

How to read OCTs: 8 fundamental diseases

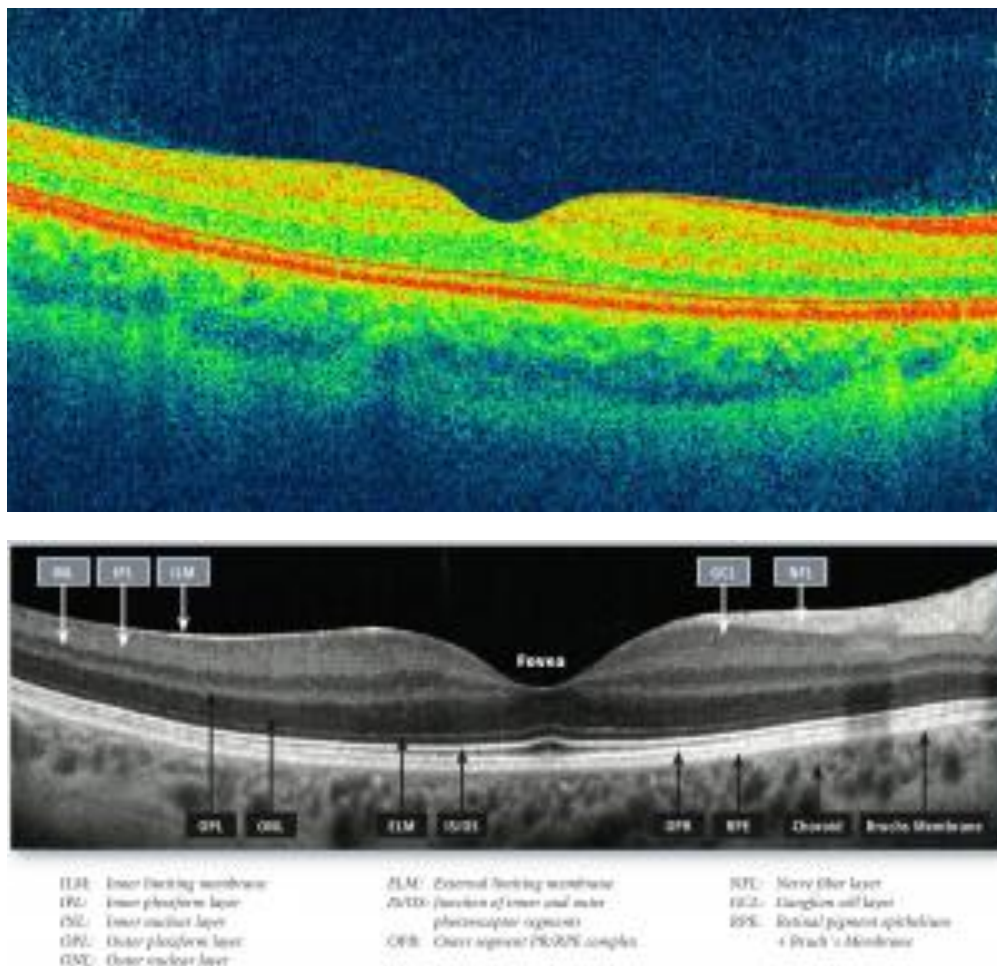
Want to accelerate your learning curve? Train your brain with our [OCT Mastery Trainer](#).

Listed here are 80-90% of the OCTs that you are going to be seeing. Most OCT is used for imaging the retina, so that's what we'll focus on. It's revolutionized the field of retina, helped us revise the pathophysiology of multiple diseases based on OCT evidence, and is a standard for the treatment of multiple macular diseases.

About OCT

Optical coherence tomography is a non-contact, high-resolution, in vivo imaging modality. It produces cross-sectional tomographic images just like ultrasound. Decreased OCT image quality can be attributable to cataracts which block light, patient motion artifact, or any other media opacity.

View of the normal retina with OCT

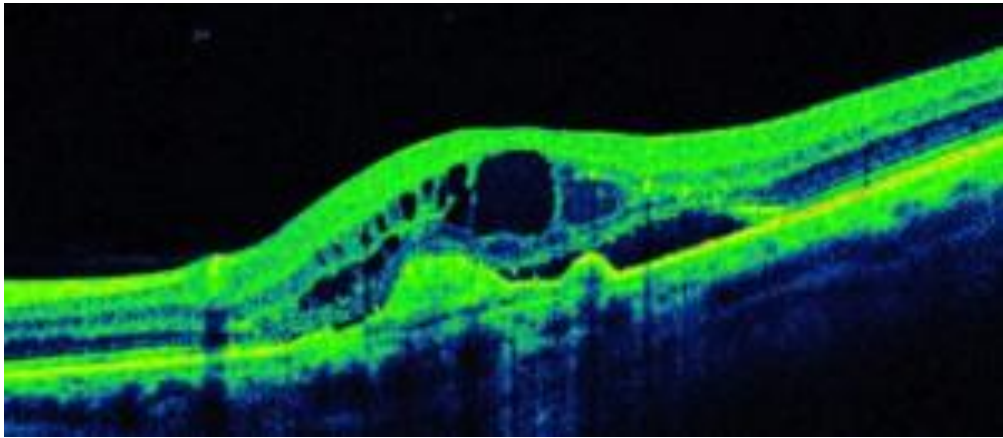


The macular OCT can be used to evaluate the premacular vitreous, macula, and choroid. We'll look at the OCT through a number of common diseases.

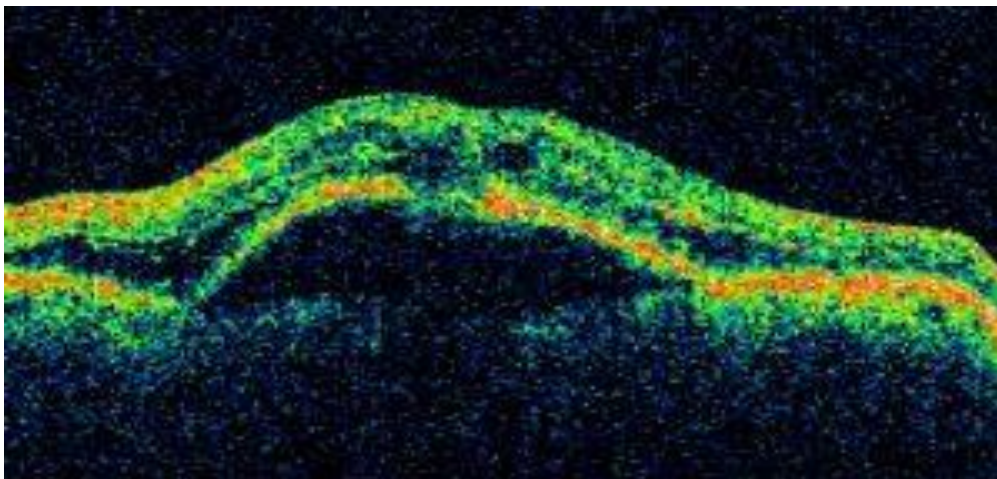
Below, we've highlighted a few diseases with their common OCT findings:

View of the retinal pathologies with OCT

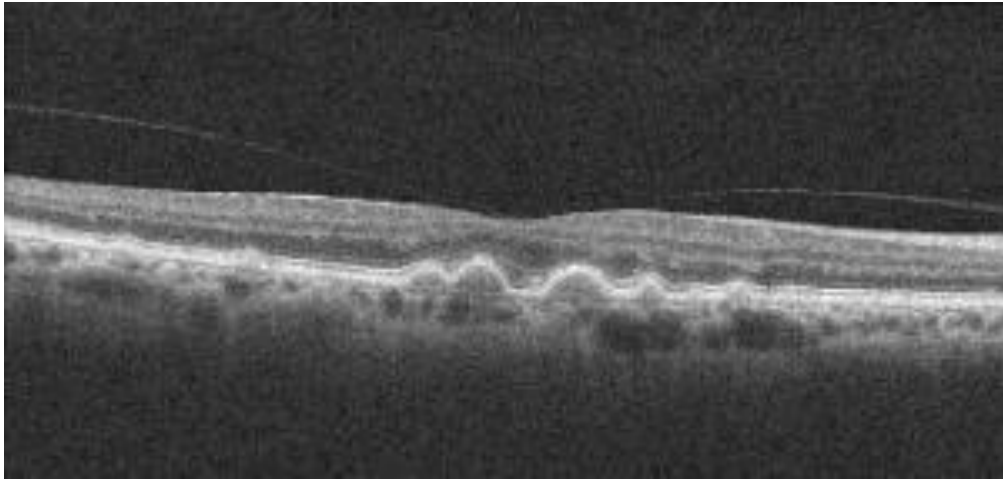
Age-related macular degeneration (AMD)



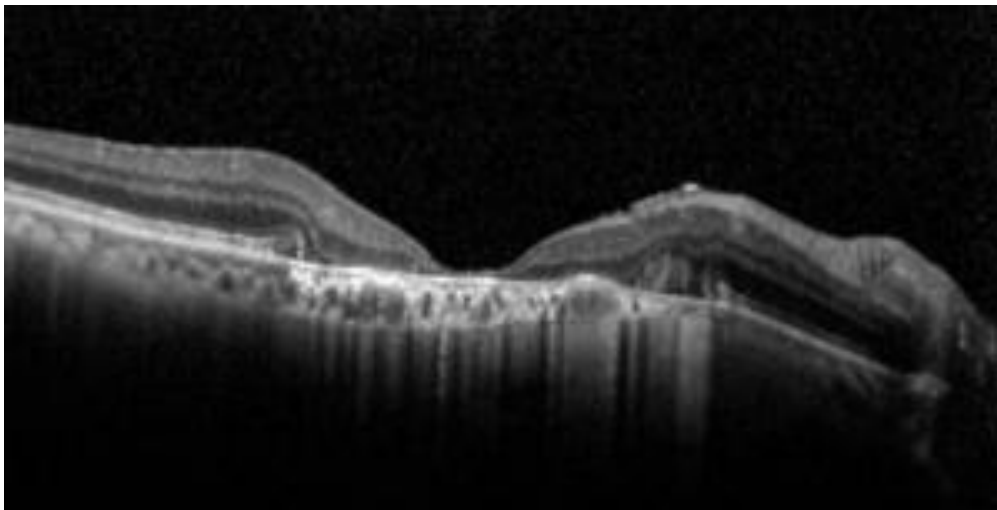
Wet AMD leads to intraretinal fluid (IRF) and subretinal fluid (SRF) accumulation. The choroidal neovascular membrane (CNV) can be visualized.



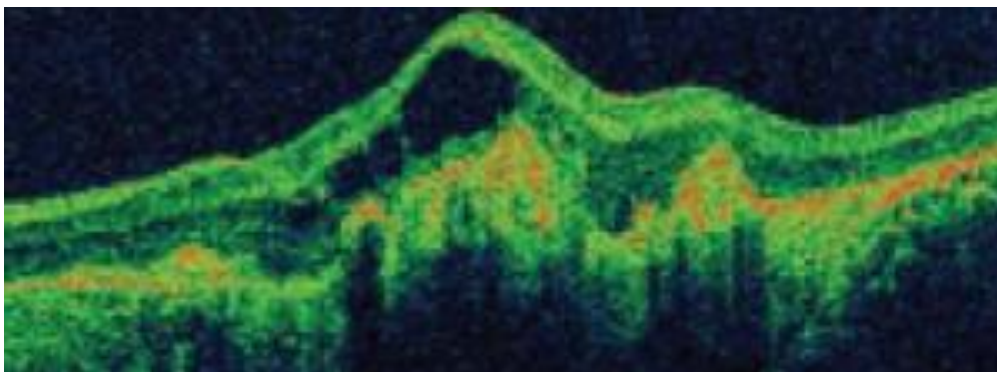
This is an OCT of a pigment epithelial detachment (PED) in wet AMD with some adjacent subretinal fluid (SRF) and an overlying area of focal intraretinal fluid (IRF).



Drusen: Lumps of deposits under the RPE.

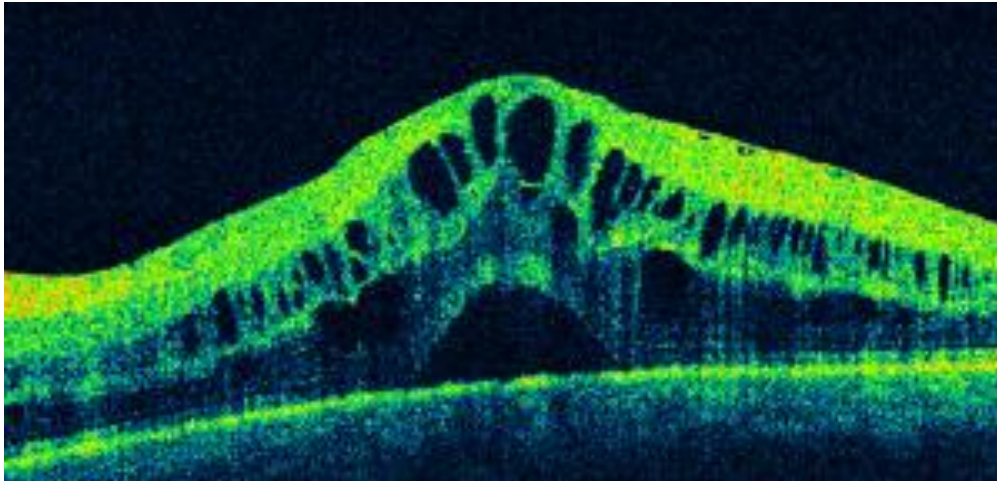


Geographic atrophy: Atrophy of the outer retinal layers with OCT signal penetrating deeper into the choroid.



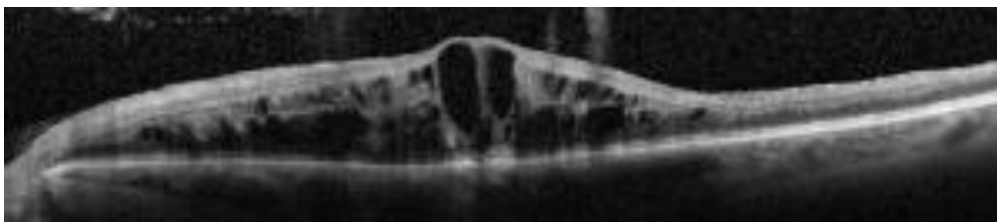
Another example of wet AMD: Eyes show fibrovascular pigment epithelial detachments (PEDs), neovascular membranes and subretinal fibrosis along with fluid.

Diabetic macular edema (DME)

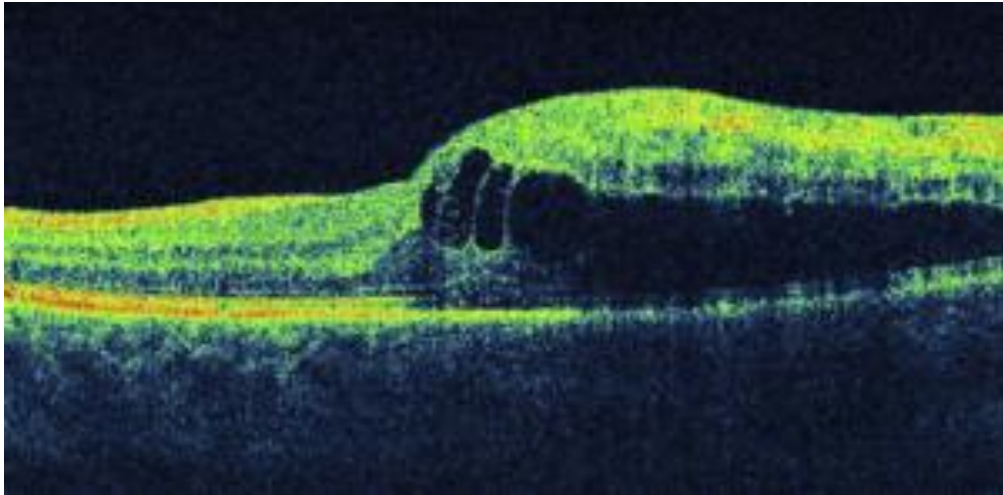


This is classic DME with cystoid intraretinal fluid pockets in the outer plexiform layer (OPL). Subretinal fluid (SRF), which is present in severe DME, is also seen here.

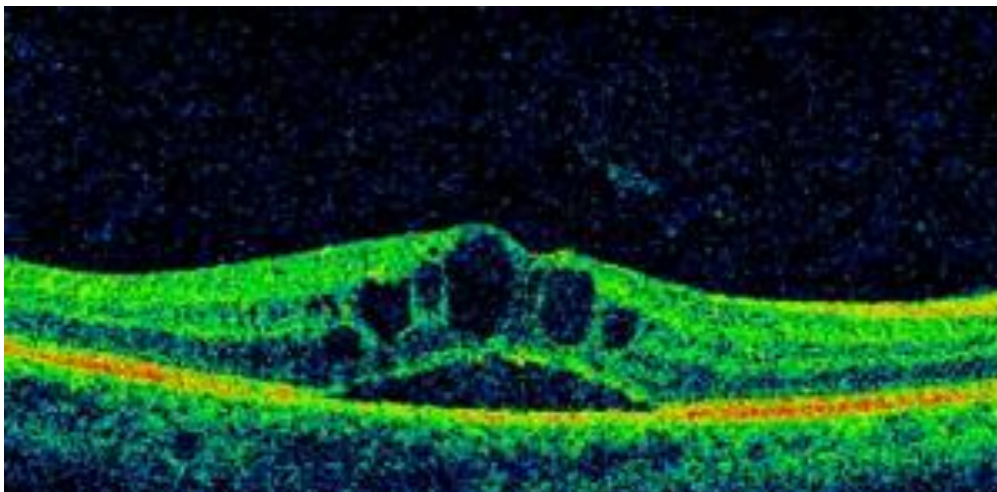
Retinal vein occlusions (RVOs)



This central retinal vein occlusion (CRVO) causes severe cystoid macular edema (CME). There isn't a clear differentiation between CME from CRVOs and CME from diabetic retinopathy on OCT, but the fundus appearance is obvious.

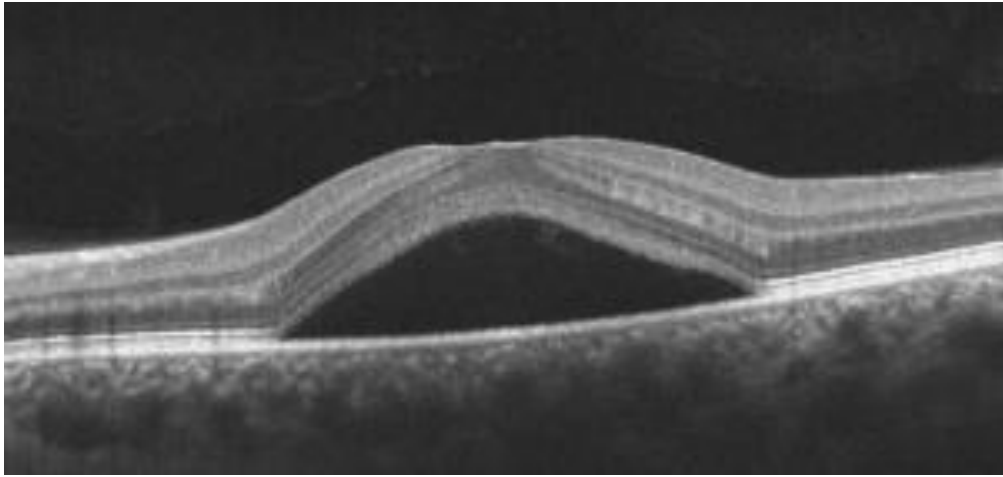


In comparison to CRVO, this branch retinal vein occlusion (BRVO) shows retinal edema on the temporal side of the macula, which is a more common finding in BRVO. You know it's the temporal side because the nasal side of the OCT has a thicker retinal nerve fiber layer (RNFL).

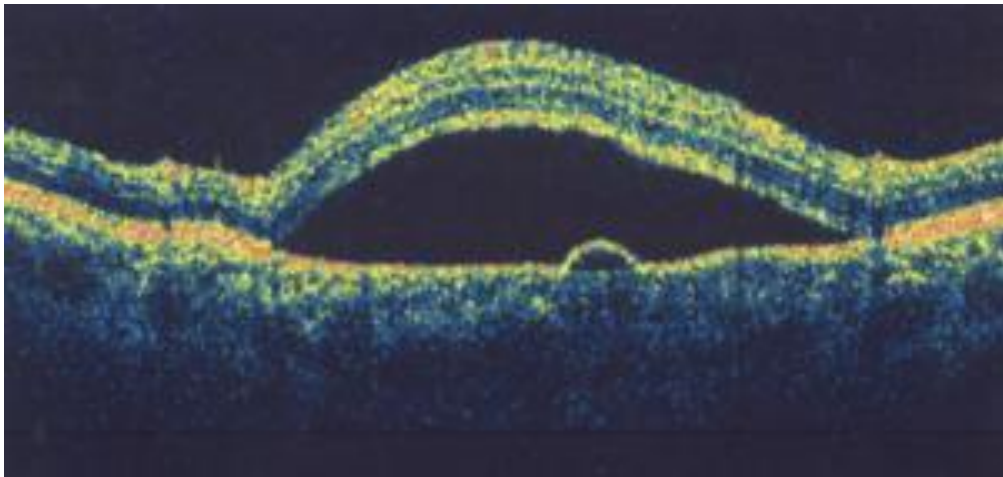


Here is a BRVO with central macular edema. Chronic RVOs lead to inner retinal atrophy, which is also characteristic of the disease.

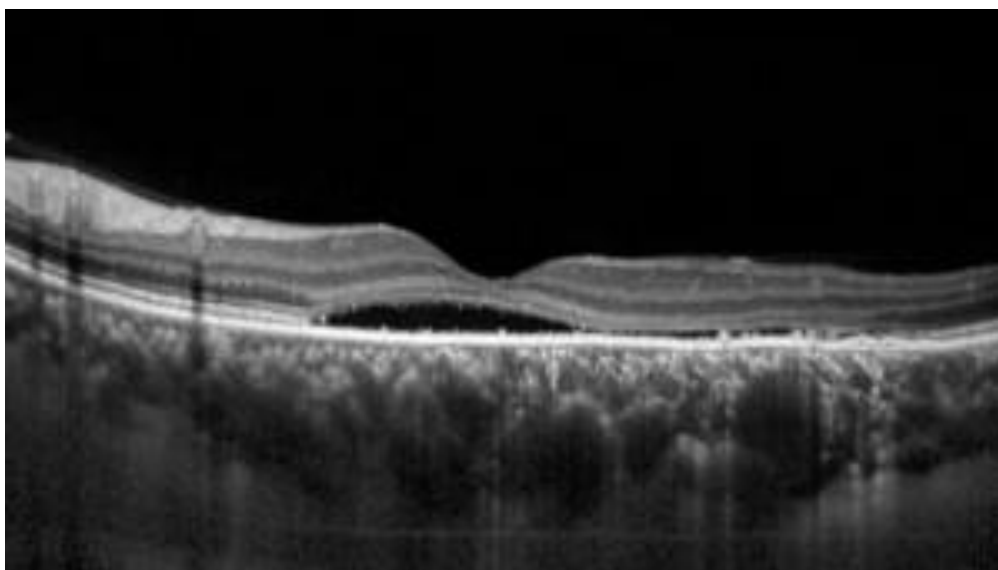
Central serous chorioretinopathy (CSR)



CSR has a central SRF collection, no intraretinal fluid (IRF), and a thickened choroid.

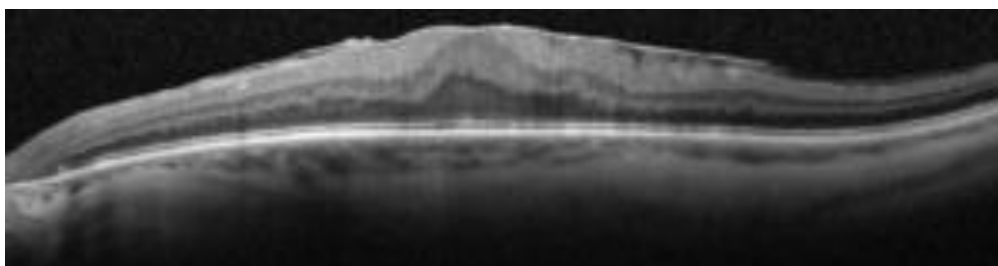


With CSR, there can often be a component of pigment epithelial detachment (PED) inside the area of serous detachment. These PEDs can be quite large.

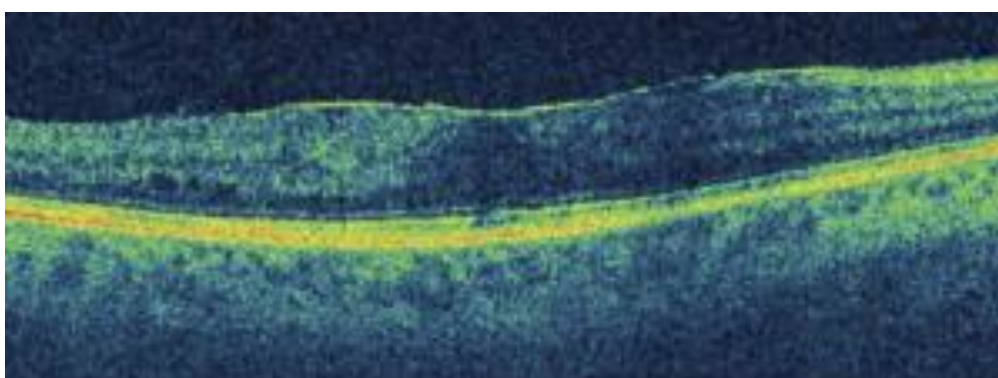


This example of CSR displays a very thick choroid.

Epiretinal membrane (ERM)

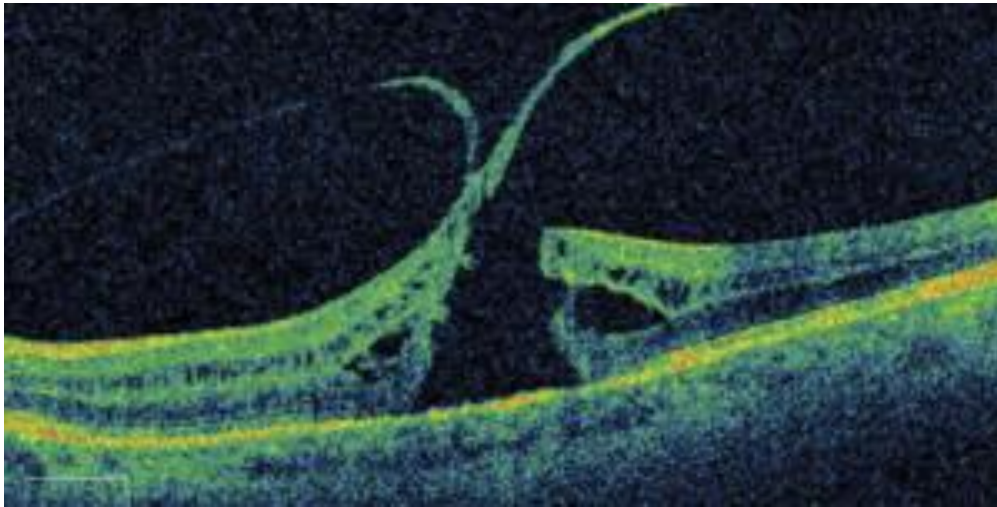


A dense epiretinal membrane (ERM) can be seen here leading to inner retinal wrinkling and distortion of the foveal contour. A severe ERM can also be associated with cystoid macular edema.

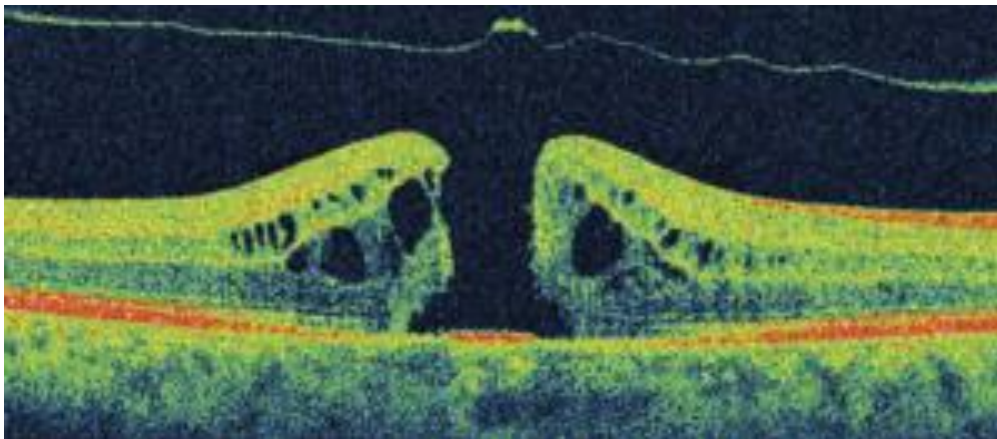


A mild-moderate ERM.

Macular Hole (MH)

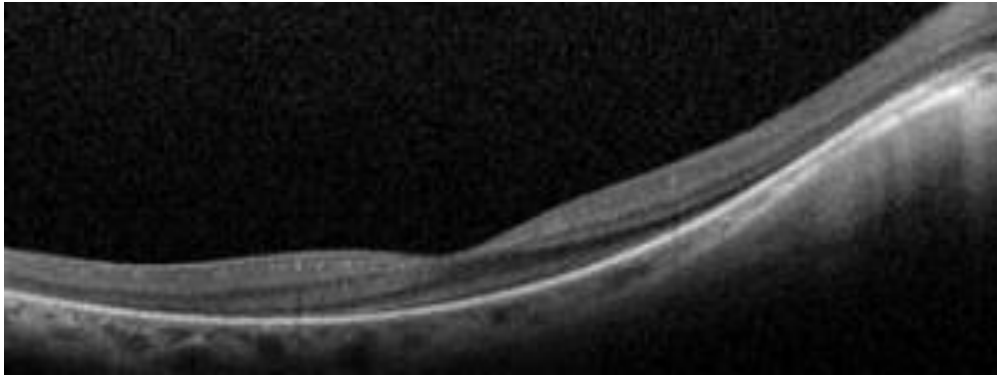


Full-thickness macular holes (FTMH) are very easy to diagnose with OCT. They are always a foveal, full-thickness defect that can have associated cystoid macular edema. Here, there is traction from the posterior hyaloid membrane that opens the hole in a “can opener” effect.

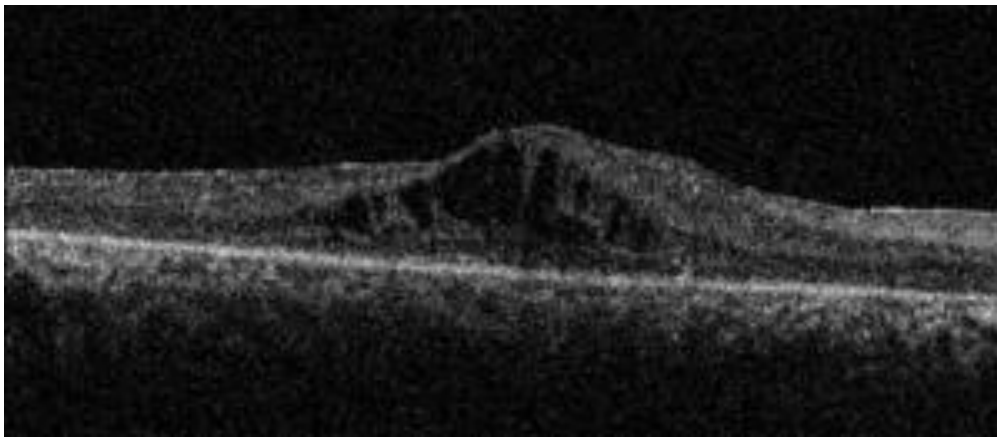


Here, the posterior hyaloid has separated, leaving a central operculum and a full thickness defect.

Retinitis pigmentosa (RP)

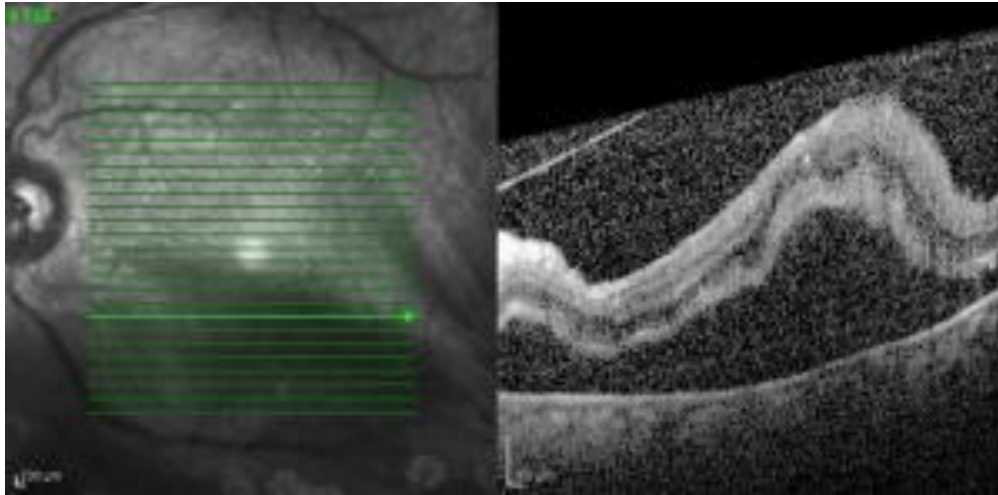


RP is a rod-cone dystrophy. The photoreceptor layer is completely lost except for a central island. Along with it comes thinning of the outer nuclear layer (ONL), which is where the cell bodies of the photoreceptor cells reside.



Vision loss from RP can also come from CME (cystoid macular edema) which is something to keep in mind for your RP patients. You can treat this with topical dorzolamide.

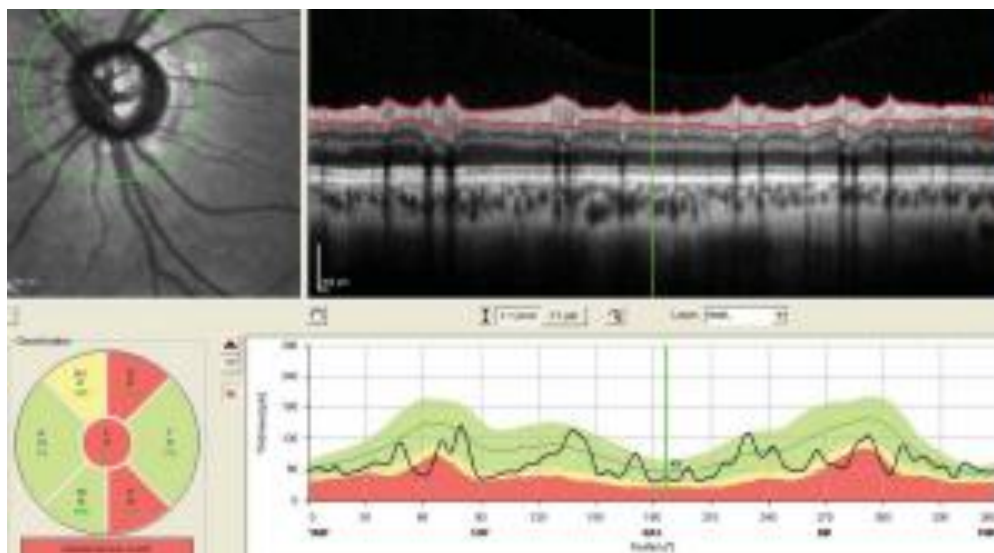
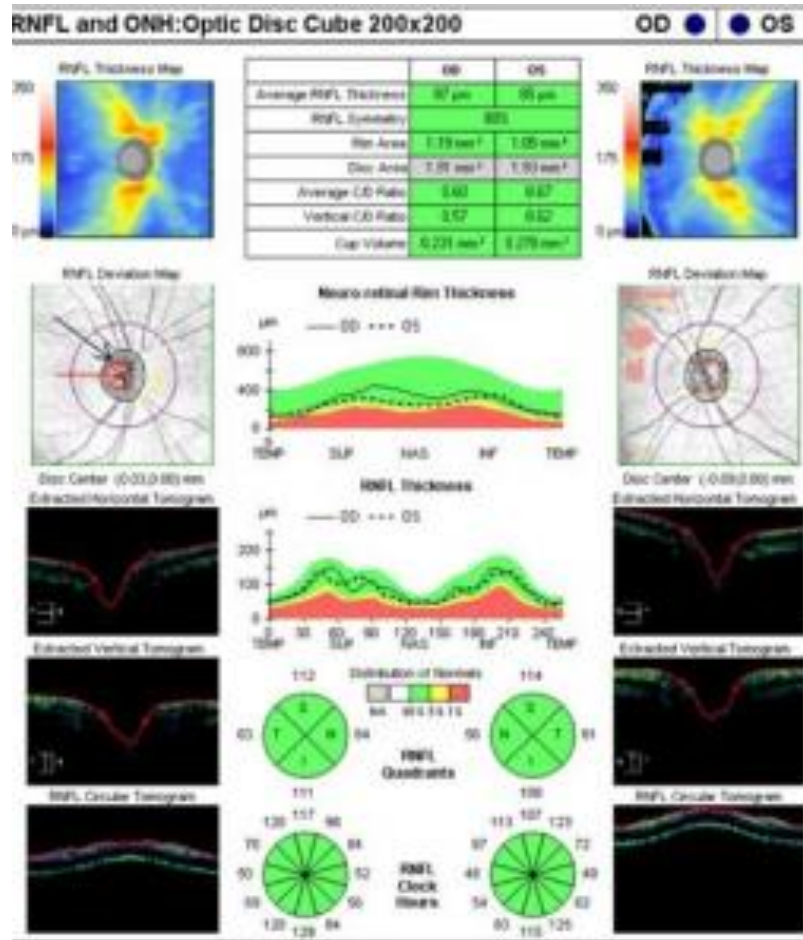
Retinal detachment



A retinal detachment is usually diagnosed clinically and with exam, but shallow macular detachments are sometimes hard to appreciate early on. If any doubt, a retinal OCT can demonstrate a detachment easily.

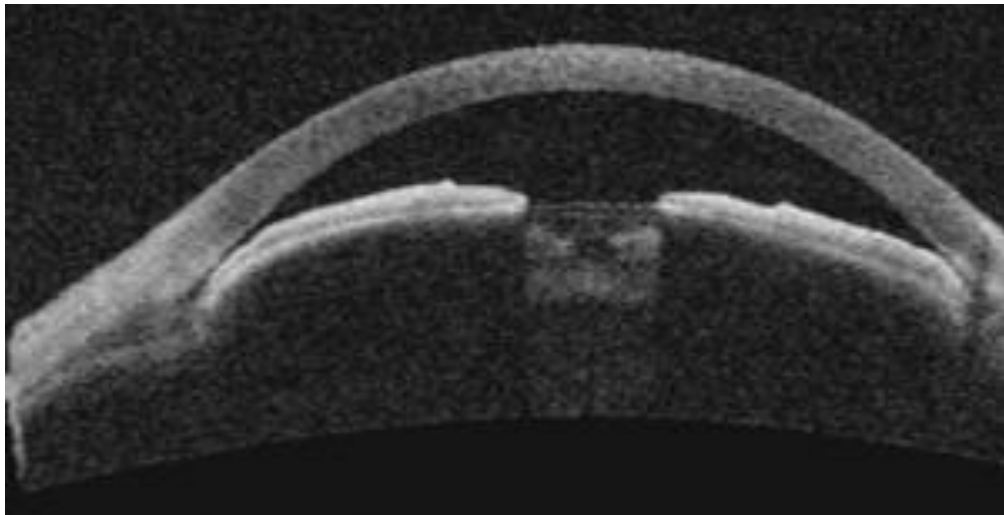
Optic nerve OCT

Optic nerve and nerve fiber layer OCT helps in the management of glaucoma. The OCT machines provide automated, serial analysis of the nerve fiber layer thickness, cup-to-disc ratio, and other measurements. They can compare the patient's optic nerve and nerve fiber measurements against age-matched normal patients to show areas of loss. These analyses have become an important adjunct to visual field testing in the treatment of glaucoma. It can also be used to track optic nerve edema.



Anterior segment OCT (AS-OCT)

Anterior segment OCT is most commonly used to evaluate the iridocorneal angle, such as for patients with narrow angles. It can also be used for corneal biometry to measure the thickness and steepness of the cornea.



AS-OCT of an eye with narrow angles.

Conclusion

- 1. OCT is a non-contact, cross-sectional imaging modality providing high-resolution images of the macula.**
- 2. Summary of the diseases in this article:**
 - 1. Wet age-related macular degeneration (AMD)**
 - 1. Intraretinal fluid (IRF) and subretinal fluid (SRF) accumulation**
 - 2. Pigment epithelial detachments (PEDs)**
 - 2. Diabetic macular edema (DME)**
 - 1. Cystoid macular edema (CME), intraretinal fluid pockets in the outer plexiform layer**
 - 2. SRF (subretinal fluid) if severe**
 - 3. Central retinal vein occlusions (CRVO)**
 - 1. Severe CME**
 - 4. Branched retinal vein occlusions (BRVO)**
 - 1. Retinal edema on temporal side of macula**
 - 2. Chronic RVOs lead to inner retinal atrophy, which is characteristic of the disease**
 - 5. Central serous chorioretinopathy (CSR)**

1. Central SRF (subretinal fluid) collection, no IRF (intraretinal fluid), and a thickened choroid
2. Can have PED (pigment epithelial detachment) inside the area of SRF (subretinal fluid) accumulation

6. Epiretinal membrane (ERM)

1. Inner wrinkling and distortion of foveal contour
2. Cystoid macular edema if severe

7. Macular hole

1. Foveal, full-thickness defect
2. Can have associated

8. Epiretinal membrane (ERM)

1. Inner retinal wrinkling and distortion of foveal contour
2. Cystoid macular edema if severe

9. Macular hole

1. Foveal, full-thickness defect
2. Can have associated CME (cystoid macular edema)

10. Retinitis Pigmentosa

1. Loss of photoreceptor layer, with sparing of a central island
2. Thinning of outer nuclear layer (ONL)
3. CME can be present (cystoid macular edema)

11. Retinal detachment

1. Usually diagnosed clinically and with exam, but OCT can be used to check shallow macular detachments

How to interpret corneal topography: 5 clinical uses

Angela Chen, B.S., Benjamin Lin, M.D., Shawn Lin, M.D.

***Note:** Technically, topography and tomography are different imaging modalities (explained below). However, both are colloquially referred to as topography. Except for our section differentiating between them, we will also refer to both as topography.

In this article, we will review what corneal topography and tomography are, why they are useful, and how to interpret a normal Pentacam scan. We will also review 5 clinical uses for topography that will prepare you well for cornea clinic.

Topography vs. Tomography

This is the technical distinction between topography and tomography:

1) Corneal **top**ography is a non-invasive imaging technique for mapping the surface curvature and shape of the **anterior** corneal surface.

- How it's done:
 - Placido disc (topography): Evaluates the cornea based on the reflection of concentric rings (mires).
 - Widely spaced rings = flatter
 - Closely spaced rings = steeper
- **Devices: Orbscan, Atlas, NIDEK OPD**

2) Corneal **tom**ography computes a 3-D image of the cornea and assesses the entire cornea, **anterior** and **posterior** surfaces. Nowadays, tomography is most commonly used.

- How it's done:
 - Scheimpflug imaging (tomography): Evaluates the cornea using a camera that captures cross-sections of the cornea as it rotates
- **Devices: Pentacam, Galilei, Sirius**

Utility

- Management of astigmatism in cataract surgery and after corneal transplant
- Screening candidates for refractive surgery by identifying irregular astigmatism and helping estimate postoperative ectasia risk
- Detection of ectatic disorders such as keratoconus, pellucid marginal degeneration and post-LASIK ectasia

- Determining visual significance of corneal and conjunctival lesions, such as pterygia and Salzmann's nodular degeneration
- Guiding suture removal and placement of corneal relaxing incisions

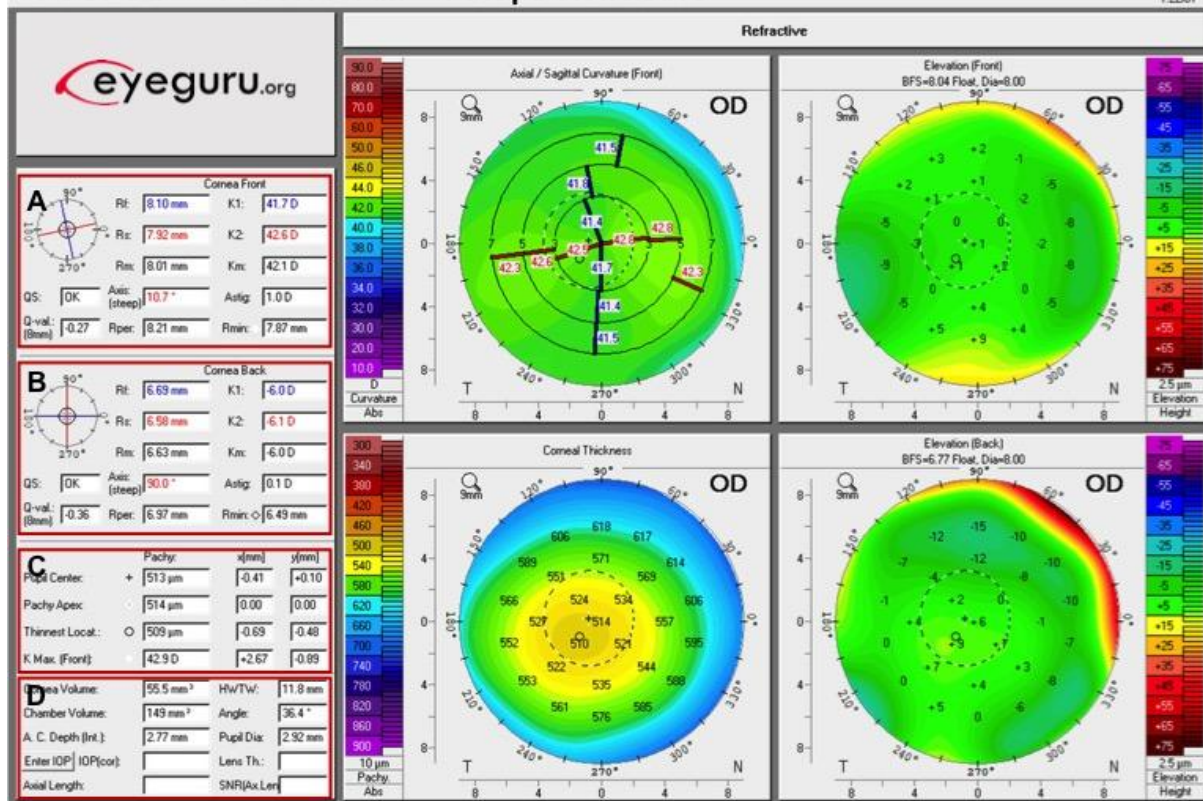
Basic Principles

Colored Maps: You will see a rainbow of colors on every topographic map. These range from warm colors (red, orange, yellow), to neutrals (green) to cool colors (blue, purple). On our representative Pentacam images below, you will see four different types of maps.

- 1) Axial map (top left)
 - Useful for assessing irregularity of astigmatism and planning suture removal after PK
 - **Warm** colors = steep (think “*steeping warm tea*”)
 - **Cool** colors = flat
- 2) Corneal thickness, aka pachymetry map (bottom left)
 - Displays distribution of corneal thicknesses across the entire measured area.
 - **Warm** colors = thin (think “in the *heat* wear *thinner* layers”)
 - **Cool** colors = thick (think “in the *cold* wear *thicker* layers”)
- 3) Anterior elevation map (top right)
 - Useful for assessing regularity of astigmatism, location of astigmatism and surgical planning for AK, toric planning
 - Warmer colors indicate where the cornea is elevated above the best fit sphere; cooler colors indicate where the cornea is depressed below the best fit sphere
- 4) Posterior elevation map (bottom right)
 - Useful for identifying forme fruste keratoconus
 - Warmer colors indicate where the cornea is elevated above the best fit sphere; cooler colors indicate where the cornea is depressed below the best fit sphere

Normal Cornea

Expected topography: Progressive flattening from center to the periphery by 2-4D, with the nasal area flattening more than the temporal area.



Interpreting Pentacam Values¹

A) Anterior corneal values

- K_1 , K_2 , K_m : The two major meridians (K_1 , K_2), determined using the 3mm ring, are 90 degrees from each other. Red corresponds with the steep meridian whereas blue corresponds with the flat meridian. K_m is the average of K_1 and K_2
- R_f , R_s , R_m : Radii corresponding with K_1 , K_2 , and K_m , respectively
- QS: Quality score (I.e. "OK," "Data gaps," "Fix," "Model") may alert the technician to retake the exam due to suspect quality
- Q-val: Describes the corneal shape factor, or eccentricity of the cornea. The ideal value is -0.26.
 - More negative values may suggest keratoconus or hyperopic correction whereas positive values may suggest myopic correction.
- Axis: The meridian that requires no cylinder power to correct astigmatism
- Astig: The central corneal astigmatism
- R_{per} : Average radius of curvature between the 6mm and 9mm zone center
- R_{min} : Smallest radius of curvature in entire field measurement

- R_{\min} may be elevated in keratoconus

B) Posterior corneal values

The same variables described for the front of the cornea are used to characterize the back of the cornea.

C) Pupil center: Calculated by finding the center point based on edge detection on the iris then the distance is calculated in mm

- Pachy apex: Corneal thickness at the apex
- Thinnest Location: Thinnest point over anterior corneal surface
- K Max (Front): Steepest point over anterior corneal surface

D) Values used in IOL calculations (out of scope of this article)

5 Clinical Uses

1) Keratoconus

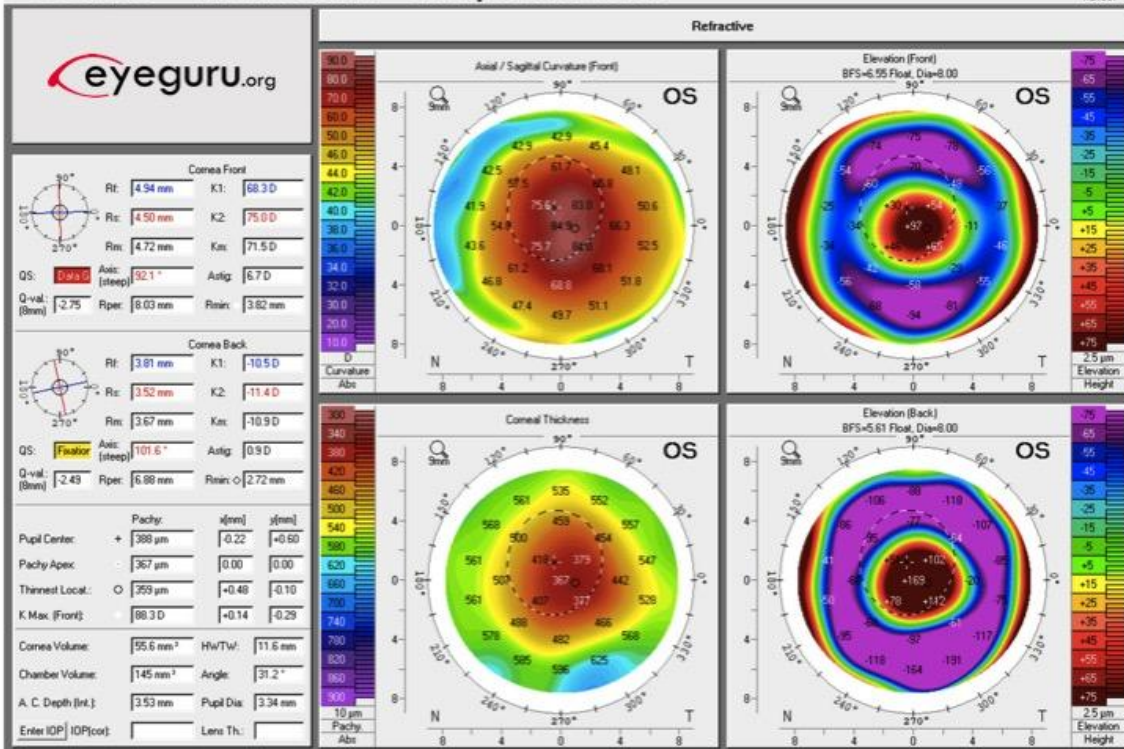
Topographic diagnosis of keratoconus is suggested by:

1. High central corneal power
2. Large difference between the power of the corneal apex and periphery
3. Differences in steepness between the two corneas of a given patient.

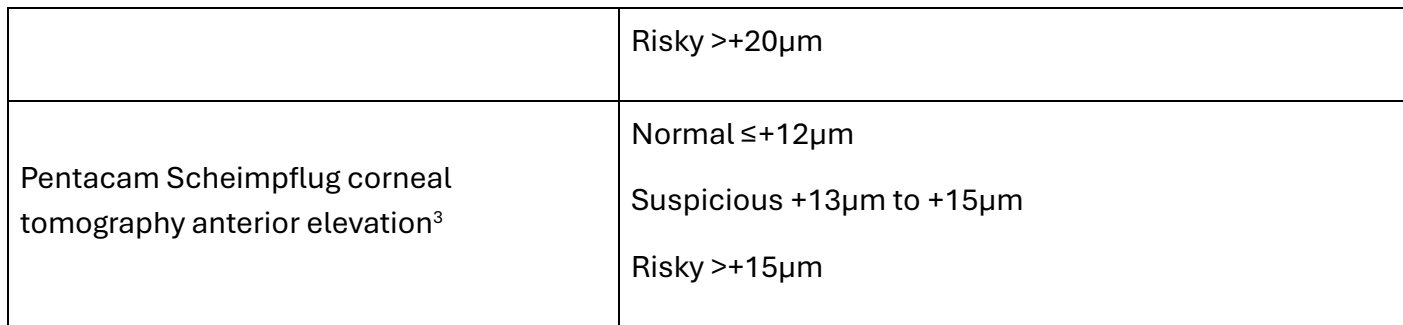
Expected topography: inferior steepening on anterior axial map and corresponding thinning on pachymetry map. There are many systems to grade keratoconus. Here are some examples of various systems, but these are not necessarily the only criteria by which to rule in or rule out keratoconus.

OCULUS - PENTACAM 4 Maps Refractive

1.21667

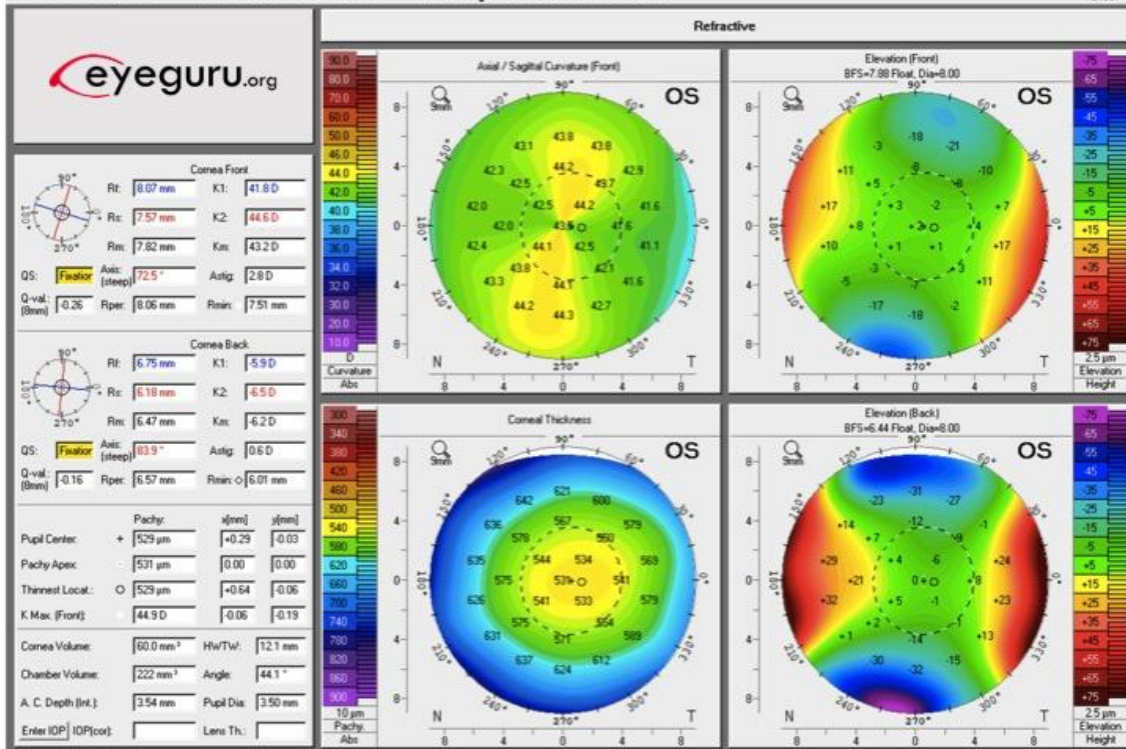


	Cutoff points for Keratoconus
Central K ²	Normal <47.2D Forme Fruste Keratoconus 47.2-48.7D Keratoconus >48.7D
Inferior-superior asymmetry index	>1.2D
Astigmatism	>2.5D
Orbscan II topography posterior elevation ³	≥35μm subclinical keratoconus ≥51μm keratoconus
Orbscan II topography anterior elevation ³	≥16μm subclinical keratoconus ≥19μm keratoconus
Pentacam Scheimpflug corneal tomography posterior elevation ⁴	Normal ≤+17μm Suspicious +18μm to +20μm



OCULUS - PENTACAM 4 Maps Refractive

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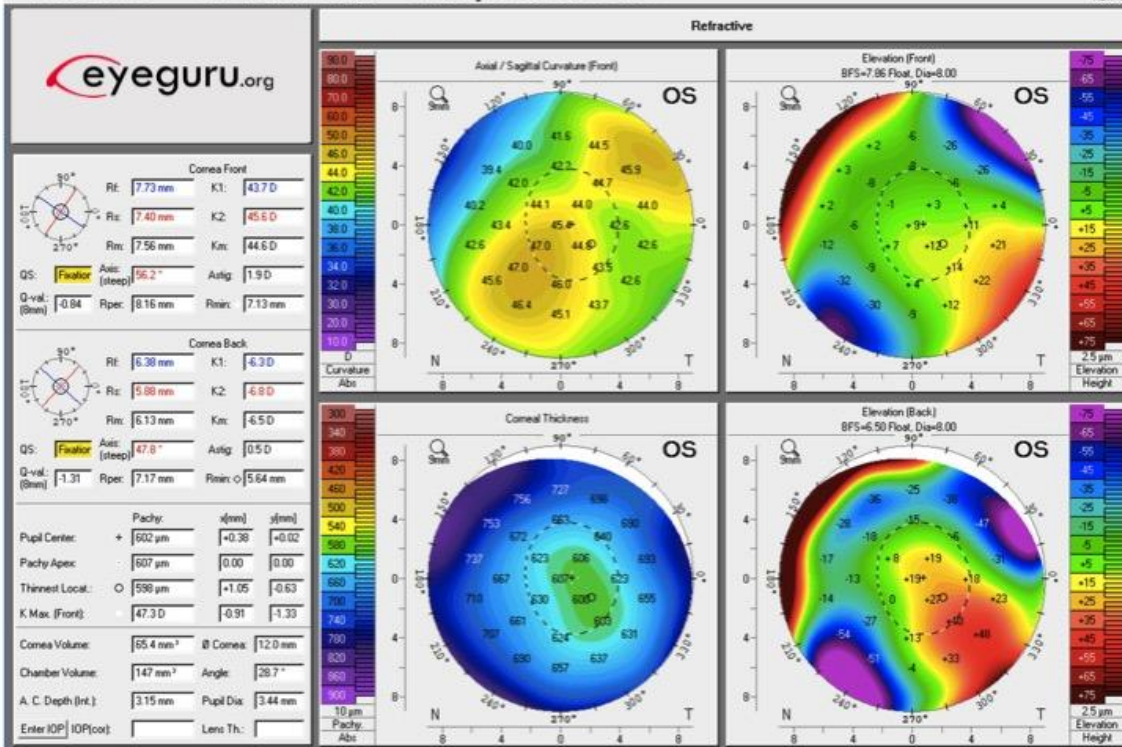


Irregular astigmatism: nonuniform steepening that cannot be corrected by cylindrical lens (BCVA of 20/50 or worse due to irregular astigmatism).

Expected topography: steep and flat axes less or more than 90 degrees apart

OCULUS - PENTACAM 4 Maps Refractive

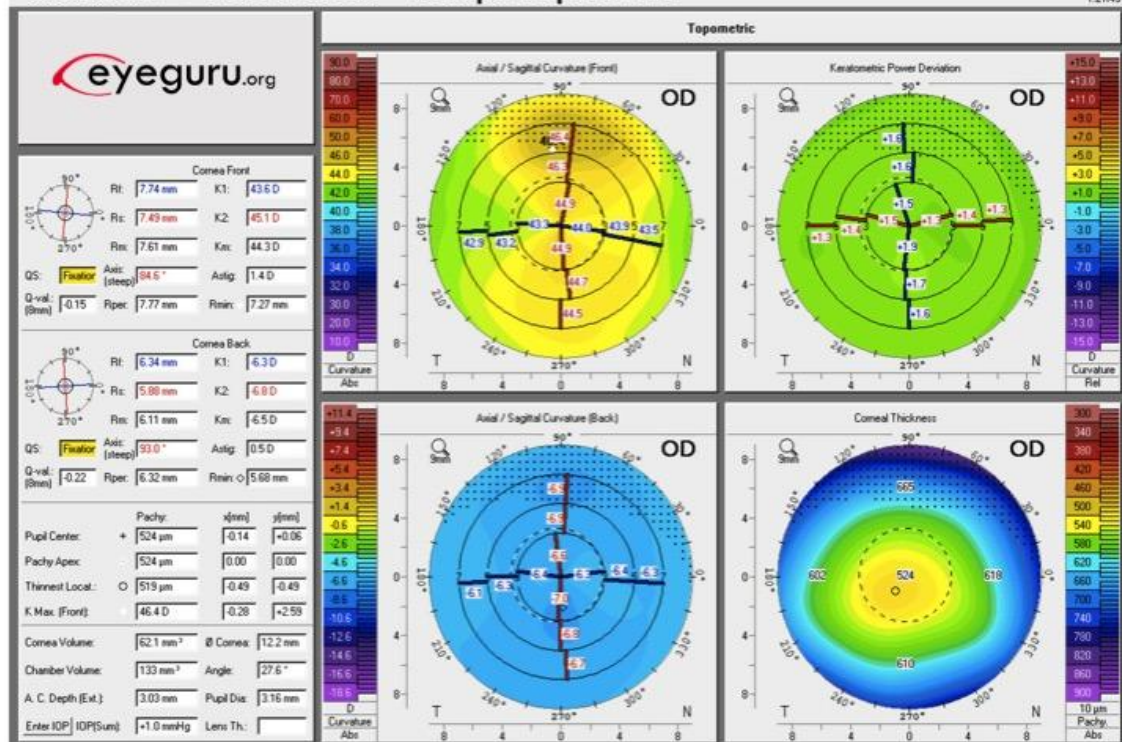
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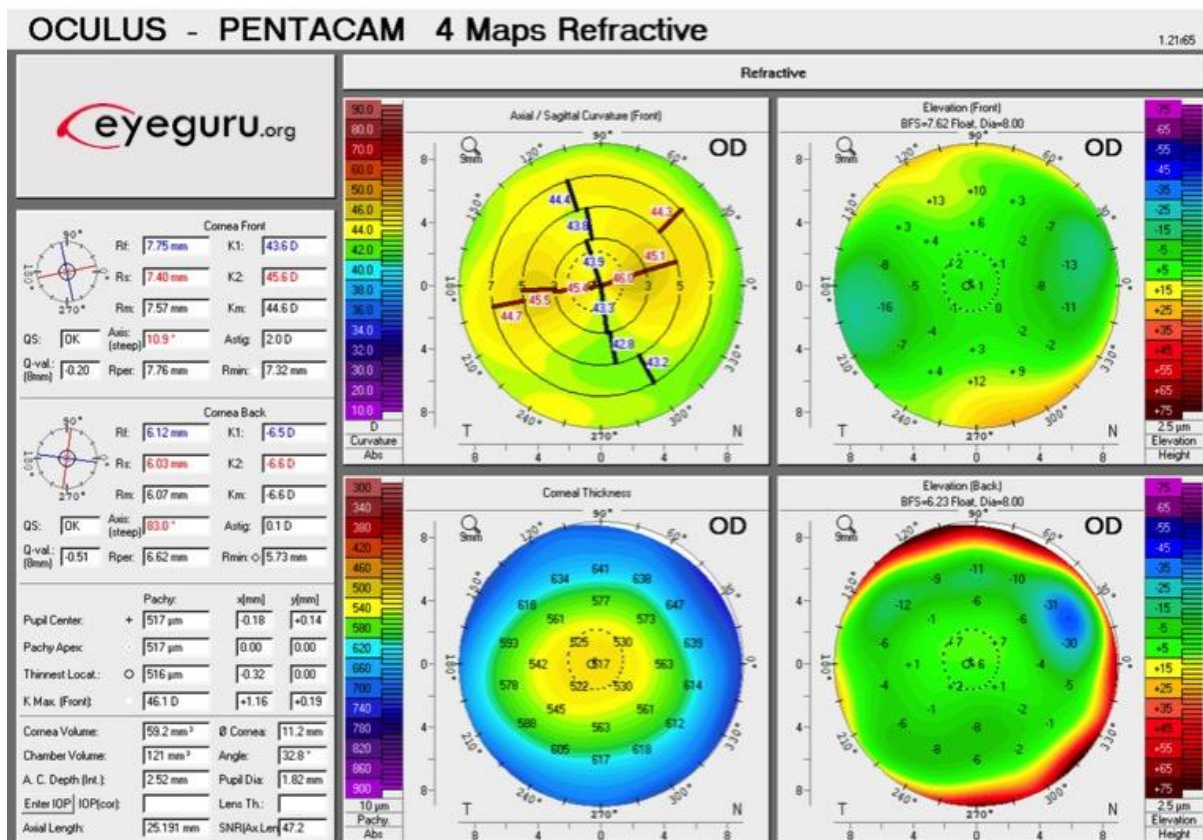
With-the rule astigmatism: Steeper in the **vertical** meridian

OCULUS - PENTACAM 4 Maps Topometric

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Against-the-rule astigmatism: Steeper in the **horizontal** meridian



4) Refractive error

Myopia is associated with **steeper** central corneal curvature

Hyperopia is associated with **flatter** central corneal curvature

However, these are not hard and fast rules, as axial length plays a big role in the overall myopia/hyperopia of the eye.

5) Refractive surgery

Preoperative assessment should be performed to rule out ectatic (e.g. irregular) patterns, which occur in disorders like keratoconus and pellucid marginal degeneration. If an ectatic disorder is suspected, LASIK is not recommended.

Refractive surgery itself can induce corneal ectasia. In preoperative planning, percent tissue altered (PTA) is used to estimate the risk of inducing a cornea ectasia. Generally, a PTA < 40% is accepted as a lower risk in a normal eye.⁵

$$PTA = (FT + AD)/CCT$$

PTA: percent tissue altered; FT: flap thickness; AD: ablation depth; CCT: preoperative central corneal thickness

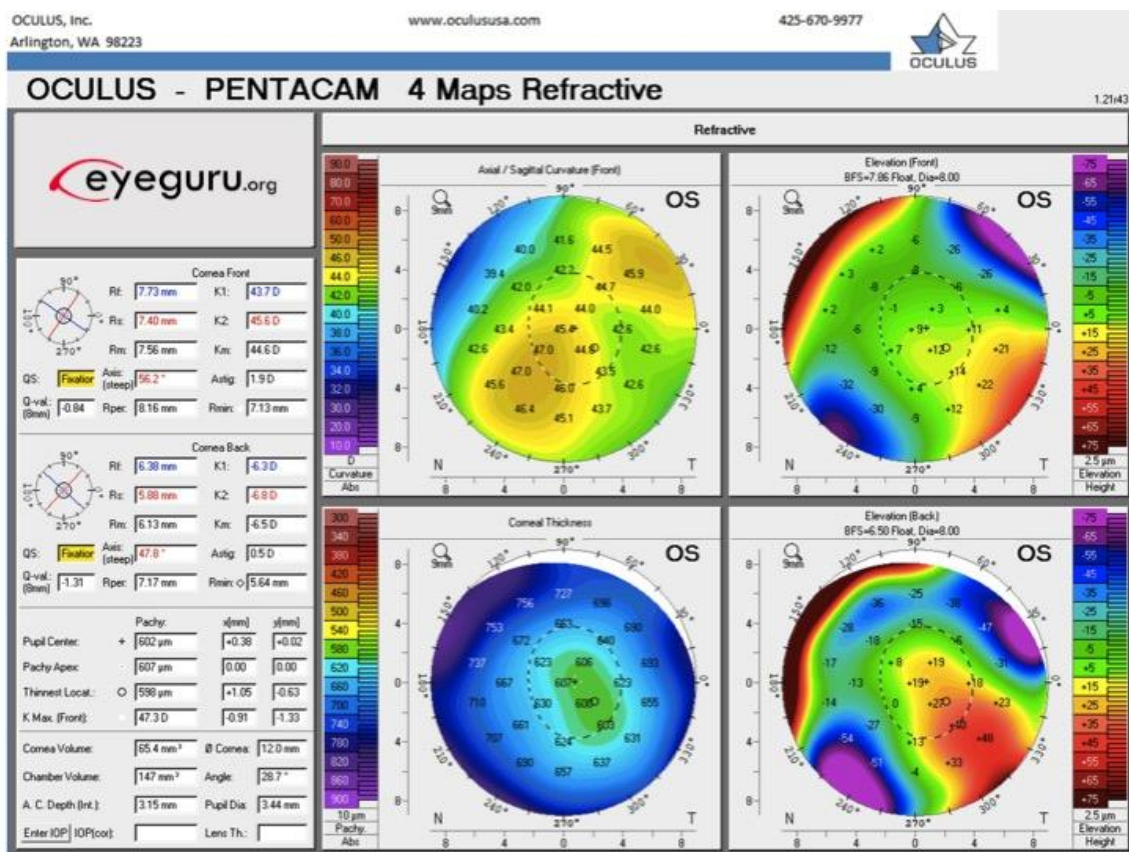
Postoperative assessment is performed to evaluate any dioptric changes at the corneal level and to rule out decentered or incomplete ablation, ectasia or other changes.

Quick Tips for Clinic

- Choose which post-keratoplasty suture to remove based on the steep axis of astigmatism on topography. Removing sutures along the steep axis leads to corneal flattening.
- Candidates for Toric IOL will have regular symmetrical astigmatism, appearing as a “bowtie” or “figure-eight” pattern on topography (can be with or against-the-rule)
- Keratoconus or pellucid eyes will have an irregular astigmatism, often with inferior steepening and corneal thinning,

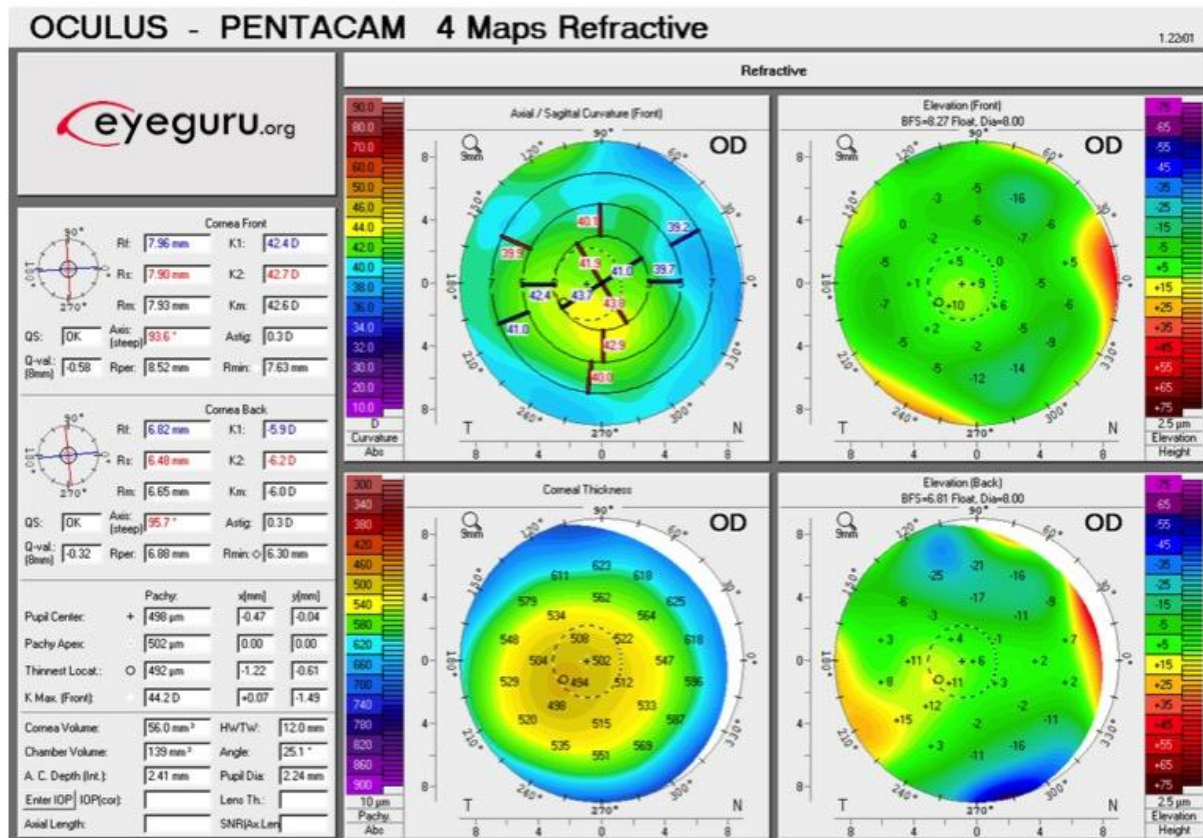
Review Questions

1) Based on this patient's topography, are they a candidate for Toric IOL?



Answer: No, the topography shows irregular astigmatism. Only patients with **regular astigmatism** are **good candidates** for **Toric IOLs**.

2) Based on this patient's topography post-LASIK, what refractive error did they have prior to LASIK?



Answer: This post-LASIK topography demonstrates central corneal steepening (“steeping warm tea” reminds us that warmer colors correspond with steeper corneal curvature). Therefore, the patient was being corrected for **hyperopia**.

References:

1. Agarwal A, Agarwal A, Jacob S. *Dr. Agarwal's Textbook on Corneal Topography (Including Pentacam and Anterior Segment OCT)*, 2/E. Second ed. New Delhi, India: Jaypee Brothers Medical Publishers (P) Ltd; 2010.
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4. Tanuj D NM, Tarun A. *New Investigations in Ophthalmology*; 2017.
5. Santhiago MR, Smadja D, Gomes BF, Mello GR, Monteiro ML, Wilson SE, et al. Association between the percent tissue altered and post-laser in situ keratomileusis ectasia in eyes with normal preoperative topography. *Am J Ophthalmol*. 2014;158(1):87-95.e1.

How to interpret visual fields: 5 most common patterns

What is automated perimetry?

Here, we'll only talk about the Humphrey visual field perimeter, which is used for 99% of visual field tests. It's an **automated, static** perimeter (unlike Goldmann kinetic perimetry which requires a human operator, and uses a moving target). The Humphrey uses fixed points of light which are shown at different intensity levels. The software automatically varies the intensity of the points of lights at each location to determine the **threshold** – the intensity of light where the patient can see it 50% of the time.

Which subtest should I order?

HVF 24-2

This is ordered for 90% of glaucoma patients. This is your baseline exam that all glaucoma suspects and glaucoma patients need at routine intervals.

HVF 10-2

This is ordered for the 10% of glaucoma patients who are so advanced that the HVF 24-2 is mostly black, with only a central island of remaining vision. Macular diseases including plaquenil toxicity exams also need 10-2.

HVF 30-2

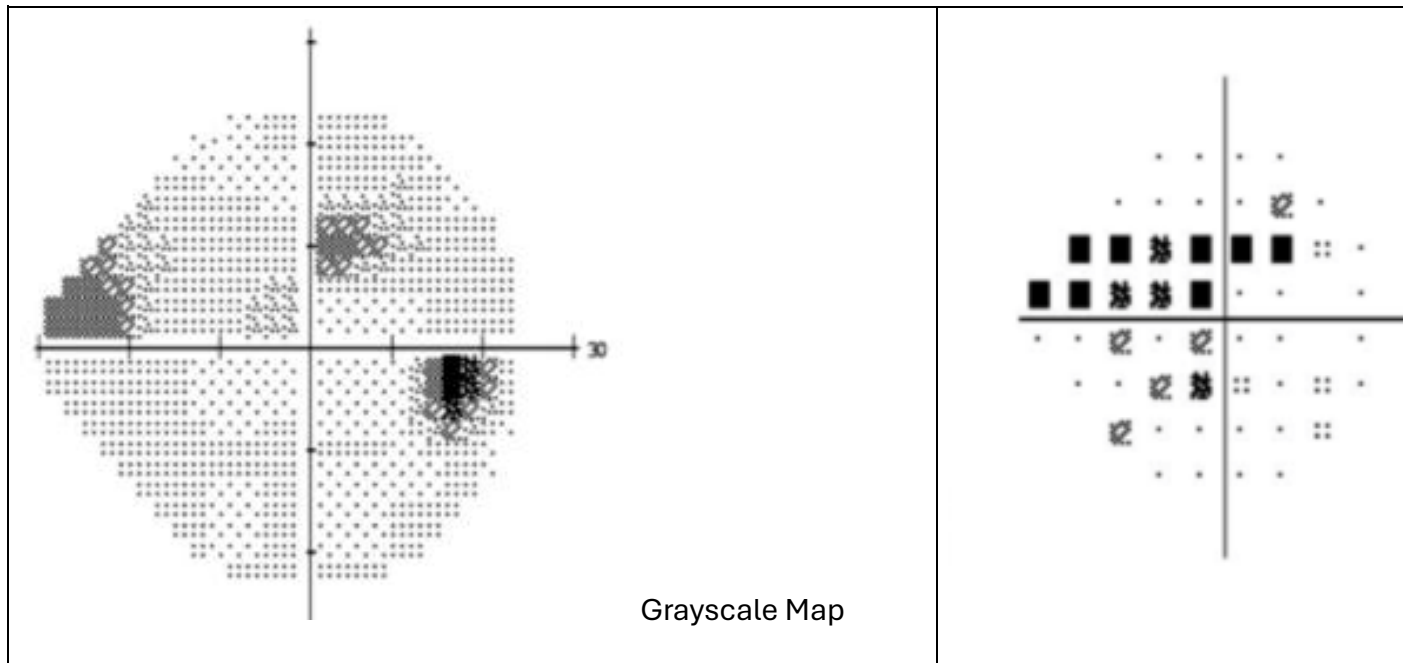
Generally, we order this for neuro patients. It has a wider angle and can capture peripheral field defects.

Reliability indices

- Name, demographics, etc: Make sure you are looking at the right patient!
- Fixation loss: The HVF will routinely flash dots in the patient's physiological blind spot to check if the patient has his / her gaze fixated on the center. If the patient can actually see the spot, then it's recorded as a fixation loss. Reliable tests have below 20% fixation loss (although many people have their own opinions about these upper limits).
- False positive: The user pressed the button when there was no stimulus. They were "trigger happy". Reliable tests have below 33% false positives.
- False negative: The user did not see a stimulus which was brighter than one they saw earlier in the same test. Reliable tests have below 33% false negatives.
- Stimulus characteristics: 99% of visual fields (VFs) will use the size 3 white stimulus. Other sizes and colors are used for patients with late disease or retinal disease.

Which picture do I look at?

Yes, there are a lot of graphs. The two most important to look at are the Grayscale Map and the Pattern Deviation. The rest of this article will explain how to interpret these.



How do I tell if things are changing over time?

This is the million dollar question. This is what every patient will want to know and how you will decide whether to step up drop therapy, add laser, or take the patient to the operating room.

As a very, very general guideline, you can look at the density / size of the field defect, the pattern standard deviation, and the mean deviation (MD) to see if it is worsening. However, your decision should also take into account the normal variability between each visual field, the optic nerve head appearance, pressures, patient compliance, OCT, visual symptoms, etc.

This is a very complex topic and somewhat beyond the discussion of this post, so talk to your seniors and your attendings if you aren't sure!

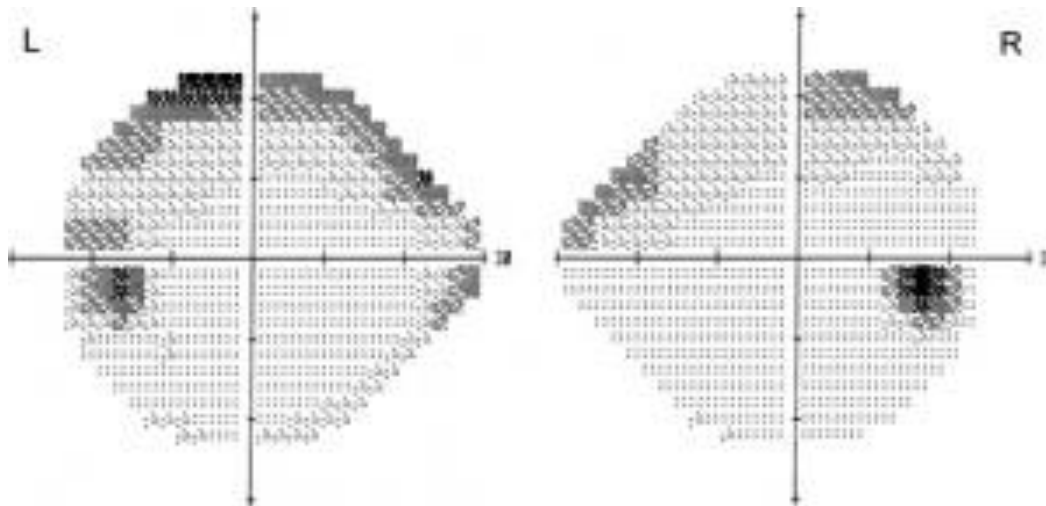
Top 5 most common visual field patterns

1) Nonspecific / low Reliability / inattention / patient hungry

For every interpretable, reliable visual field you get, you will also get another in which the patient thinks he should be scanning the dome for lights the whole time, is poorly positioned, is exhausted from waiting in your clinic for hours, or is too elderly and arthritic to push the button in time.

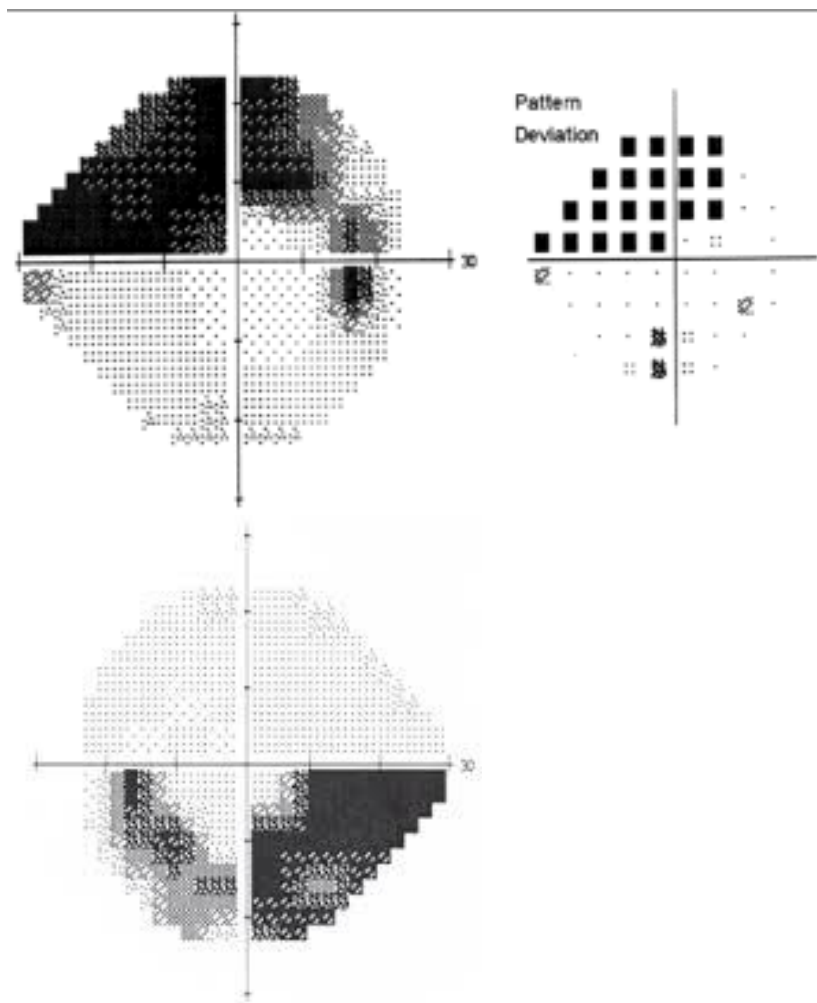
These types of inattention errors will usually register as high fixation losses, false positives, or false negatives. Or, the visual field could just be patchy all over.

If these errors are not too bad, the general gist of the field can be deduced, especially if compared to prior fields. Most often, as long as everything else is stable (IOP, ONH appearance), we just reorder these fields in a few month's time. If you simply cannot get a visual field due to patient cooperation or attention, you can order an optic nerve OCT to follow the optic nerve head objectively (though thinning does not always necessarily correlate to field loss).



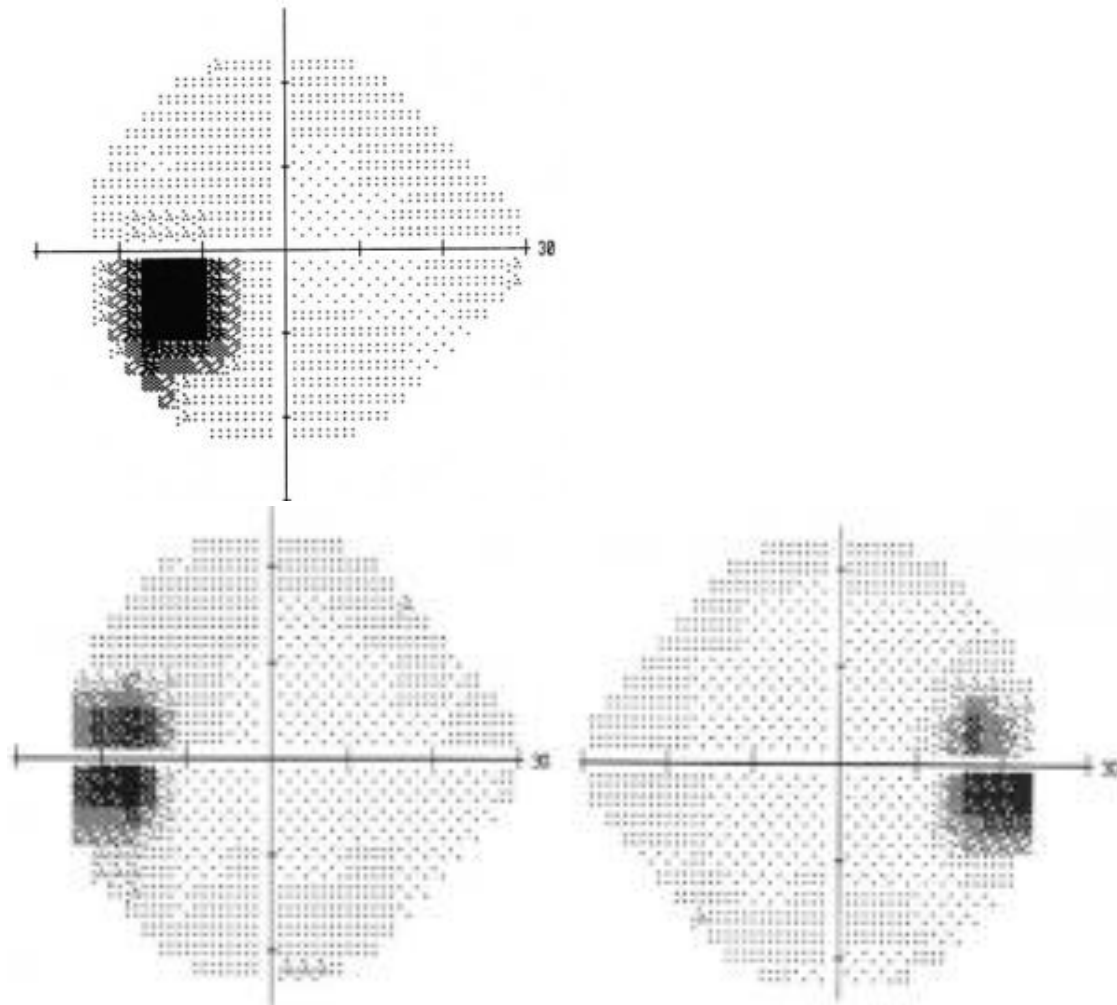
2) Superior / inferior arcuate defect

The most common early to mid stage glaucomatous field. The reason these look like arcs and come off the blind spot is that they represent the loss of bundles of nerves as they come out of the optic nerve head. The horizontal border is the horizontal raphe, which is an imaginary line dividing the upper and lower hemispheres of the retina. These are probably 25%-35% of the fields we see.



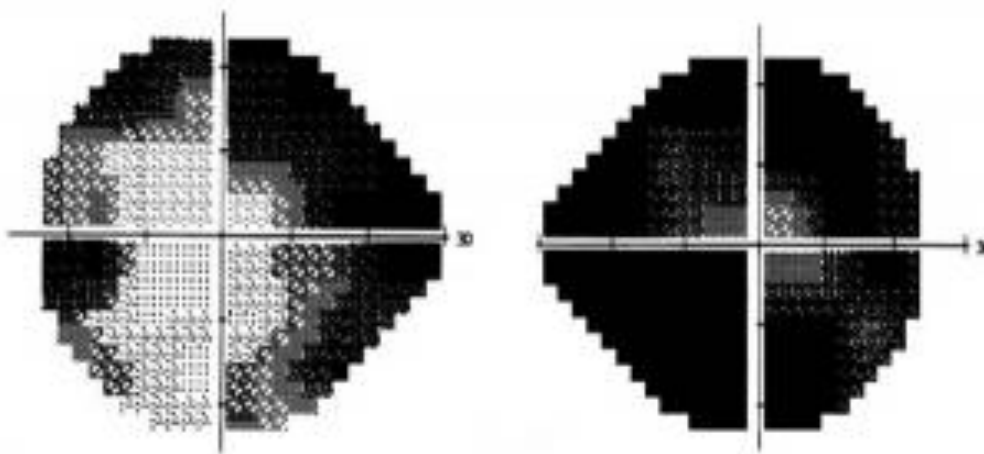
3) Blind spot enlargement

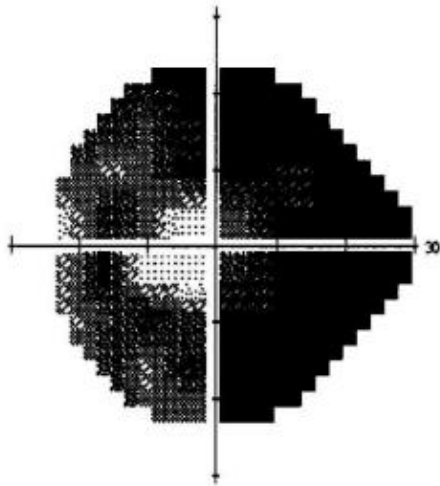
This can be seen in glaucoma, but also can occur with papilledema and optic nerve head swelling. This would likely be seen in patients with idiopathic intracranial hypertension (aka pseudotumor cerebri).



4) Severe constriction with a central island

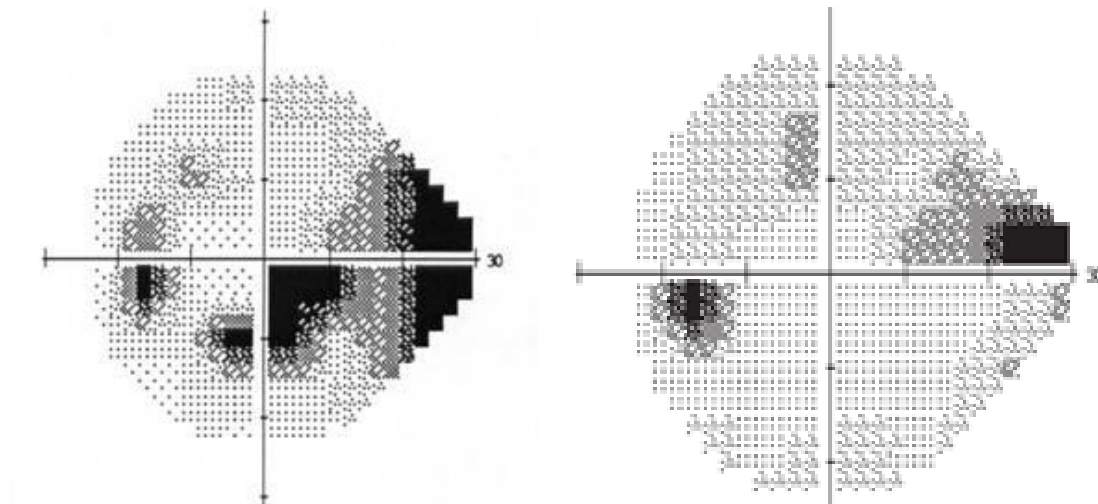
Unfortunately, this is end stage glaucoma. At this point, many patients still have great central vision of 20/20 to 20/50, but peripheral vision is nearly gone. Here, we switch patients over to an HVF 10-2 to better follow their progression.





5) Nasal steppe

This is another common glaucomatous field. About 10% of fields show this.



Conclusion

Use this order to interpret your Humphrey visual field every time:

1. Confirm it's the right patient with name and date of birth
2. Confirm it's the right/left eye
3. Look at the reliability indices
4. Look at the pattern
5. Look at the GHT, mean deviation, VFI, and pattern standard deviation
6. Compare to the previous visual fields

How to interpret ophthalmic ultrasound: 5 most common scans

Uses for ophthalmic ultrasound

There are a few different types of ultrasound that can be performed on the eye. The “A scan” is performed by placing an ultrasound transducer directly on the cornea or using an immersion shell after some numbing drops are applied. It performs a single line scan which can be used to measure axial length or numerically compare the reflectivity of different structures. The “B scan” is usually performed by placing the transducer on the patient’s closed eyelid. It creates the typical 2D image that you associate with ultrasound. Ultrasound biomicroscopy (UBM) is performed with a much higher frequency than the A and B scans and is primarily used to evaluate the anterior chamber angle and ciliary body.

Here is a summary of what the different ultrasound scans are used for:

1. B scan: Used for evaluating the retina, retinal detachments, vitreous choroidal masses, tumors, and nevi.
2. A scan: Used for ultrasound biometry (e.g. calculating axial length).
3. Ultrasound biomicroscopy (UBM): Used for evaluating the iridocorneal angle and ciliary body.

Basics of B scan

We’re going to focus on B scan in this article. Here are the key concepts you need to know to understand B scan ultrasound for the eye.

Scan orientations

First, for the purposes of ophthalmic ultrasound, the posterior of the eye is centered on the optic nerve, not the fovea.

There are 3 scan orientations.

1. Axial: The probe is placed in the visual axis. A horizontal axial view would show the optic nerve and macula.
2. Longitudinal: The probe is placed on the eye with the plane of the ultrasound beam facing towards the pupil. The ultrasound images will show the retinal periphery to the posterior pole.
3. Transverse: The probe is placed on the eye, but oriented so the plane of the ultrasound beam is parallel to the limbus. If the entire retina were a clock, the ultrasound image from a transverse scan would show several clock hours of the retinal periphery in one frame.

Of the 3 orientations, transverse is used the most because it allows you to pan the probe and integrate that quadrant of the retinal periphery into a 3D mental image. This is something that you will understand and get much better at with a little practice in clinic.

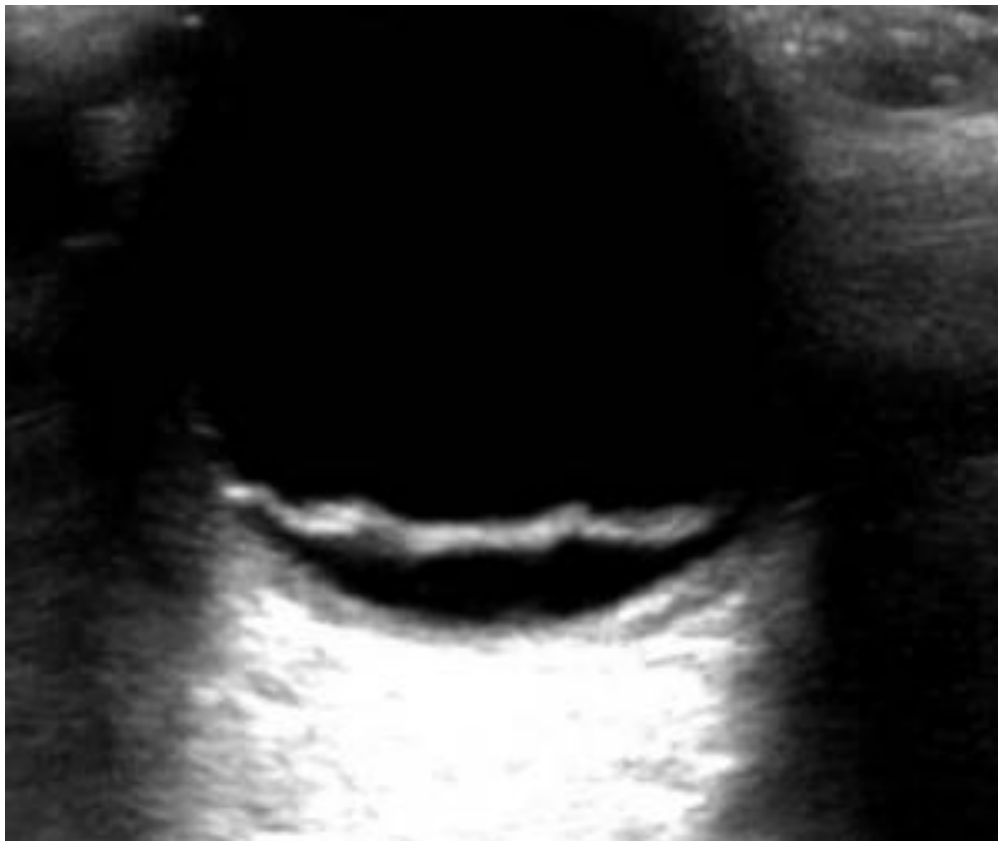
Dynamic scans

Performing a dynamic scan just means having the patient move their eye back and forth to evaluate how the structures are moving. This is most important in differentiating vitreous detachments from more emergent retinal detachments. The posterior hyaloid membrane (which separates the vitreous from the retina) moves rapidly and tumbles loosely in the eye, like a “washing machine”. The retina undulates more slowly and is more echogenic than the hyaloid.

Example ultrasounds

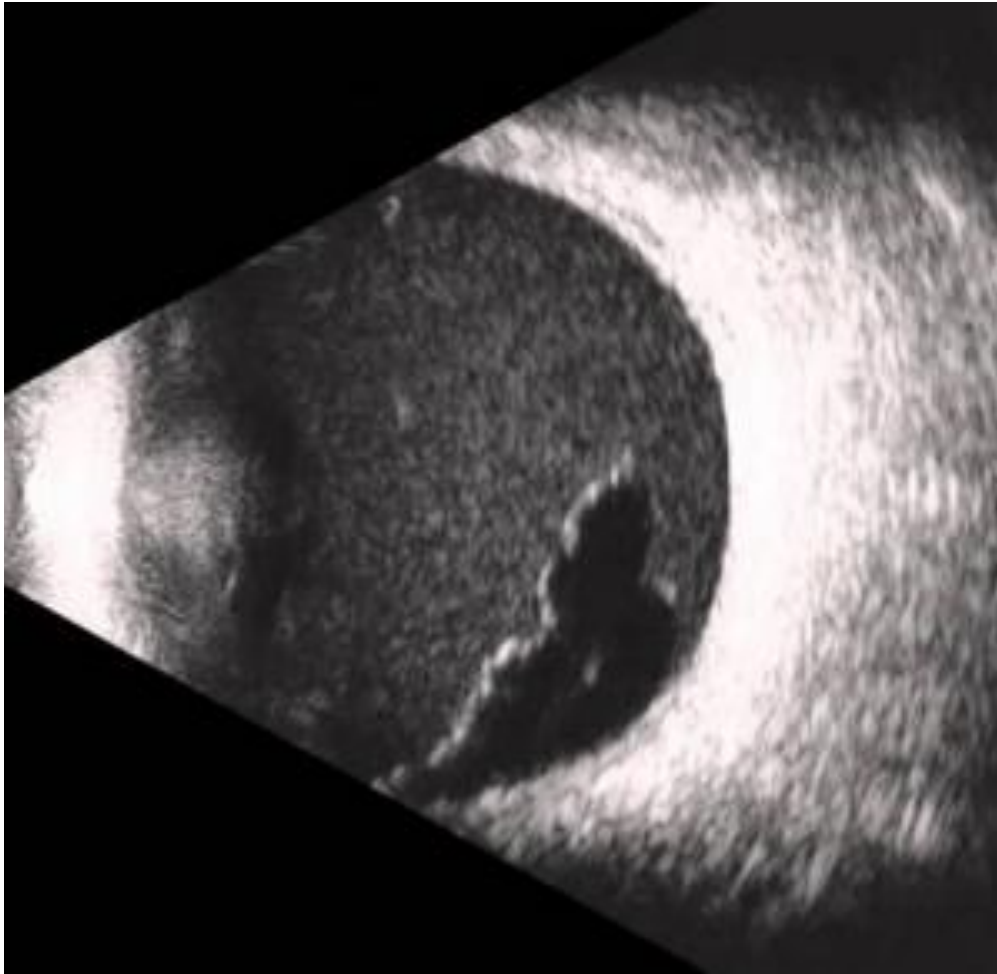
Retinal detachment

Retinal detachments have a characteristic undulating movement of the retina with dynamic scans. The retina moves at a slower speed than the posterior hyaloid and its reflectivity is higher. You can use ultrasound using the axial, transverse and longitudinal views to delineate where the retina has detached.



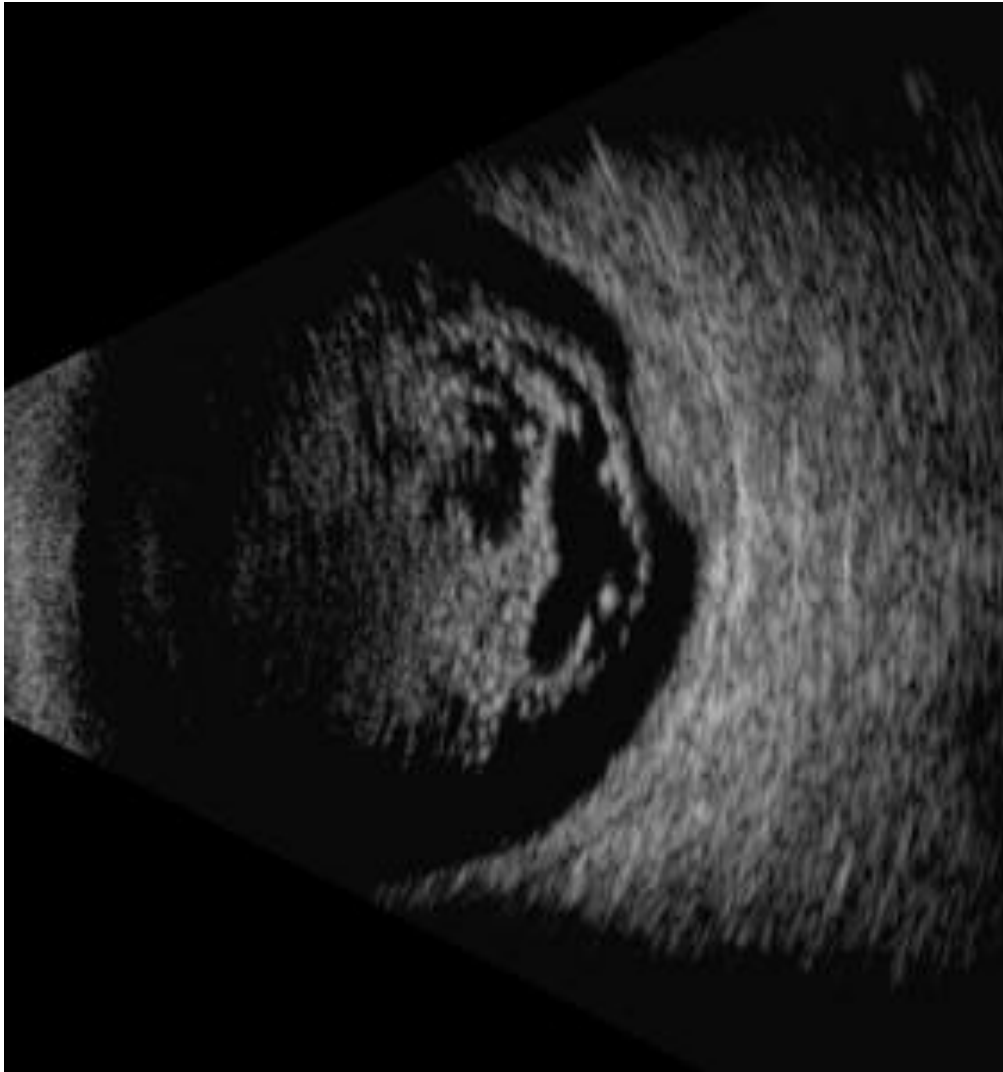
Vitreous hemorrhage

Vitreous hemorrhages are seen commonly in the setting of acute vision loss in one eye. They can happen in diabetic retinopathy and almost every other retinal neovascular disease.



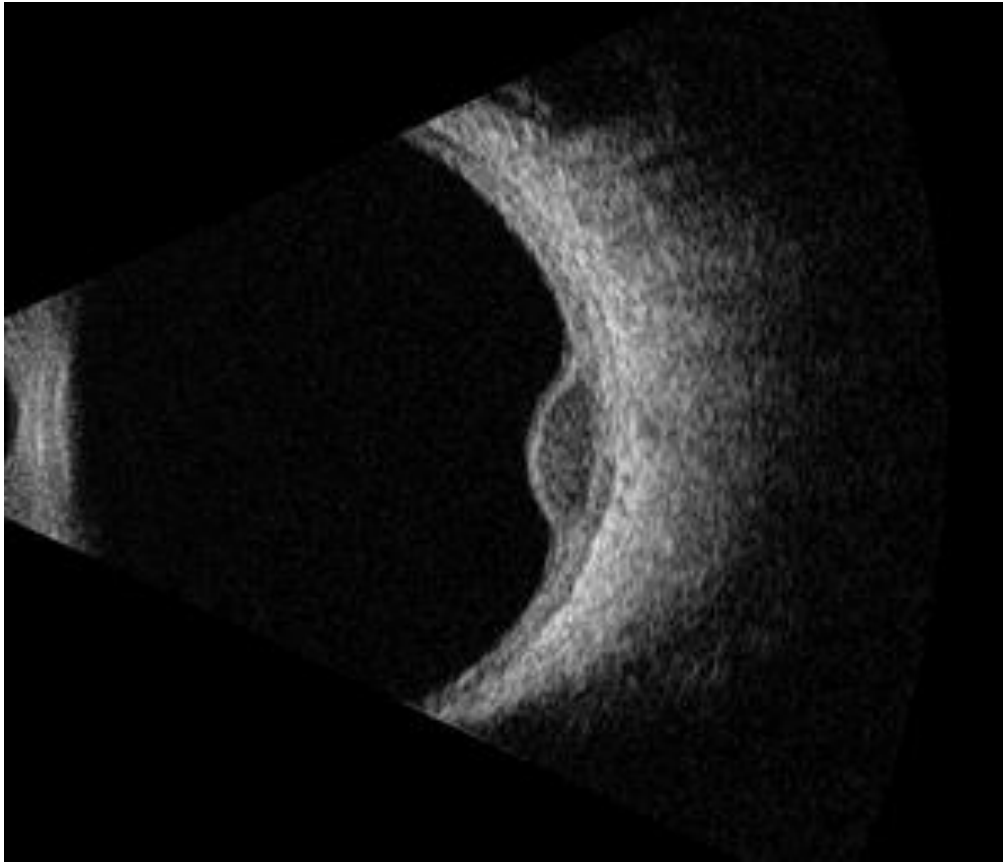
Choroidal nevus

Choroidal nevi can be differentiated from choroidal melanoma in that they have a uniform, high internal reflectivity.



Choroidal melanoma

Choroidal melanomas have a low to medium internal reflectivity due to the fact that they are more vascular.



Choroidal hemangioma

Choroidal hemangiomas have a uniform, high-internal reflectivity.

