELM) as an extra layer within the outer nuclear layer (ONL) composed of the cell nuclei of the photoreceptors. You can see that the retinal pigment epithelium (RPE) and Bruch's membrane are essentially one layer, with minimal separation between them; the universal nomenclature for these two layers is the RPE Bruch's complex (RPE/BM complex). If Bruch's membrane appears clearly separate from the RPE, this is a form of pigment epithelial detachment (PED).

Figure 1 also shows the normal profile of the foveal pit. Note the dark line for the outer segments (OS) of the photoreceptors. At the fovea, this line thickens— it is thickest at the centre of the fovea (the foveola). Here, there are only cones, and their outer segments are elongated to increase surface area and volume of the photopigment discs.

You can also see that the ONL is thickened centrally as expected. This is due in part to the 1:1:1 connection between central cones, bipolar and retinal ganglion cells (RGSs), as well as the outward shift of the nuclei of the retinal support cells away from the foveola. Remember that this thickened part of the OS is normal at the foveola and must not be mistaken for pathology.



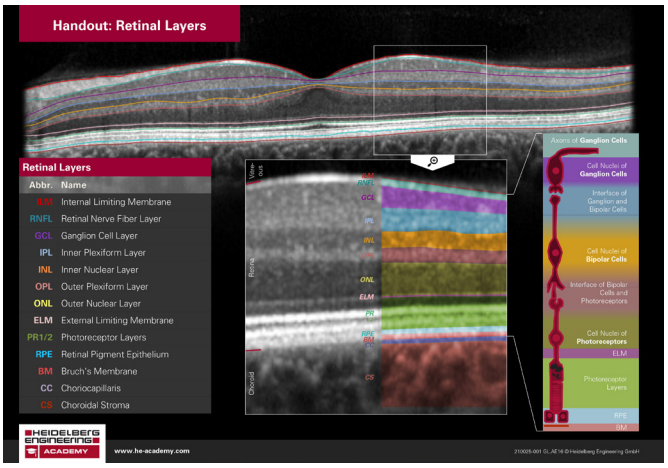


Figure 2: Recap of retinal layers

Figure 2 show how certain layers are hyperreflective and others are hyporeflective. On positive black and white scans, it is clear that the hyperreflective layers are the:

- RPE/BM complex
- Inner segments of the photoreceptors (IS)
- Retinal nerve fibre layer (RNFL) – though this tends to be slightly less hyperreflective than RPE/BM or IS

Other layers have varying degrees of reflectivity, but those that tend to be the most hyporeflective are the:

- Outer segments (OS) – the most hyporeflective layer
- Outer nuclear layer (ONL)
- Inner nuclear layer (INL)

On false colour scans (Figure 3), the most hyperreflective layers appear as 'hot' colours, like reds and oranges, whereas the more hyporeflective layers appear 'cooler', like blues and green.

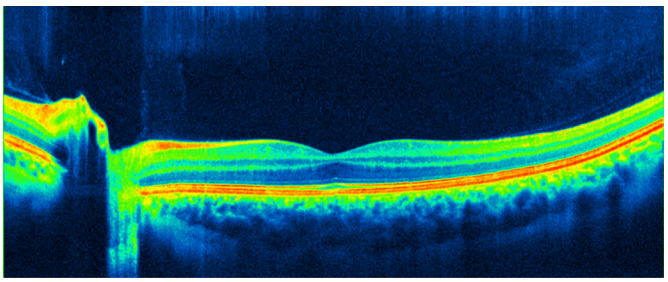


Figure 3: False colour scan

On negative black and white scans (Figure 4), the more hyperreflective layers appear darkest and the more hyporeflective layers appear brightest.

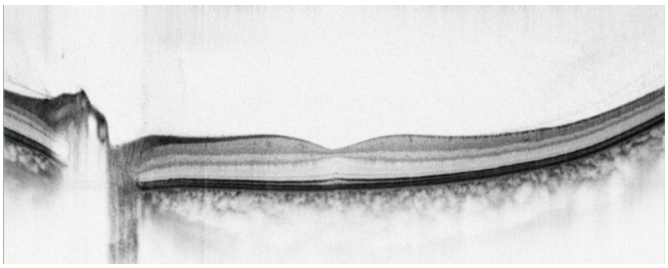


Figure 4: Negative black and white scan

Most OCT devices give you the choice of viewing scans as black and white (positive or negative) or as false colour. It is down to your personal preference, but this author does find false colour images slightly grainier and harder to view sometimes.

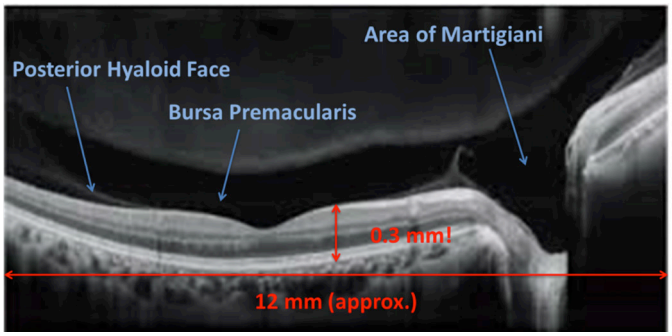


Figure 5

It is very important to remember that OCT scans are always hugely stretched vertically. This is evident when looking at Figure 5, where it is clear the scan is not to scale. This is done by the computer to allow easier differentiation of layers and discerning structures or lesions.

From Figure 5, you will also notice what initially looks to be a posterior vitreous face detachment (PVD). However, if you look more closely, the posterior hyaloid face is intact and correctly positioned at the inner limiting membrane (ILM), loosely attached at the fovea and firmly attached at the optic nerve head (ONH). You can see a 'hollow' area of the vitreous called the Bursa Premacularis. This is sometimes easier to see in false colour (as in Figure 3). The 'hollow' area above the disc is called the Area of Martigiani. These are physiologically normal parts of the vitreous and should not be mistaken for PVDs.

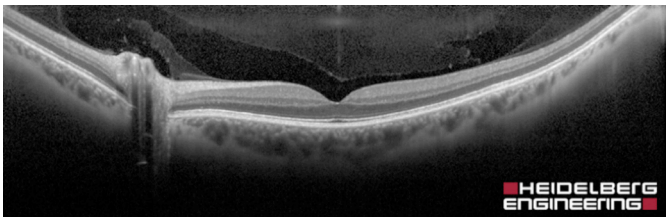


Figure 6: Another example of a wide field scan showing pre macula bursa

Scan types

Volumetric scans

In Part 1, you will have learnt about the many different posterior scan types available on most OCTs. One of the most important scan types is a volumetric scan, also known as a 3D cube scan, a mesh scan or a map scan. These scans can be used to measure tissue thickness, usually at the macula and the optic nerve head, and compare it to a normative database.

Before looking at specific pathology, it is worth understanding the way the data is presented on such volumetric scans.

Macula map scans

The macula map is a scan of the posterior pole, covering the macula area, sometimes stretching as wide as a standard colour fundus image (45°). The scans typically range in size from 6 x 6mm to 12 x 9mm. Most OCTs use a normative database covering 6 x 6mm; some cover 9 x 9mm (increasing the diagnostic value of the volumetric scans).

Macula maps typically provide information on the overall retinal thickness, a measure of the ganglion cell layer (GCL) or the ganglion cell complex (GCC), and comparison of these measurements against normative data.

Thickness temperature maps

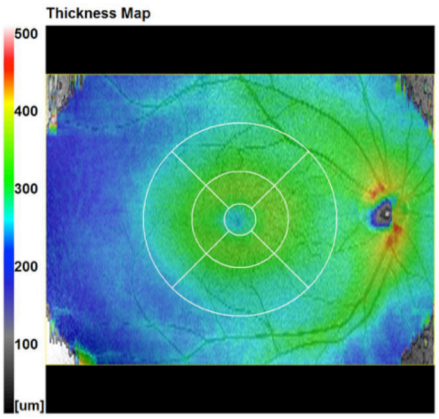


Figure 7: Retinal thickness map

In Figure 7, you can see a map of the posterior pole including the macula and optic nerve head. There is a scale on the side showing total retinal thickness (ILM to the RPE/BM complex) in microns. The cooler colours represent thinner areas, whereas warmer colours represent thicker areas. You can see that a normal image like this has a thinner central foveal zone (as expected) and an area of thickening around the superior and inferior ONH and following the main vessel arcades and nerve fibre bundles.

Clinicians sometimes ignore these thickness temperature maps, but they can have some use for immediate understanding of the presence of certain problems.

In Figure 8, we can see there is a round white patch at the central macula. It appears white as it is off the thickness scale. It is immediately evident from this image that there is a very raised central lesion. Furthermore, because the lesion is rounded and regular, it is very likely that it is caused by some form of leakage/ oedema lifting and separating the retina or layers of the retina (in this case central serous retinopathy [CSR]).

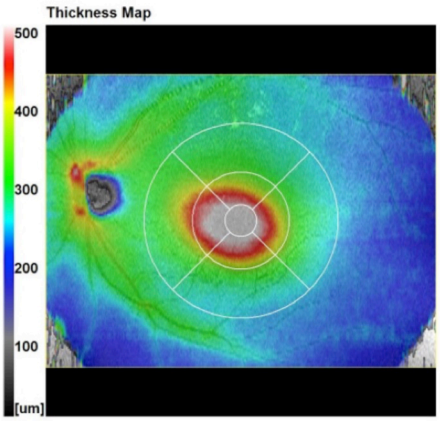


Figure 8: Round, regular central raised lesion

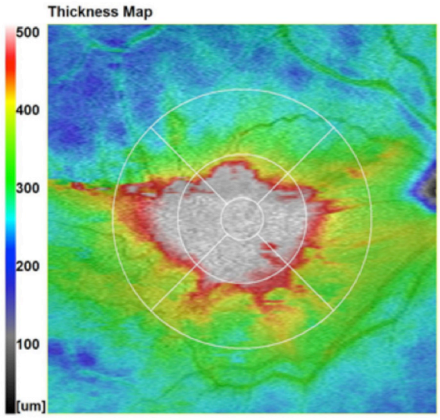


Figure 9: Irregular larger lesion

In comparison, in Figure 9, the raised white area is far more irregular and widespread — this usually indicates tractional lifting or very severe oedema causing widespread detachment (in this case an epiretinal membrane [ERM]).

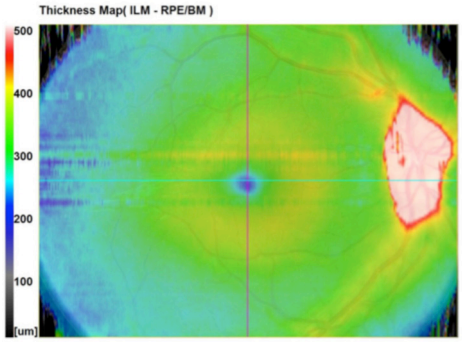


Figure 10: Very raised disc

Figure 10 shows that the whole disc area and the surrounding retinal tissue is very raised. Where such an extensive area is raised, it is likely to be papilloedema.

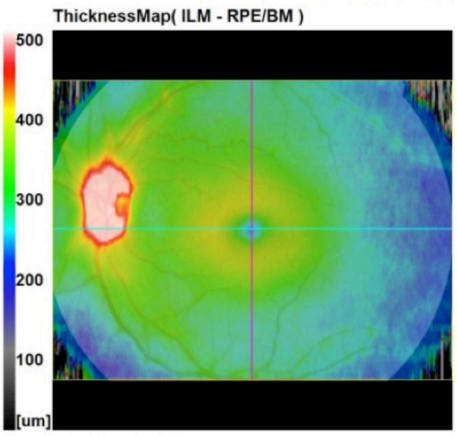


Figure 11: Slightly raised disc

In Figure 11, although the disc is raised, there is still some cup visible. This is likely to be caused by buried disc drusen (see later).

Normative data charts

Most OCTs provide a chart which represents statistical analysis of tissue thickness compared to normative data. Therefore, it is essential that, when entering new patient data into the OCT, you input their age, gender and ethnicity correctly. Also, please ensure that where a patient has been transferred to an OCT patient database, such as previous colour fundus data, you will need to ensure that age, gender and ethnicity has been entered for these patients too.

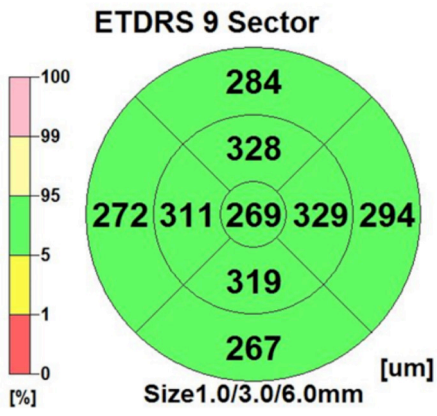


Figure 12

The ETDRS chart shown in Figure 12 was not originally designed for OCT — it came from the Early Treatment Diabetic Retinopathy Study some decades ago. The chart originally helped study centres map out areas of the macula. Here, it is used in OCT to map out macula sectors. The numbers in each sector represent average total retinal thickness in that sector. The colours used here are not like the thickness temperature map. Instead, they represent a probability score.

The colour scale on the side of Figure 12 represents 100% of the normal population within the normative database. Imagine that this scale actually represents a normal distribution (Bell or Gaussian curve; Figure 13)

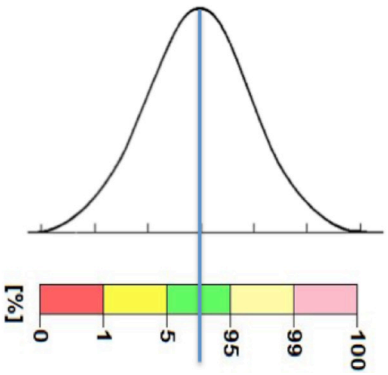


Figure 13

It is now clear that the green represents the central 90% of the normal population. This means that each green sector is the same thickness as 90% of normal data. This does not mean there is definitely no pathology present, but that there is less likely to be.

The bright yellow colour is the first standard deviation (SD) thinner; 1–5% of the normal population would have a retina that thin. Red is the second SD thinner; 0–1% of the normal population would have a retina that thin. Likewise, 'lemon' is the first SD thicker; 1–5% of the normal population would have a retina that thick. Pink is the second SD thicker; 0–1% of the normal population would have a retina that thick.

Again, yellow and red areas do not immediately mean that pathology is present and these should not be used as a 'traffic light' system. For example, a high myope could have a thin retina in comparison to most of the normal in his/her age, gender and ethnic group. The ETDRS could be red all over, but may well be normal for such a patient. In such circumstances, you must take into account all the other information presented to you by the patient, other tests and previous records.

The author has found that where there are pink sectors on the ETDRS, although it could be normal, it is far less likely to be than if red. So, for example, the ETDRS for the patient in Figure 8 was all pink and was highly unlikely to be normal (it turned out to be a CSR).

As seen in Part 2 on glaucoma, some devices measure the thickness of the ganglion cell layer (GCL) alone, some measure the GCL with the inner plexiform layer (IPL) and some measure what is called the ganglion cell complex (GCC). The GCC is the innermost five layers of the retina (ILM, RNFL, GCL, IPL, INL). It is now well known that the GCC is affected by glaucoma and the whole GCC shrinks during the disease process, often showing thinning before the RNFL at the disc. However, there is a lot of physiological variation in ocular structure and the most frequent sites of axonal injury are the inferior and superior poles of the optic nerve head which have a lot of fibres from outside the macula. Variations in optic nerve head (e.g. myopic, tilted etc.) can affect RNFL measurements but manufacturers have addressed this with a wider normative data base and use of Bruch's membrane opening as a landmark to guide scans.

Focal GCC loss/rate of global RNFL change/macular ganglion cell layer complex are all important measures in the detection of glaucoma. It is important to take accurate, repeated scans over time to demonstrate progression or non-progression.

Most patients will have seen a colour fundus image, or you may have a picture of one in your consulting room. I like to say 'Imagine that this picture of the back of the eye is like the top of a cake. The colour picture is the icing on the cake, but we know there are layers underneath, but we can't really see them properly. OCT allows us to take a slice through the cake and turn it side on so we can see the layers going down. This helps us spot all kinds of conditions much earlier than when using a camera or looking directly into the eye. With En Face OCT, instead of taking a slice through the cake, we peel off the icing at look at the layer underneath and we can peel off layers to look at underlying layers going through the retina.' This analogy can be useful when describing OCT to patients and they tend to understand the value of OCT this way.

Shadows, reflectivity and reverse shadows

Some structures like larger blood vessels, exudate and vitreous floaters cast shadows on the B-scan. Some layers are more hyperreflective than others, while others are more hyporeflective. There are also circumstances where, due to loss of RPE in particular, there is reverse shadowing or a 'window defect' in the choroid.

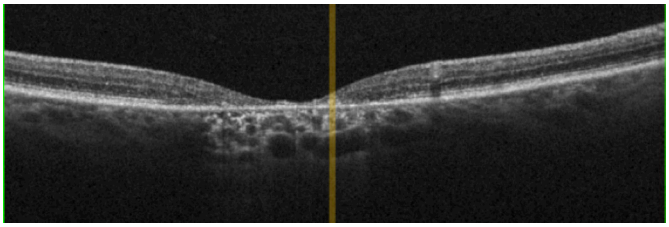


Figure 14: This rather extreme example shows a cone dystrophy. Choroidal vessels are more brightly visible

From experience, blood in the inner retina and above Bruch's membrane, normally casts a shadow. When the blood is where it should be (i.e. within a vessel) the shadow tends to be minimal and retinal layers are still discernible below. Where the blood has leaked (i.e. haemorrhage), the shadow is denser and often none of the layers below (outer) are seen. Where the leaked blood is fresh, it tends to be hyporeflective in most cases and where the leakage has become exudative, it is very hyperreflective and the shadow is often the densest with no layers visible underneath.

Thick areas of pigment, vitreous floaters, large blood vessels, hard exudates and leaked blood are the main causes of shadows.

Key lesion and fluid types

Drusen

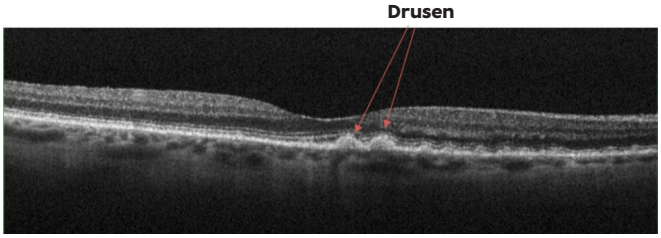


Figure 15: Drusen

As can be seen in Figure 15, drusen do not cast shadows. Drusen are cellular deposits made up of membrane proteins (e.g. vitronectin, clusterin), complement activators, amyloid, lipofuscin, cholesterol, immunoglobulins, immune complex, glycation products and more.

They always occur between the RPE and Bruch's membrane and as such are pigment epithelial detachments (PEDs). Sometimes they are referred to as drusenoid PEDs. Generally, small drusen have a similar slightly hyperreflective appearance as the RPE; larger or older drusen can appear less hyperreflective and more 'empty' (Figure 16). It is important to differentiate an 'empty' drusenoid PED from a serous PED (see later).

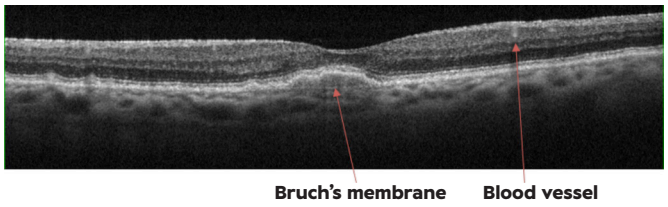


Figure 16: Large drusen

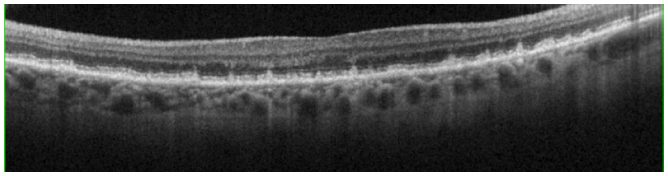


Figure 17: Tiny drusen (often termed familial or autosomal drusen)

Pigment epithelial detachments (PEDs)

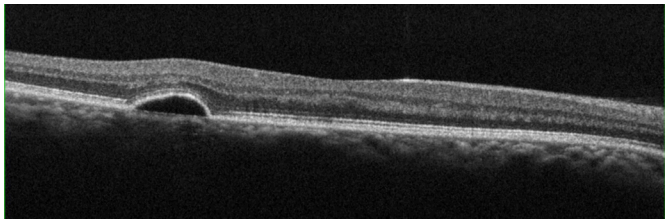


Figure 18: Serous PED

From Figure 18 it is clear that the PED is serous as the space under the RPE and above Bruch's membrane is completely hyporeflective. You will never find empty/hollow spaces; they will always fill up with fluid. Where the fluid is clear/serous, there is no reflectivity and the space is totally black. We know it is a PED as Bruch's membrane is separate from the RPE/BM complex, which should not be the case.

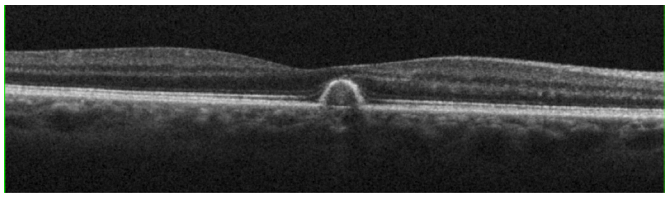


Figure 19: Turbid PED (non-serous/drusenoid)

In Figure 19, it is evident a PED exists, but the space is not totally black and so this slightly hyperreflective space is either turbid fluid or drusenoid deposits. Turbid fluid tends to present where new blood leakage or CNV vessel 'leakiness' leads to blood-related contents mixing with serous fluid. Turbid fluid, therefore, often represents neovascular potential. However, it should be noted that drusenoid PEDs contain solid matter that can sometimes look slightly similar to turbid fluid.

In longstanding AMD, it is possible that you will see old, drusenoid PEDs and newer serous PEDs. This can signify a risk of change from dry to wet AMD and thus it is important to be sure which types of PED are present. In such circumstances, other types of fluid may also be present.

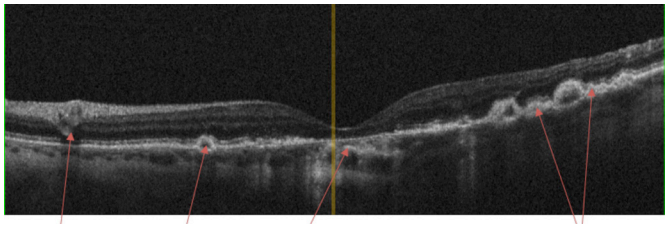


Figure 20: Drusen, serous PEDs and geographic atrophy

Exudate and haemorrhages

As previously mentioned, blood usually casts a shadow on OCT B-scan images. It is useful to look at a few examples before we start to examine specific conditions.

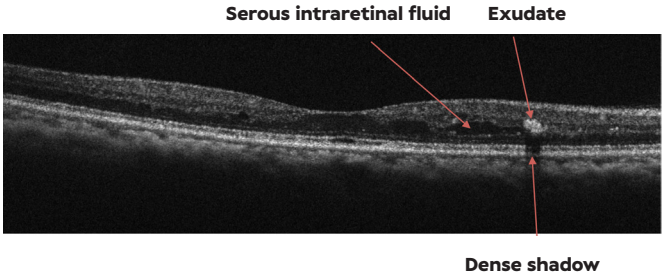


Figure 21: Exudate

In Figure 21, you can see the hyperreflective nature of exudate. Most exudate, particularly from diabetic eye disease (DED), will appear around the IPL and INL generally. Note the dense nature of the shadow with little or no visibility of outer layers.

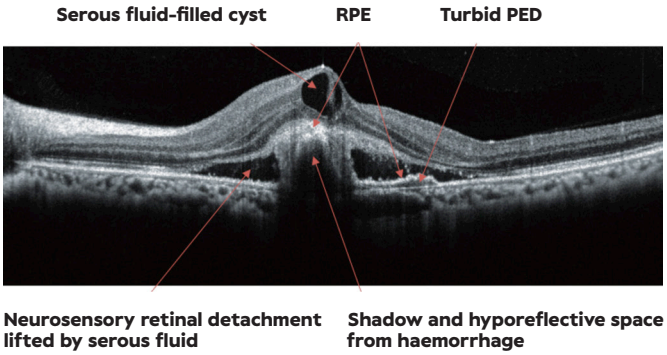


Figure 22: WET AMD showing central haemorrhage

Summary

OCT enables the identification and assessment of the individual retinal layers. By utilising the various scan types and measuring tissue thickness, clinicians can gain a focused view on an area of interest. This article has provided an overview of the main causes of shadow on an OCT image and highlighted the appearance of common lesions (e.g. drusen and PEDs). An in-depth understanding of what a normal OCT image should look like, alongside the knowledge of the expected appearance of anatomical anomalies, will allow for the accurate detection of abnormal features before signs are visible at the retinal surface.

