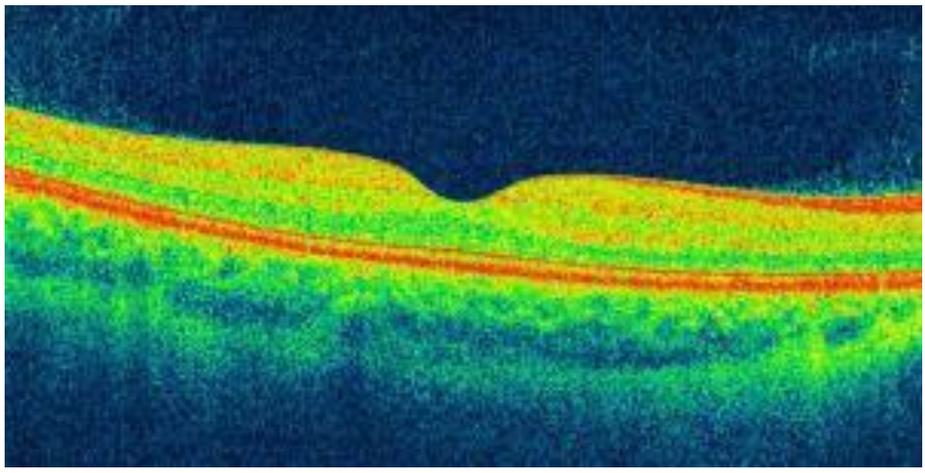
How to read OCTs: 8 fundamental diseases

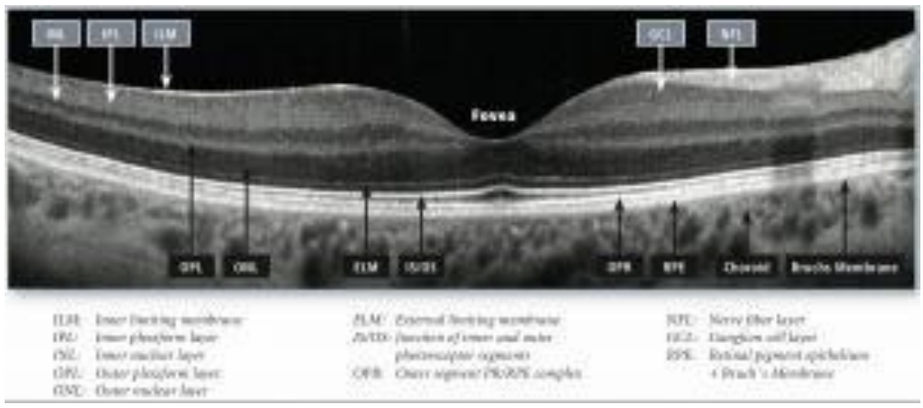
Listed here are 80-90% of the OCTs that you are going to be seeing. Most OCT is used for imaging the retina, so that's what we'll focus on. It's revolutionized the field of retina, helped us revise the pathophysiology of multiple diseases based on OCT evidence, and is a standard for the treatment of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



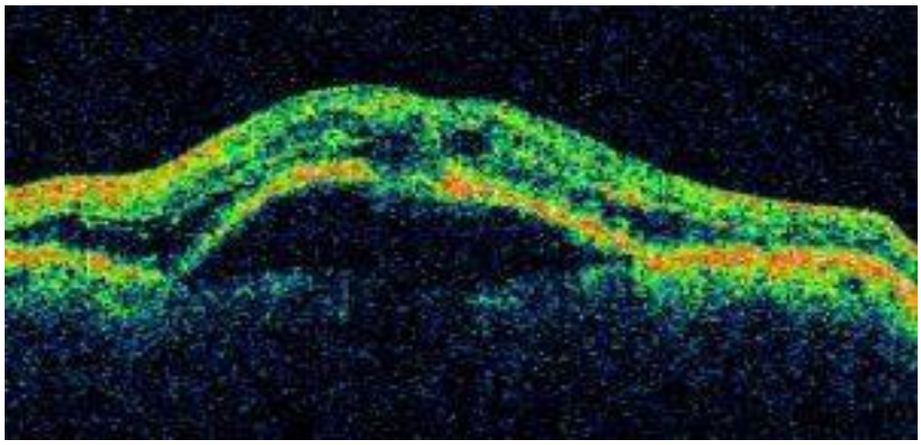


The macular OCT can be used to evaluate premacular vitreous, macula, and choroid. We'll look at OCT through several common diseases.

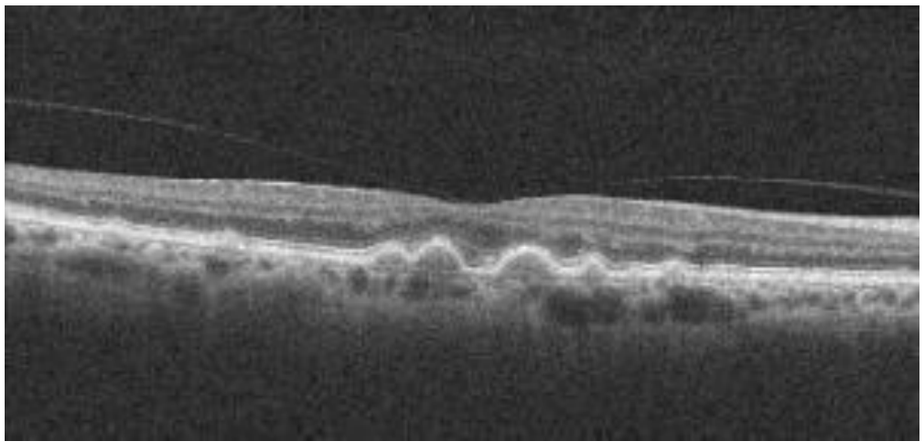
Below, we've highlighted a few diseases with their common OCT findings:

View of the retinal pathologies with OCT Age-related macular degeneration (AMD)

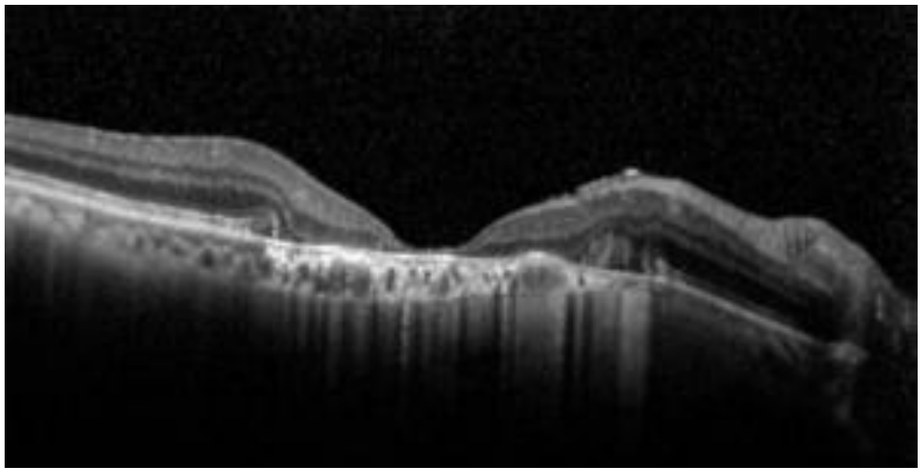
Wet AMD leads to intraretinal fluid (IRF) and subretinal fluid (SRF) accumulation. The choroidal neovascular membrane (CNV) can be visualized.



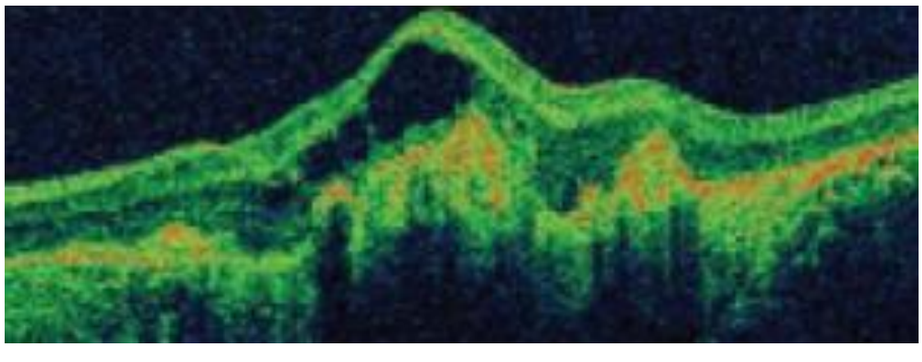
This is an OCT of a pigment epithelial detachment (PED) in wet AMD with some adjacent subretinal fluid (SRF) and an overlying area of focal intraretinal fluid (IRF).



Drusen: Lumps of deposits under the RPE.

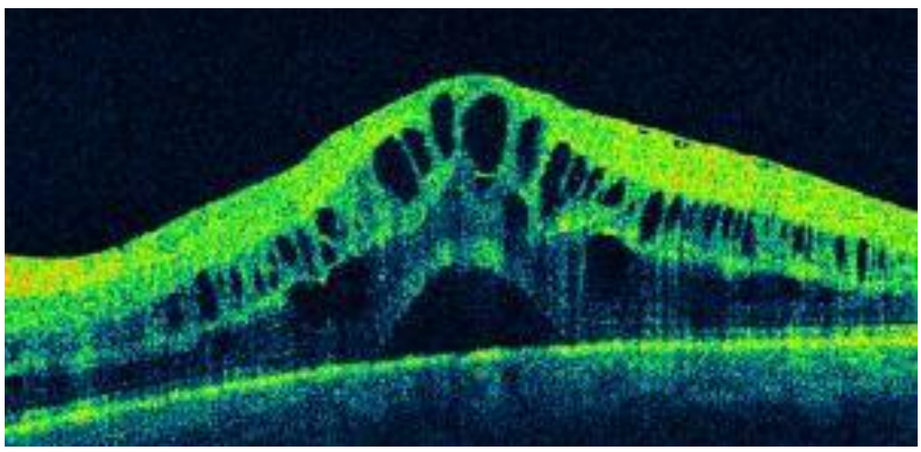


Geographic atrophy: Atrophy of the outer retinal layers with OCT signal penetrating deeper into the choroid.



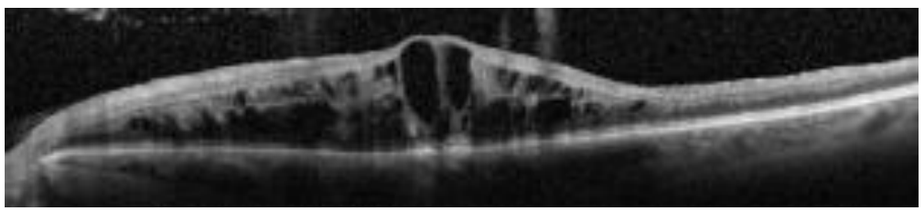
Another example of wet AMD: Eyes show fibrovascular pigment epithelial detachments (PEDs), neovascular membranes and subretinal fibrosis along with fluid.

Diabetic macular edema (DME)

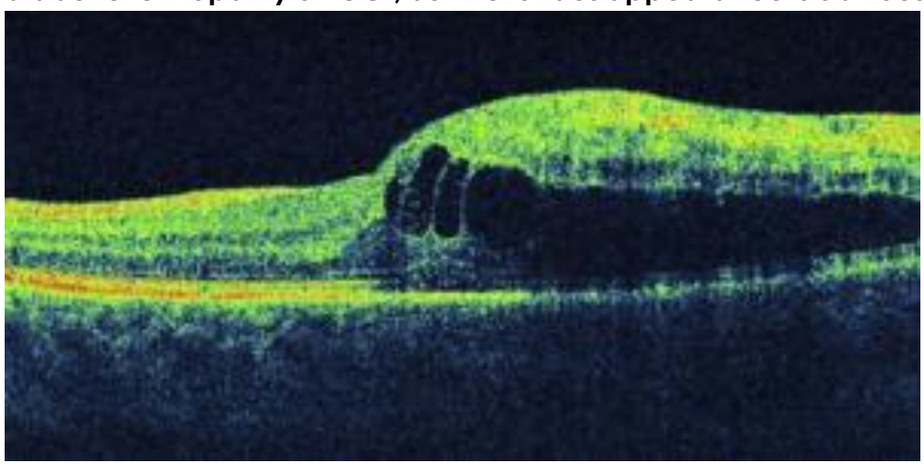


This is classic DME with cystoid intraretinal fluid pockets in the outer plexiform layer (OPL). Subretinal fluid (SRF), which is present in severe DME, is also seen here.

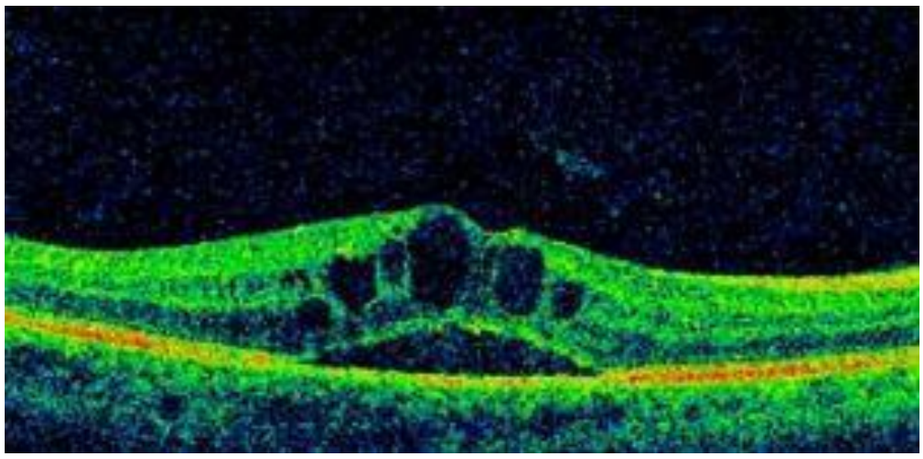
Retinal vein occlusions (RVOs)



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.

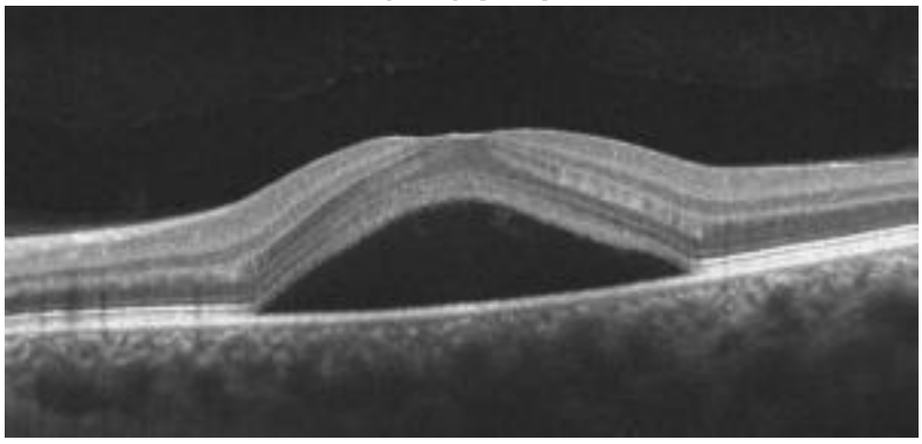


In comparison to CRVO, this branch retinal vein occlusion (BRVO) shows retinal edema on the temporal side of the macula, which is a more common finding in BRVO. You know it's the temporal side because the nasal side of the OCT has a thicker retinal nerve fiber layer (RNFL).

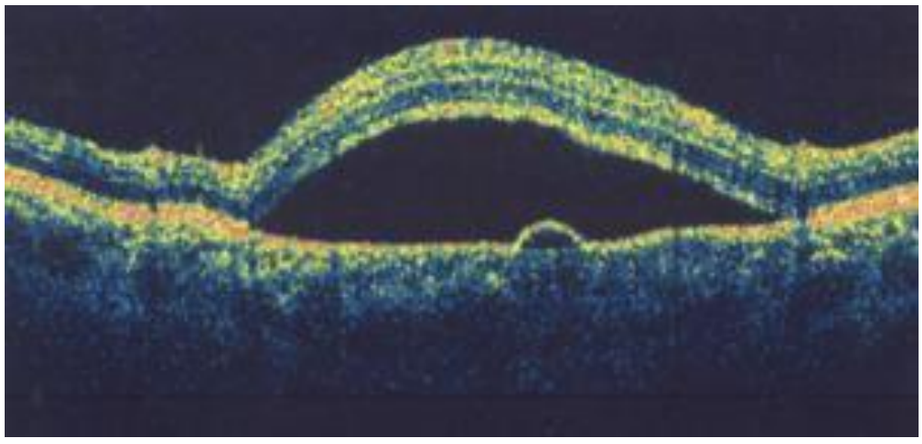


Here is a BRVO with central macular edema. Chronic RVOs lead to inner retinal atrophy, which is also characteristic of the disease.

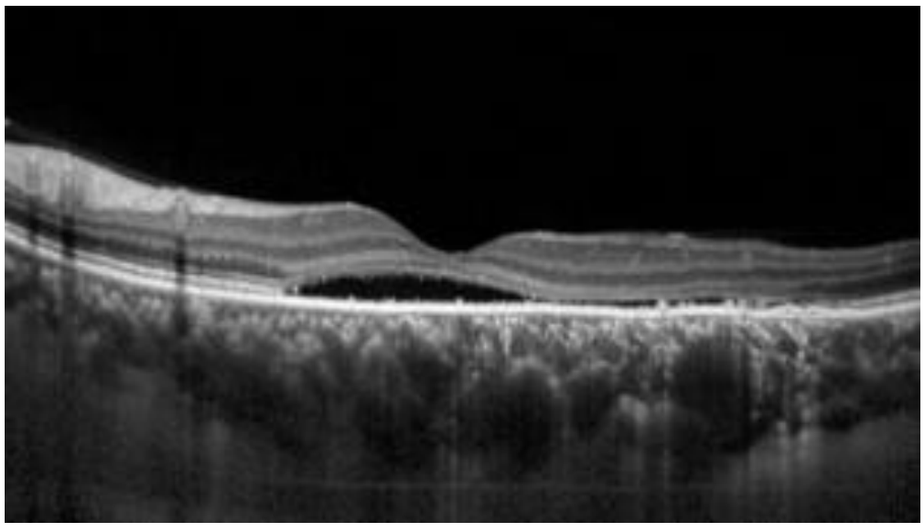
Central serous chorioretinopathy (CSR)



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

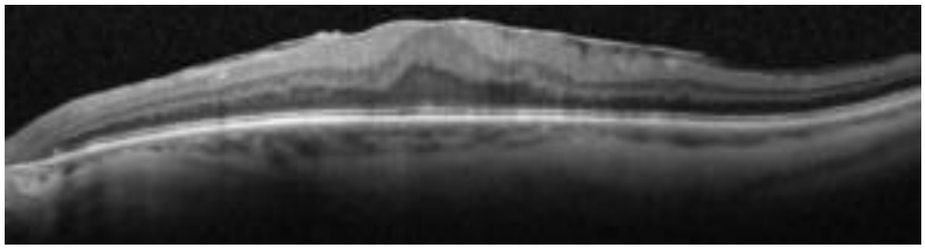


With CSR, there can often be a component of pigment epithelial detachment (PED) inside the area of serous detachment. These PEDs can be quite large.

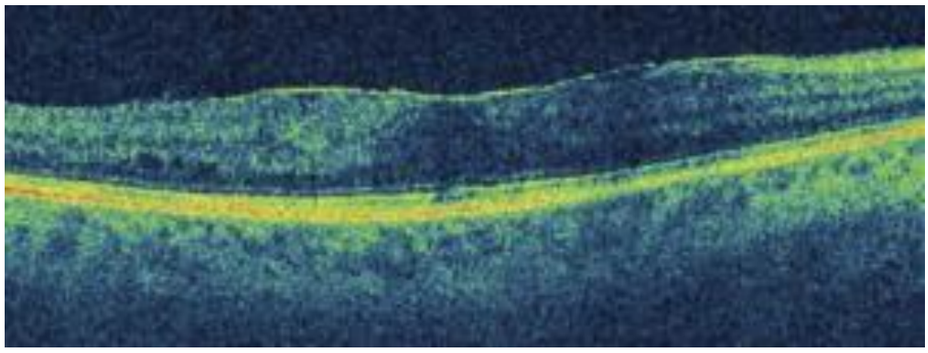


This example of CSR displays a very thick choroid.

Epiretinal membrane (ERM)

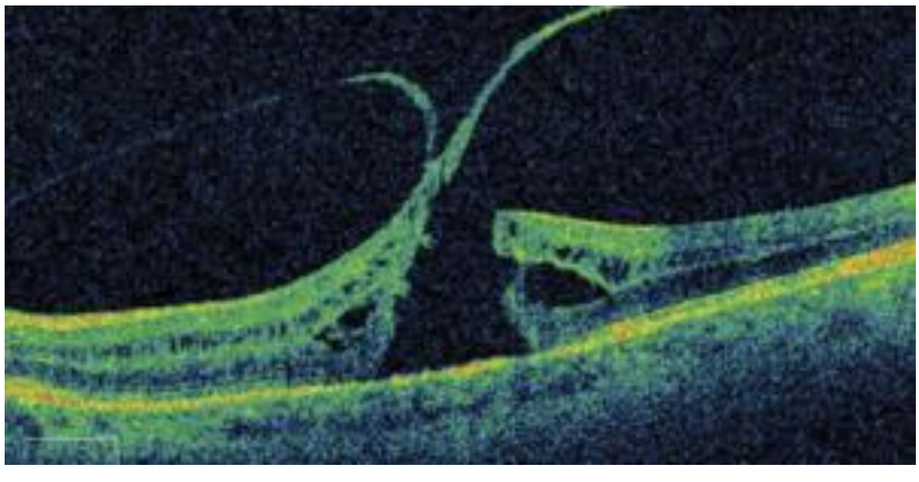


A dense epiretinal membrane (ERM) can be seen here leading to inner retinal wrinkling and distortion of the foveal contour. A severe ERM can also be associated with cystoid macular edema.



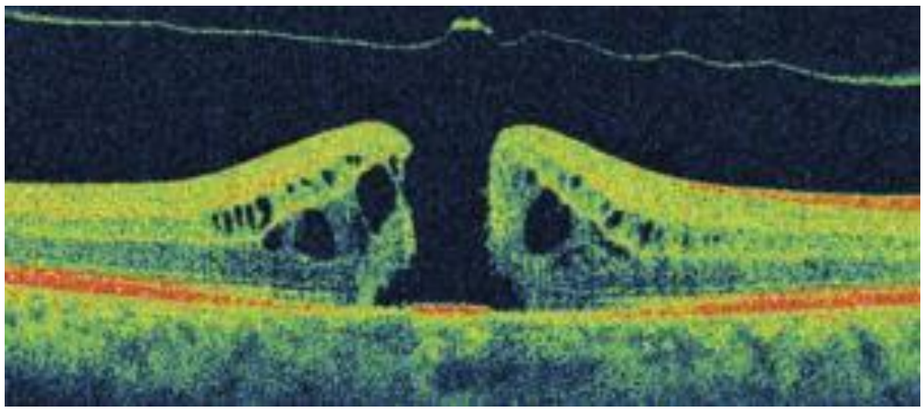
A mild-moderate ERM.

Macular Hole (MH)



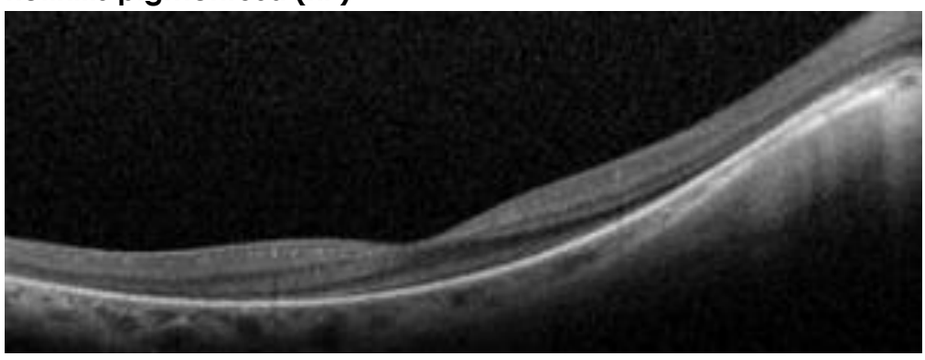
Full-thickness macular holes (FTMH) are very easy to diagnose with OCT. They are

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.

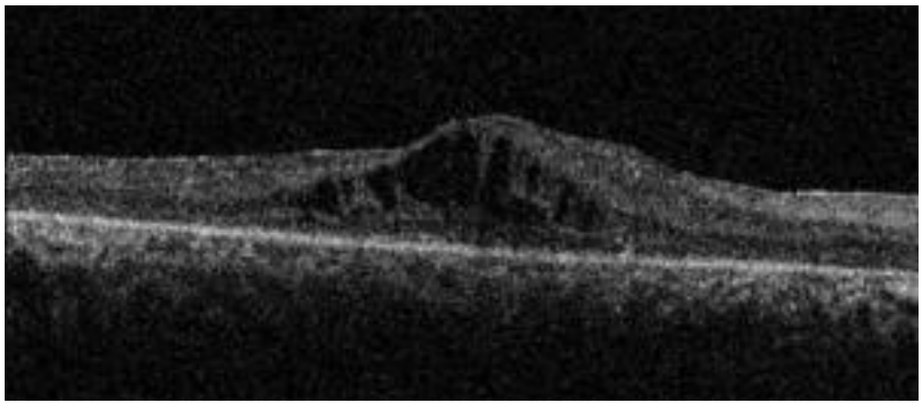


Here, the posterior hyaloid has separated, leaving a central operculum and a full thickness defect.

Retinitis pigmentosa (RP)

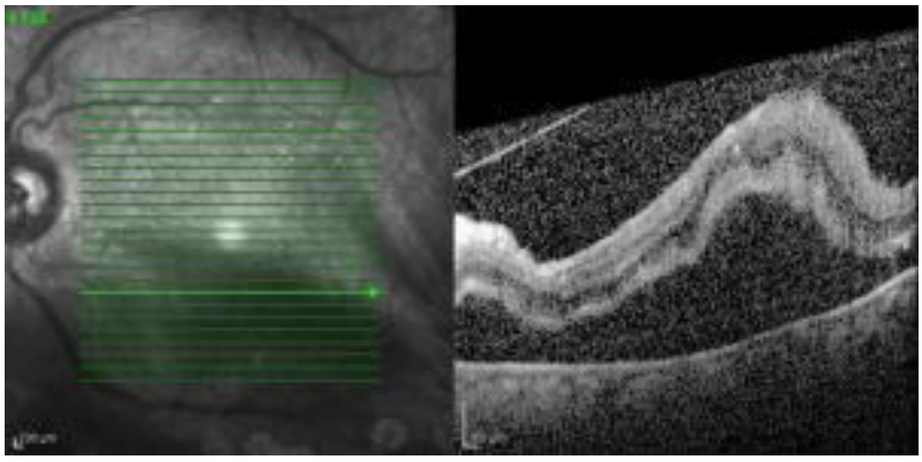


RP is a rod-cone dystrophy. The photoreceptor layer is completely lost except for a central island. Along with it comes thinning of the outer nuclear layer (ONL), which is where the cell bodies of the photoreceptor cells reside.



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.

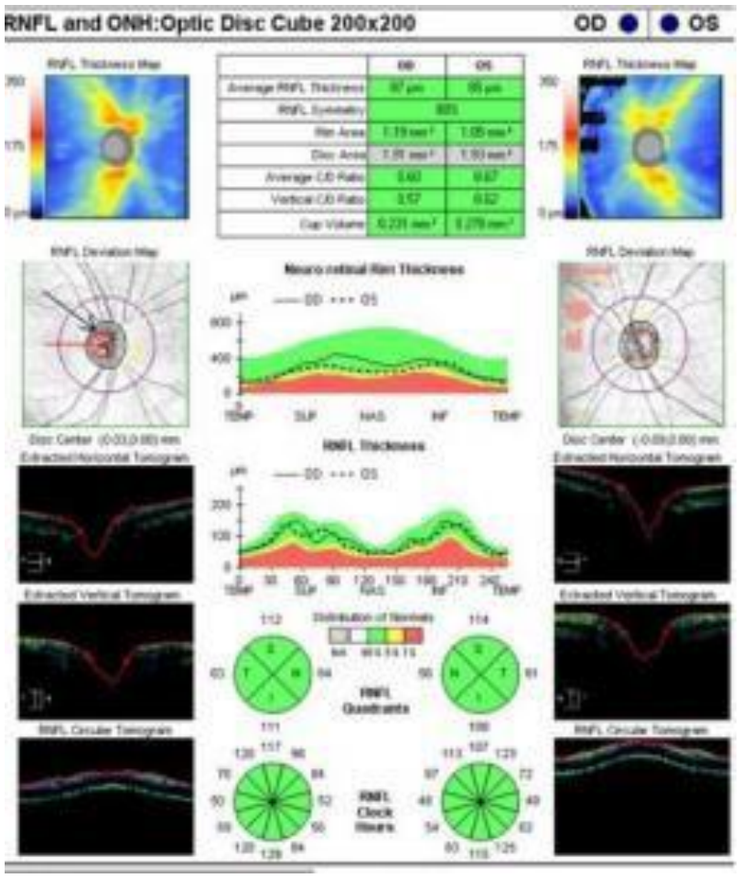
Retinal detachment

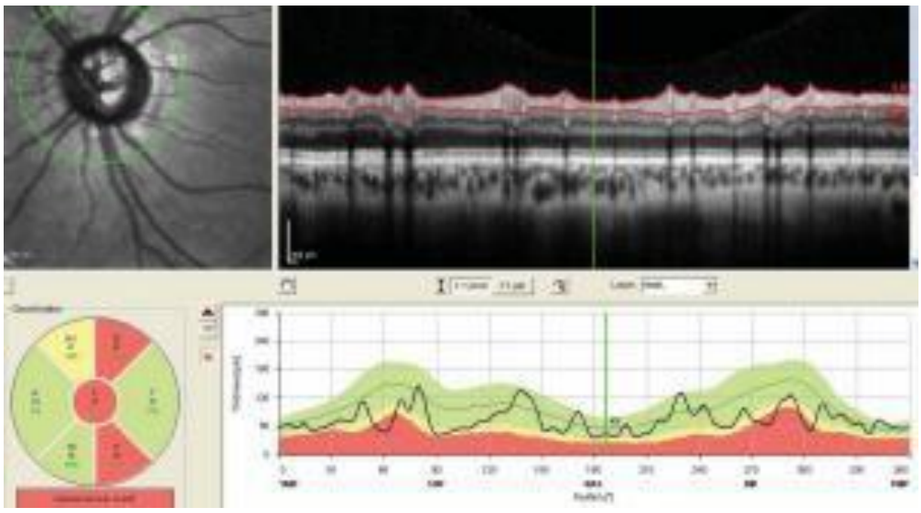


A retinal detachment is usually diagnosed clinically and with examination, but shallow macular detachments are sometimes hard to appreciate early on. If any doubt, a retinal OCT can demonstrate detachment easily.

Optic nerve OCT

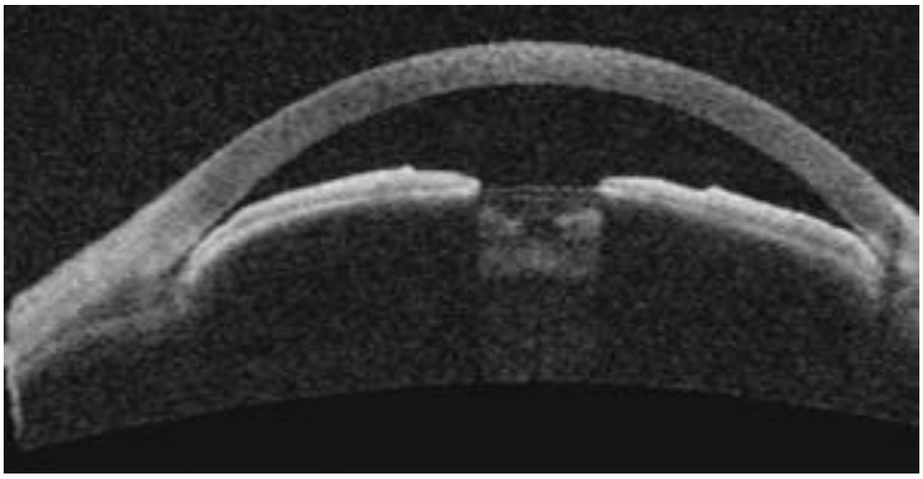
Optic nerve and nerve fiber layer OCT helps in the management of glaucoma. The OCT machines provide automated, serial analysis of the nerve fiber layer thickness, cup-to-disc ratio, and other measurements. They can compare the patient's optic nerve and nerve fiber measurements against age-matched normal 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 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

***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 to**p**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 tomography 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.

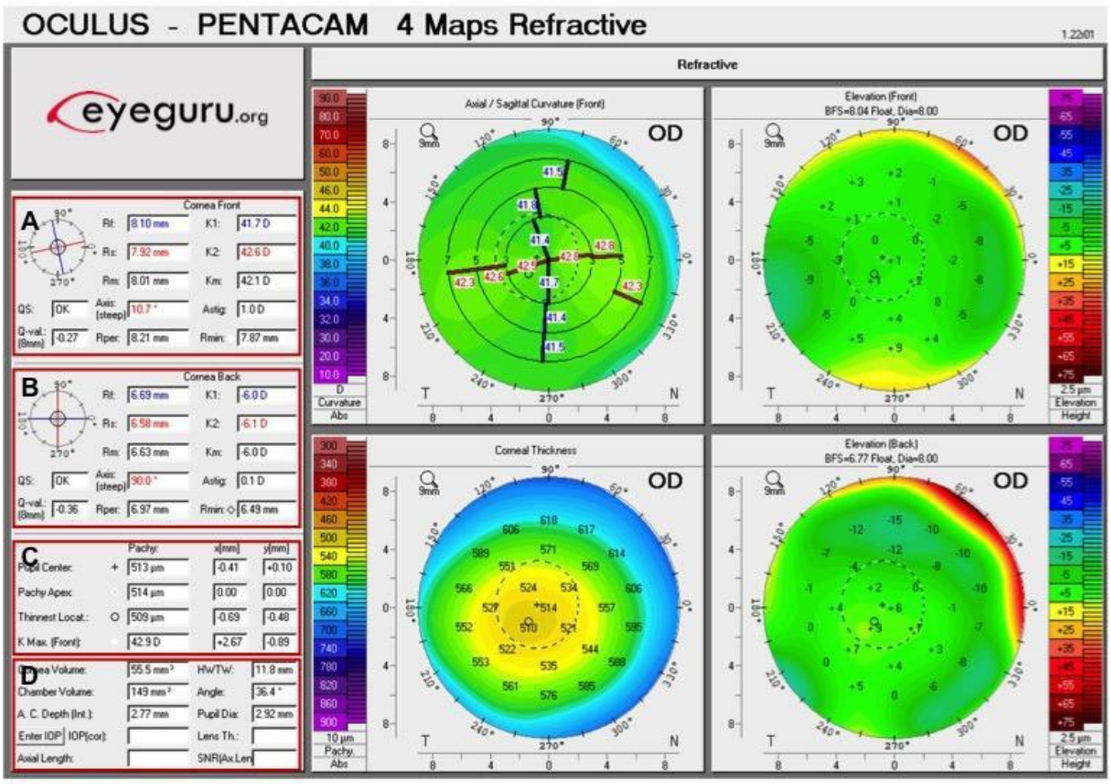
- 1) Axial map (top left)
    - Useful for assessing irregularity of astigmatism and planning suture removal after PK
    - **Warm** colors = steep (think "*steep*ing *warm* tea")
    - **Cool** colors = flat
- 2) Corneal thickness, aka pachymetry map (bottom left)
    - Displays distribution of corneal 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

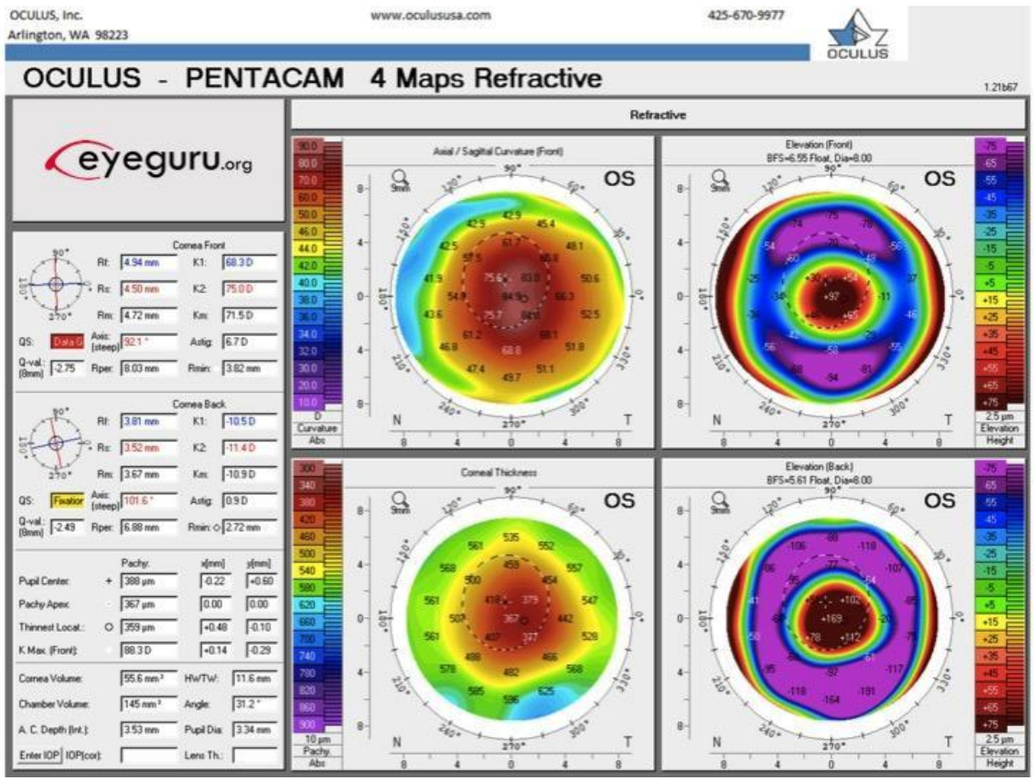
Expected topography: Progressive flattening from center to the periphery by 2-4D, with the nasal area flattening more than the temporal area.



Interpreting Pentacam Values[1]

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.

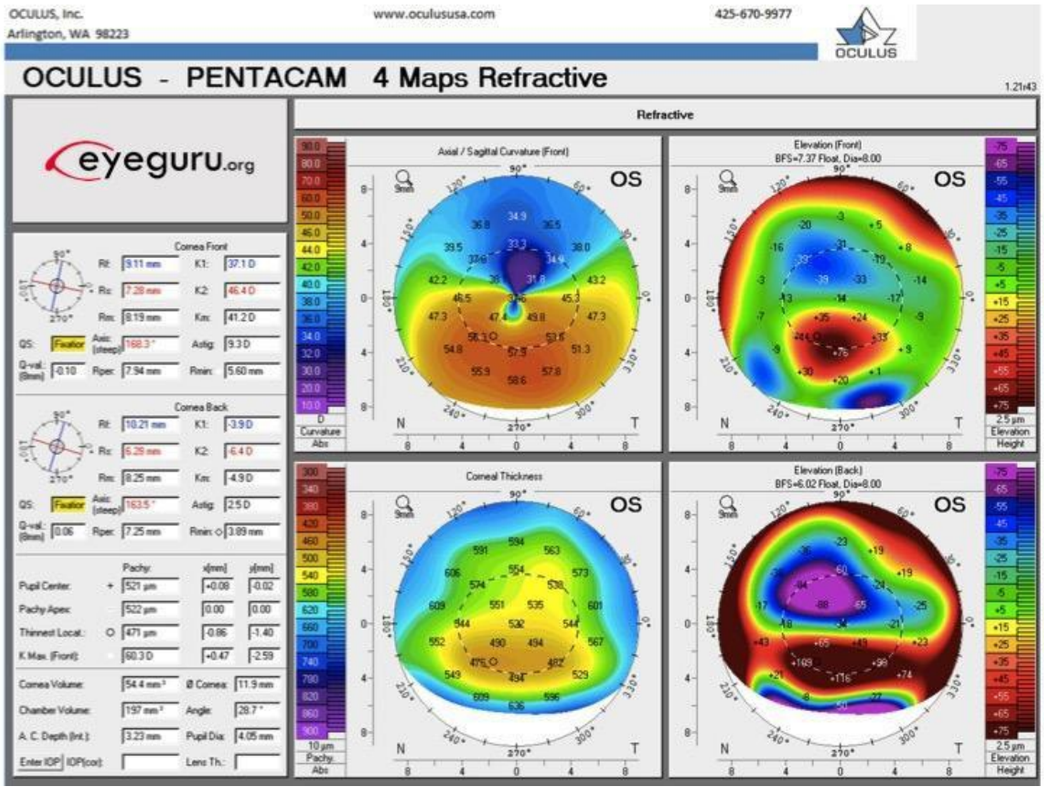
Expected topography: inferior steepening on anterior axial map and corresponding thinning on pachymetry map. There are many systems to grade keratoconus. Here are some examples of various systems, but these are not necessarily the only criteria by which to rule in or rule out keratoconus.

	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

	Risky >+20µm
Pentacam Scheimpflug corneal tomography anterior elevation[3]	Normal ≤+12µm Suspicious +13µm to +15µm Risky >+15µm

2) Pellucid marginal corneal degeneration

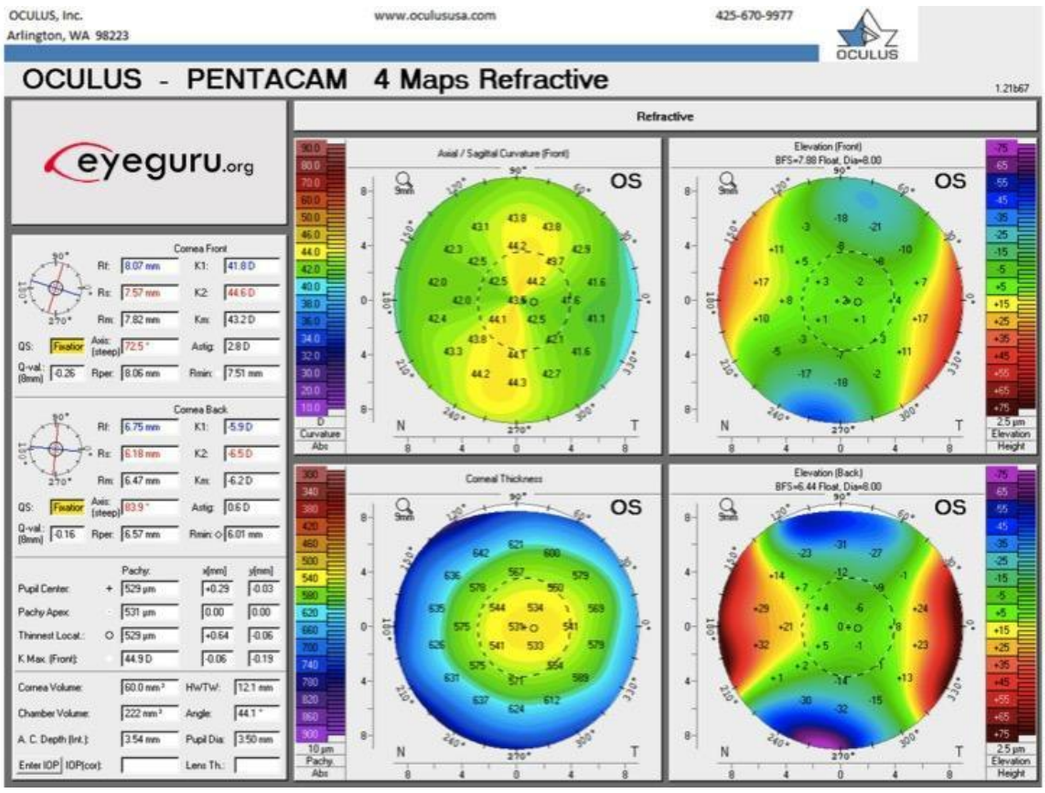
Expected topography: against-the-rule "**crab claw**" or "butterfly" pattern on axial map



3) Astigmatism

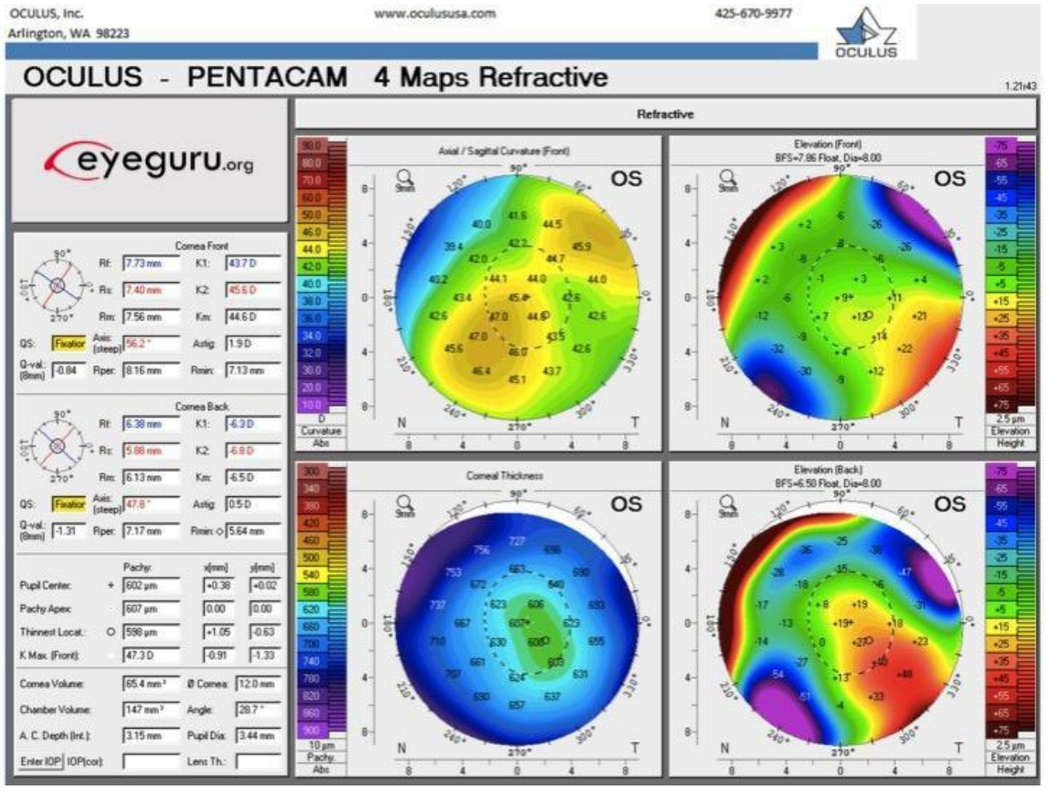
***Regular astigmatism*:** uniform steepening along a single corneal meridian that can be fully corrected with a cylindrical lens (BCVA of 20/20 or better)

Expected topography: symmetric "**bowtie**" along a single meridian

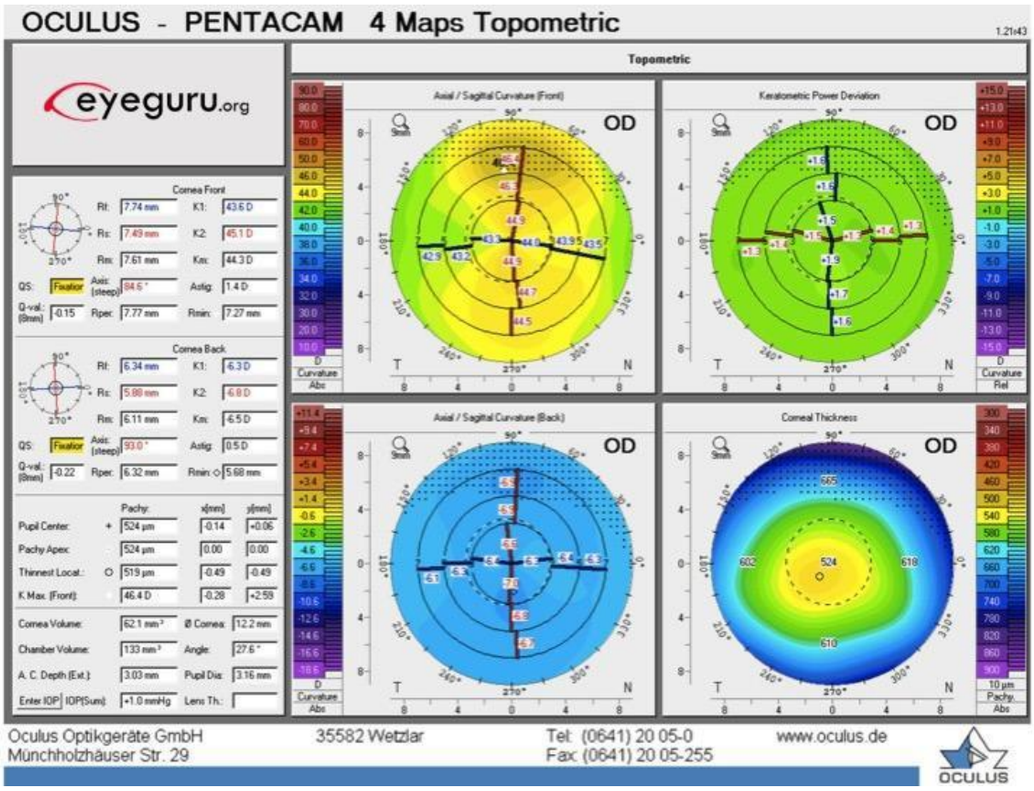


Irregular astigmatism: nonuniform steepening that cannot be corrected by cylindrical lens (BCVA of 20/50 or worse due to irregular astigmatism).

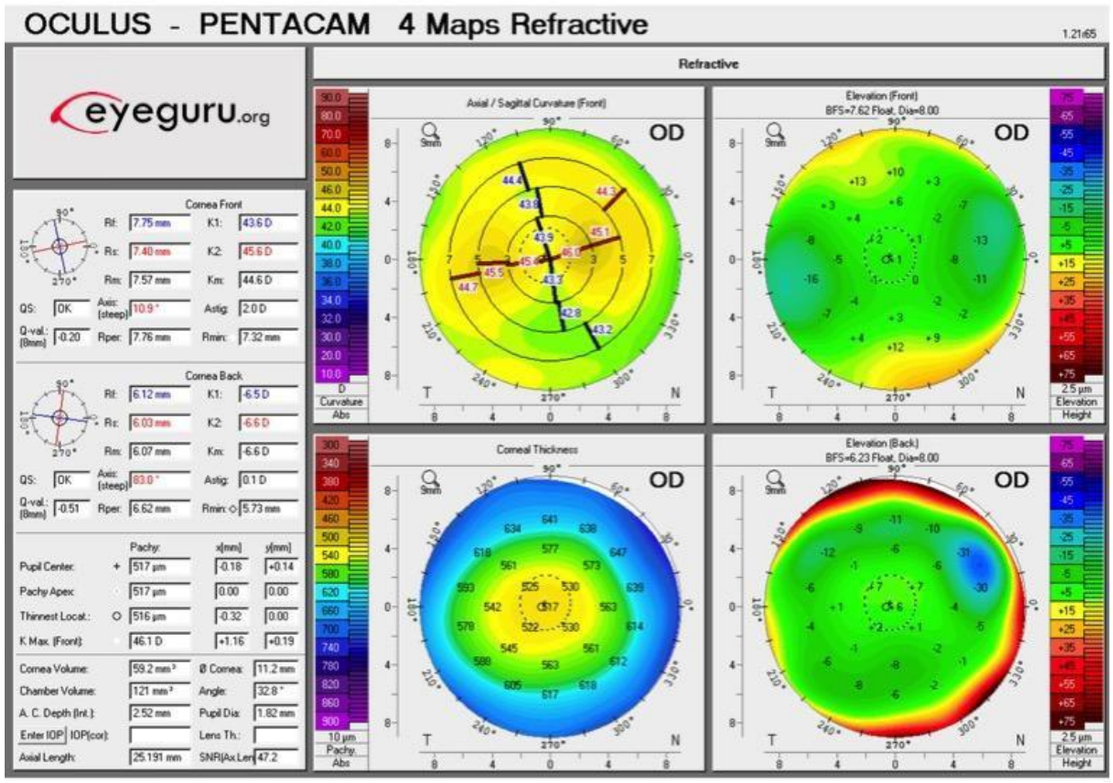
Expected topography: steep and **flat axes less or more** than **90 degrees** apart



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



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 carried out to rule out ectactic (e.g. irregular)
patterns, which occur in disorders like keratoconus and pellucid marginal degeneration. If an ectactic 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.

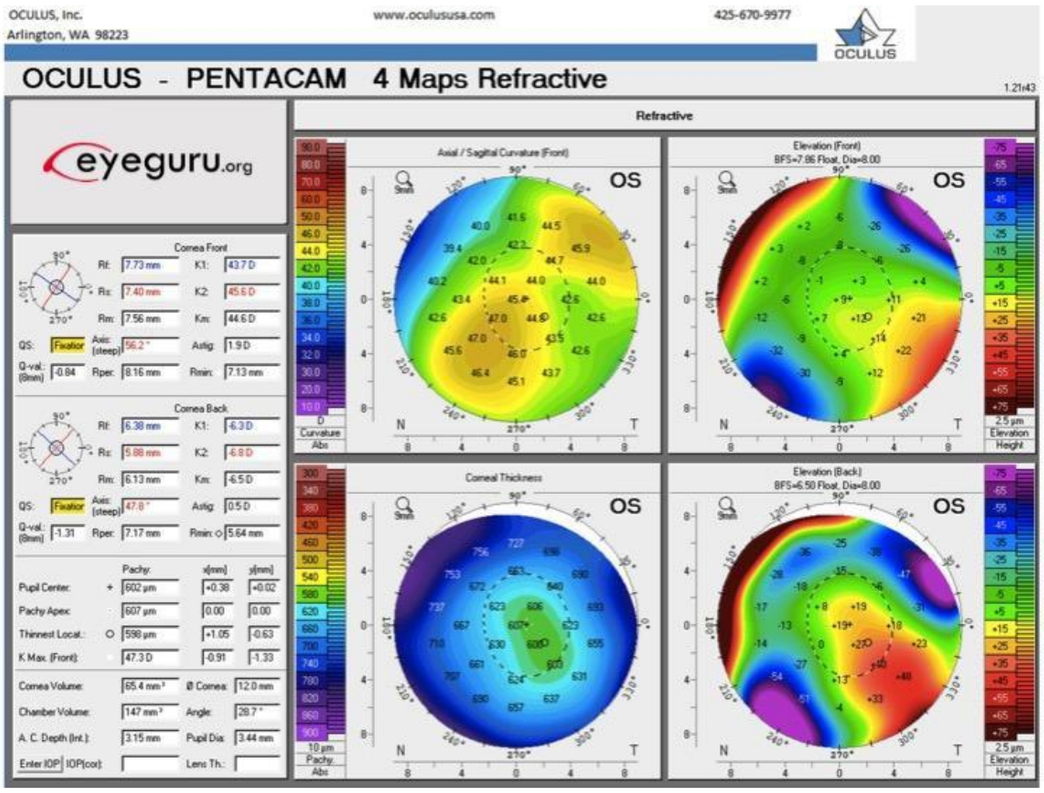
Quick Tips for Clinic

- 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,

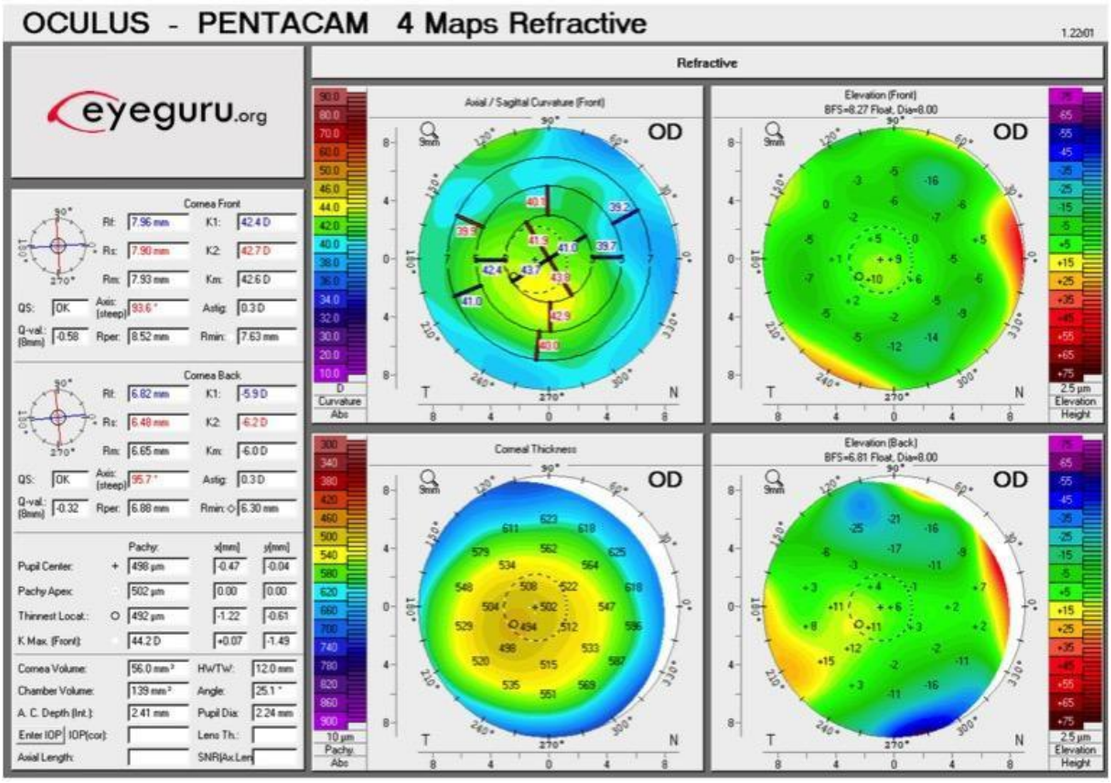
Review Questions

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.**

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.

Whichsubtestshouldlorder? 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

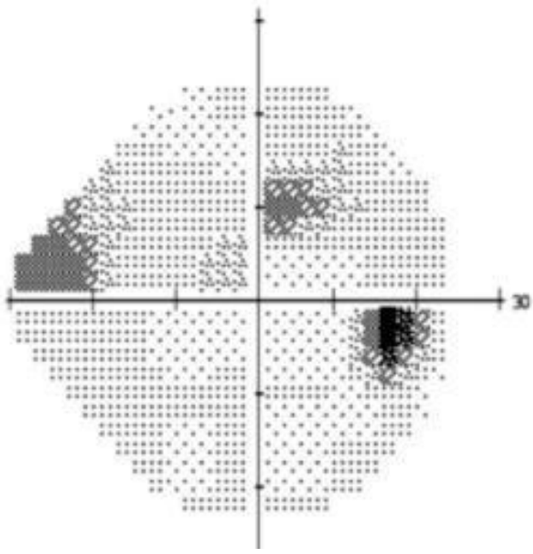
This is ordered for the 10% of glaucoma patients who are so advanced that the HVF 24-2 is mostly black, with only a central island of remaining vision. Macular diseases
including plaquenil toxicity exams also need 10-2.

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 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 diseases.



Grayscale Map

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 consider 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 discussion of this post, so talk to your seniors and your attendings if you aren't sure!

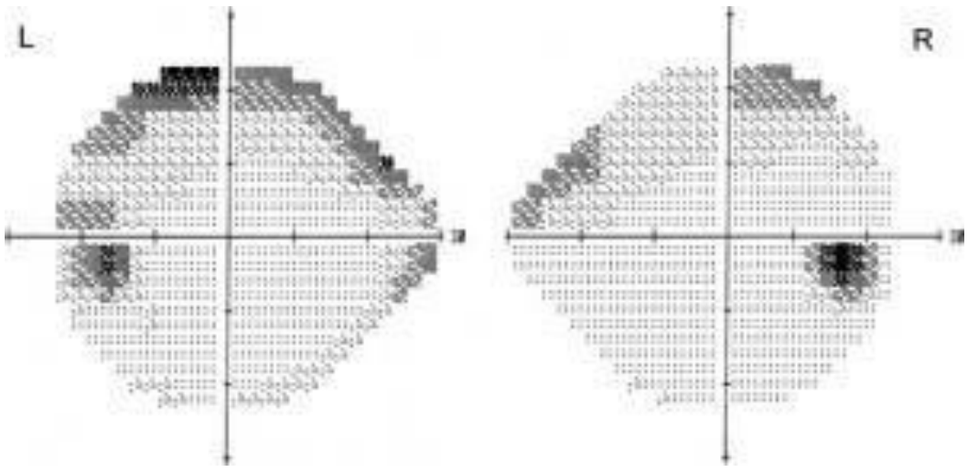
Top 5 most common visual field patterns

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.

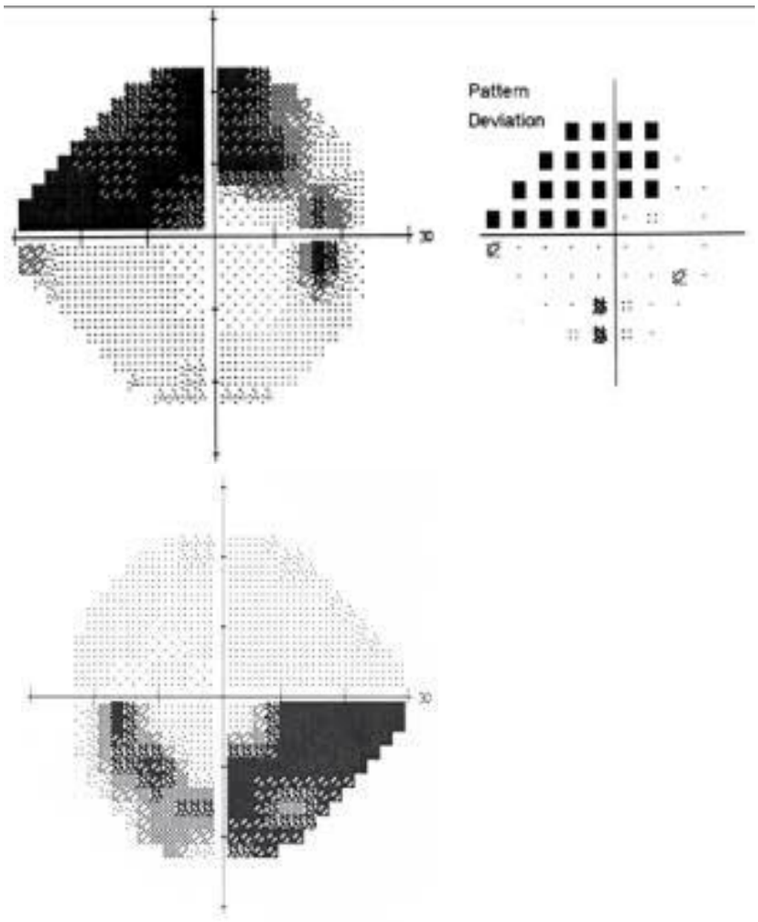
These types of inattention errors will usually register as high fixation losses, false positives, or false negatives. Or, the visual field could just be patchy all over.

If these errors are not too bad, the general gist of the field can be deducted, 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 months' 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).



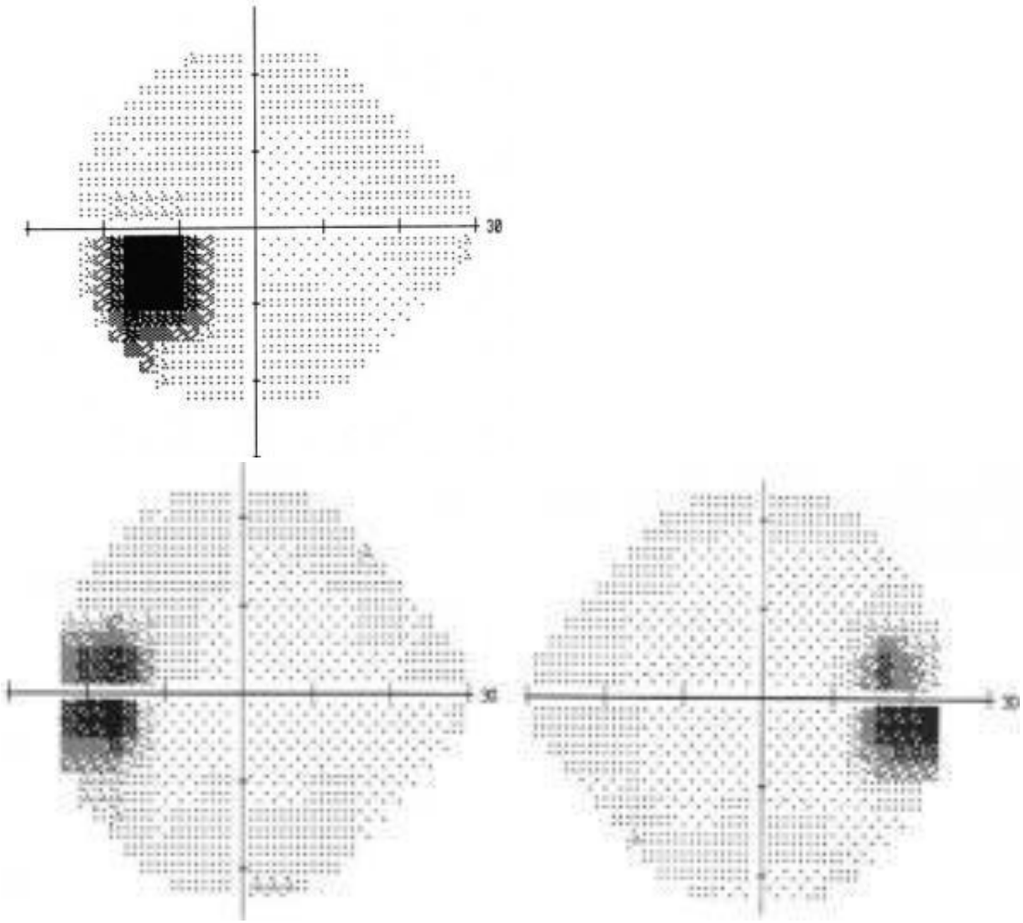
2) Superior / inferior arcuate defect

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.



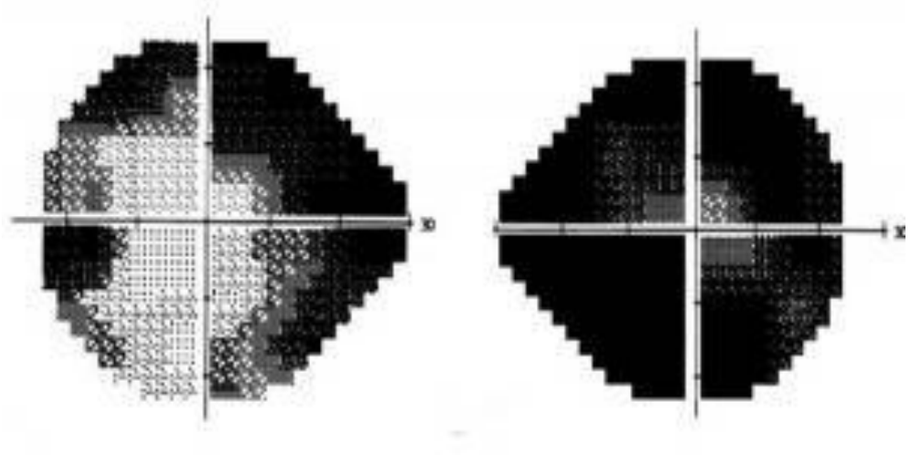
3) Blind spot enlargement

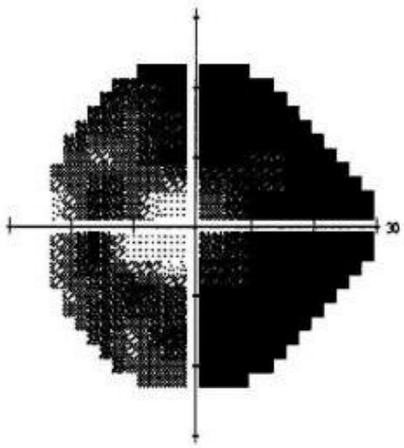
This can be seen in glaucoma but also can occur with papilledema and optic nerve head swelling. This would likely be seen in patients with idiopathic intracranial hypertension (aka pseudotumor cerebri).



4) Severe constriction with a central island

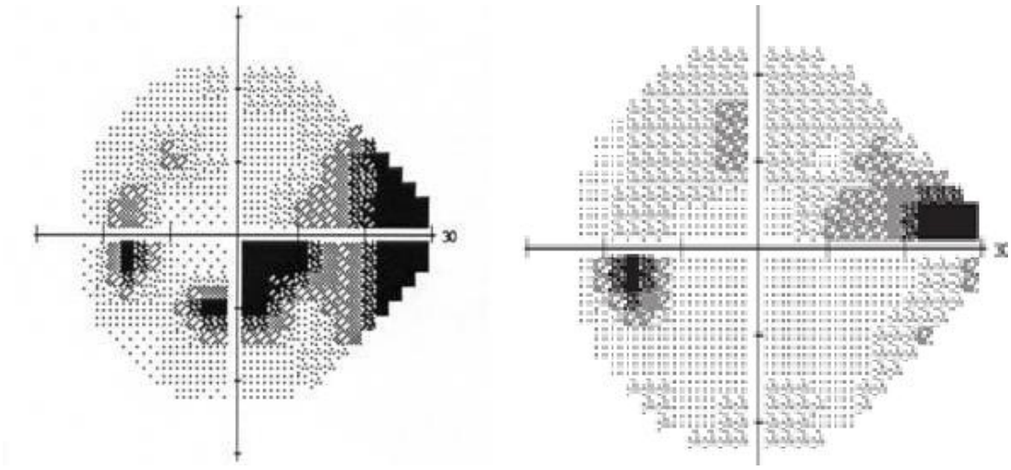
Unfortunately, this is end stage glaucoma. At this point, many patients still have great central vision of 20/20 to 20/50, but peripheral vision is nearly gone. Here, we switch patients over to an HVF 10-2 to better follow their progression.





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 ultrasounds 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

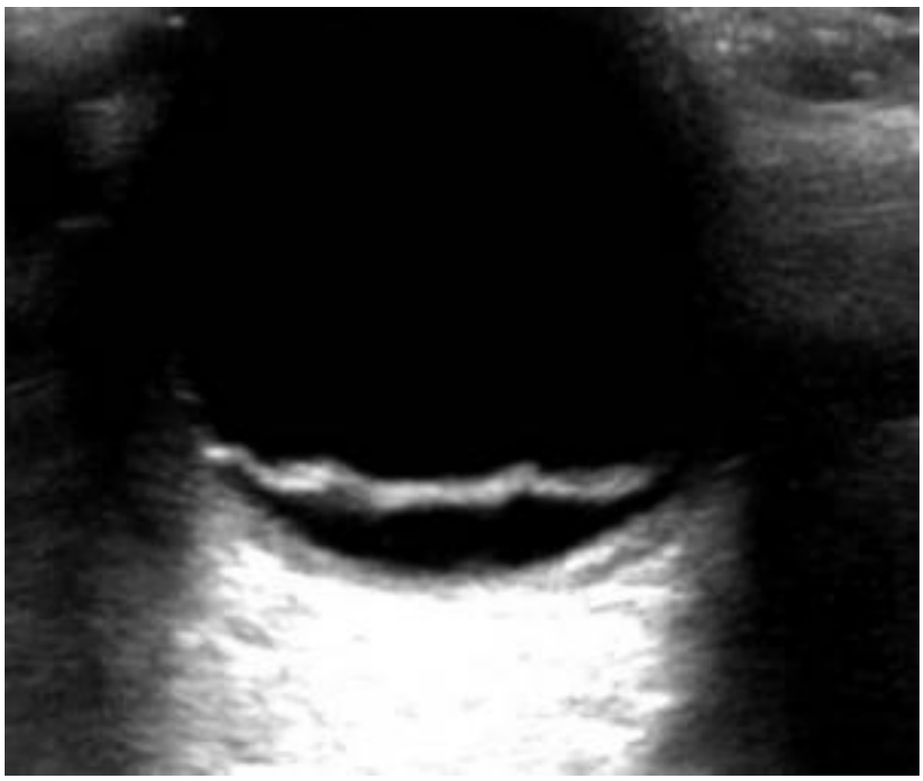
Performing a dynamic scan just means having the patient move their eye back and forth to evaluate how the structures are moving. This is most

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

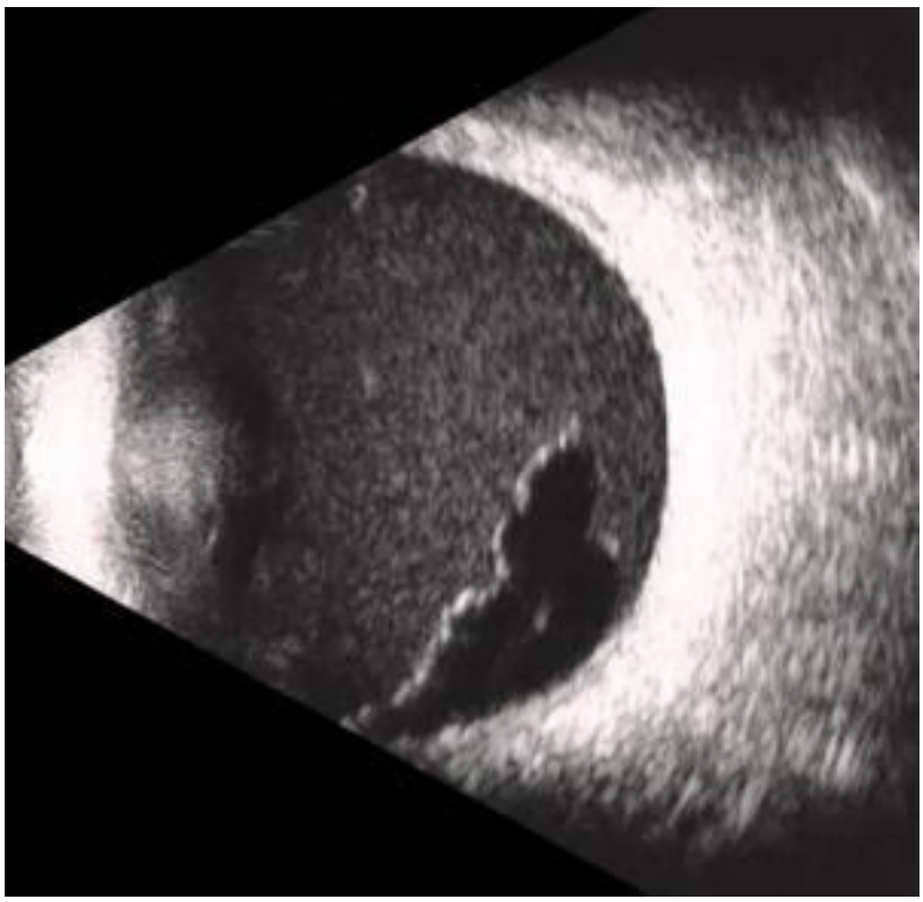
dynamic scans. The retina moves at a slower speed than the posterior hyaloid and its reflectivity is higher. You can use ultrasound using the axial, transverse and longitudinal views to delineate where the retina has detached.



Vitreous hemorrhage

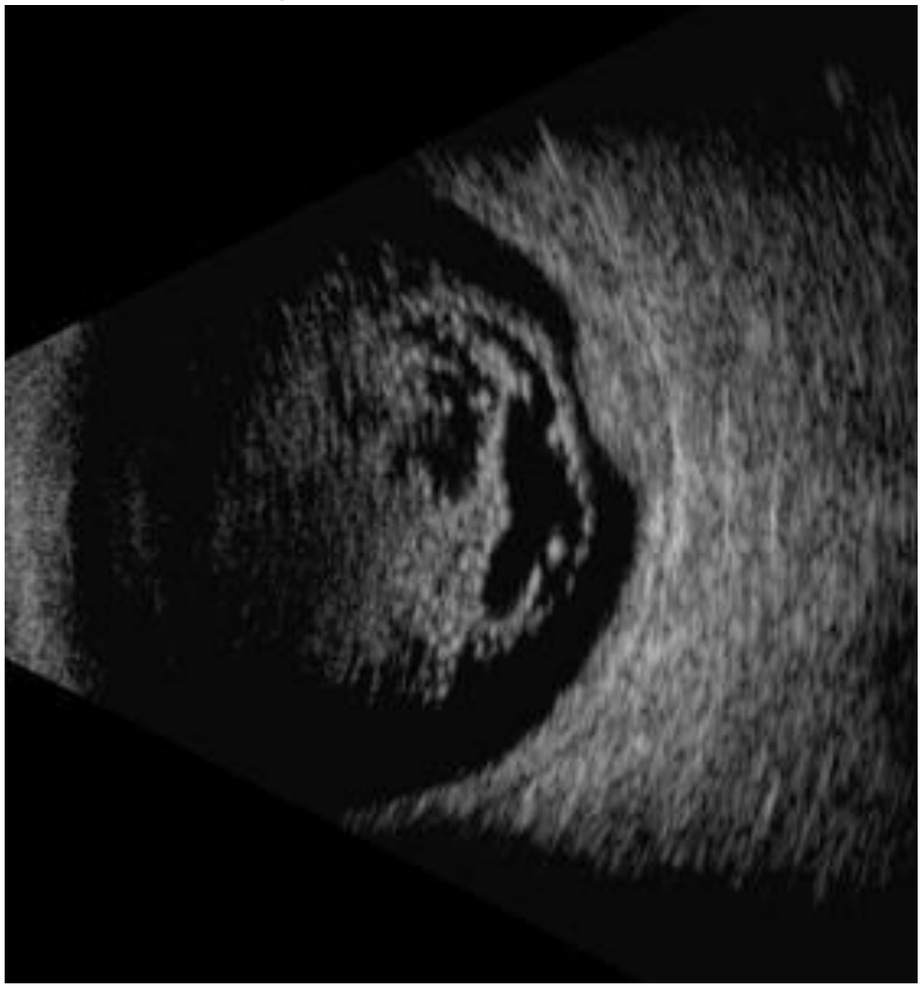
Vitreous hemorrhages are seen commonly in the setting of acute vision loss in one eye.

They can happen in diabetic retinopathy and almost every other retinal neovascular disease.



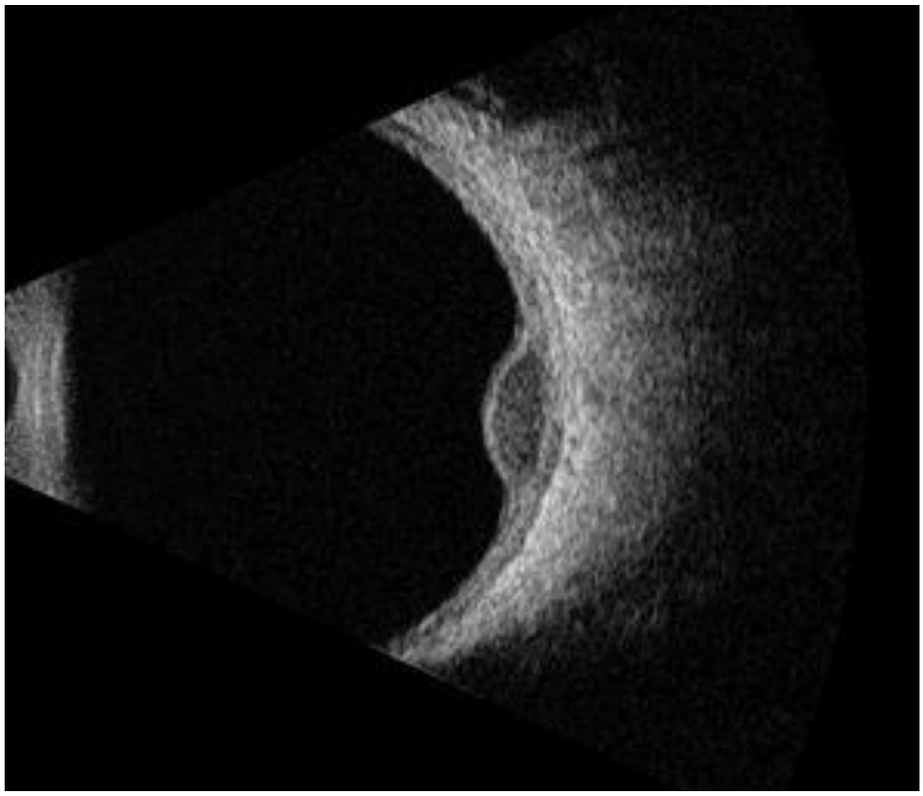
Choroidal nevus

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



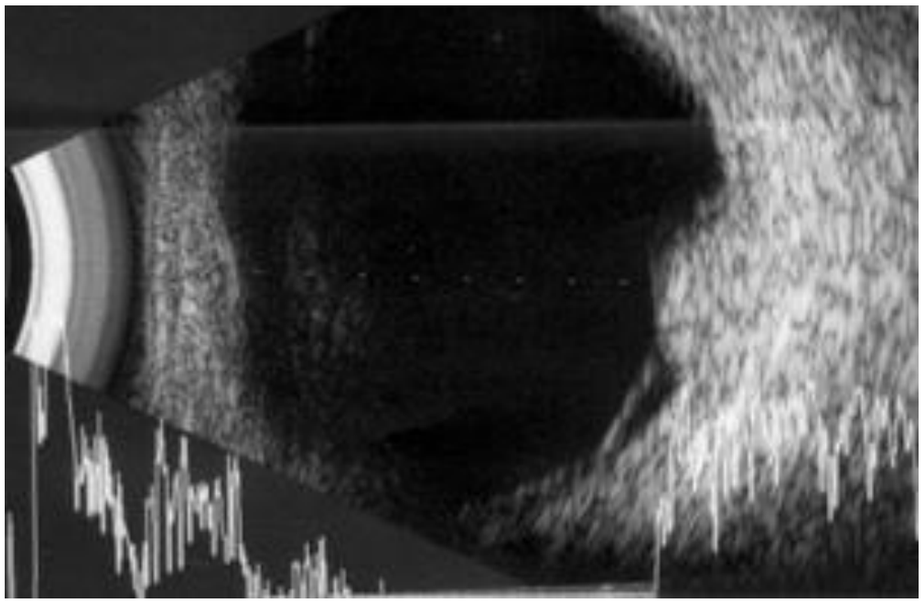
Choroidal melanoma

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.

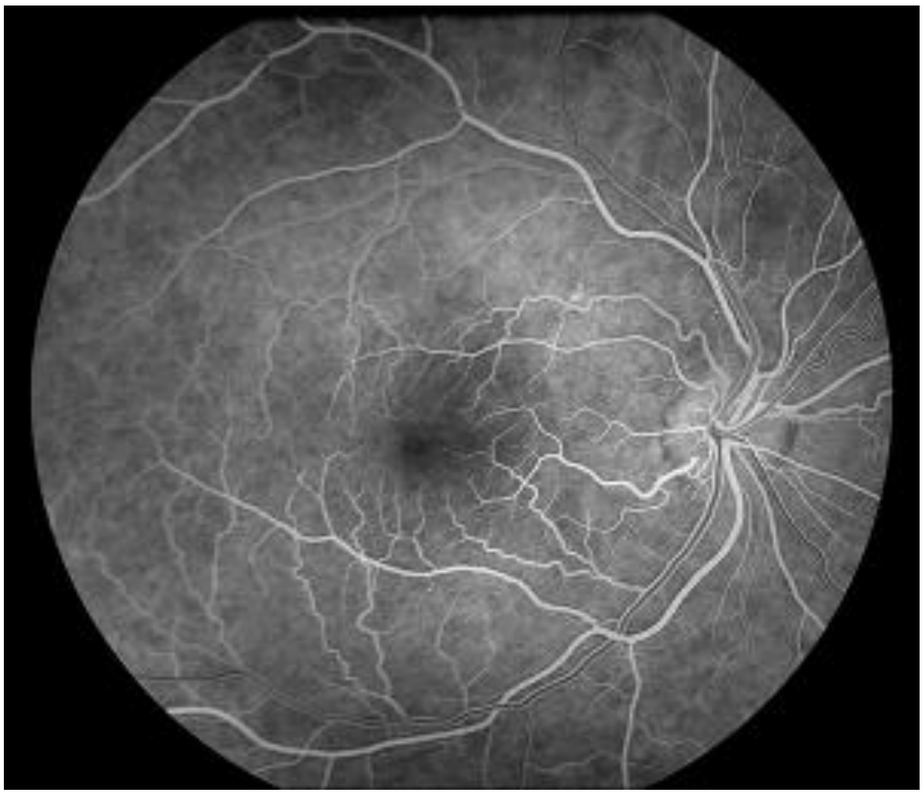


How to interpret fluorescein angiography: 6 types of defects

How does fluorescein angiography (FA) work?

Fluorescein is an organic dye. When blue light is shined on fluorescein, it fluoresces yellow-green. We do this commonly when looking at the cornea after instilling fluorescein. The same dye can be injected intravenously. A blue light camera can take pictures of the retinal circulation, and the emitted fluorescence is then passed through a yellow-green filter and sent to the camera for the final image.

In a normal eye, fluorescein can not permeate through the endothelial cells of the retinal blood vessels, nor can it pass through tight junctions in the retinal pigment epithelium (RPE). The yellow-green wavelength is also heavily absorbed by the RPE, so the choroidal fluorescence is blocked. This makes FA good for evaluating the retinal vasculature, not the choroidal vasculature.



A normal FA

In contrast with FA, indocyanine green (ICG) dye is great for evaluating the choroidal circulation. Almost all the ICG molecules are protein bound, so they do not readily produce retinal leakage or staining. ICG fluoresces in the infrared wavelength and readily passes through the RPE (retinal pigment epithelium).

Phases of the angiogram

1. *9-15 seconds* = Choroidal phase (AKA pre-arterial phase): The choroidal hyperfluorescence is present. A cilioretinal artery if there is one will fill in this phase. Delayed choroidal filling time happens in ocular ischemic syndrome (OIS).
2. *1-3 seconds later* = Arterial phase: Arteries are bright, but the veins remain dark.
3. Arteriovenous phase: Laminar flow in the veins – the walls of the veins are bright while the center of the vein is still dark.
4. *By 30 seconds* = Venous phase: Complete filling of the veins.
5. *30 seconds – 10 minutes* = Late phase: Dye has recirculated. Things that are going to leak or pool will have done so already.

Types of hyperfluorescence

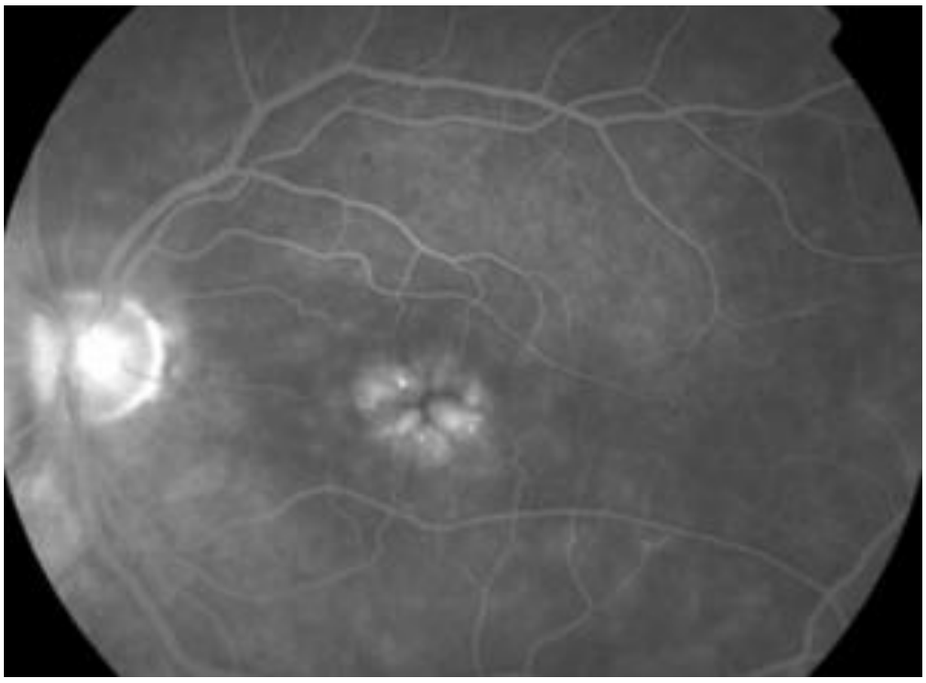
There are 4 types of hyperfluorescence (brightness) in FA:

1. Leakage: Hyperfluorescence **progressively enlarges** with fuzzy borders. The dye permeates out of leaky, incompetent blood vessels in the setting of

neovascularization, retinal vasculitis, vascular malformations, tumours, or disc oedema (dye leaks from prepapillary capillaries).

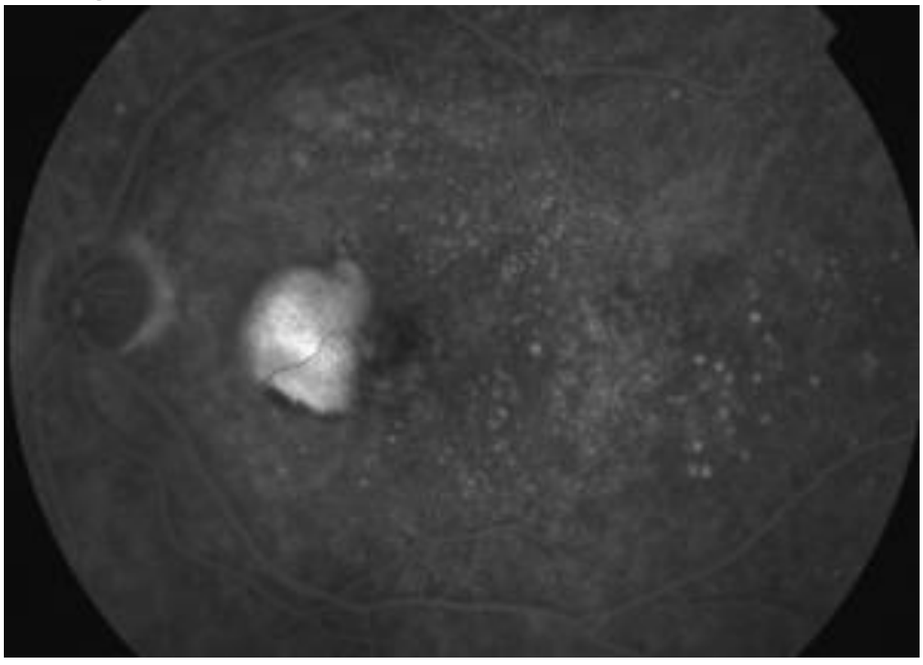
2. Pooling: Hyperfluorescence progressively enlarges to fill the fluid cavity and then **becomes fixed in size**. Usually, the dye fills a cavity like the subretinal space or sub-RPE space (in a PED).
3. Staining: Late hyperfluorescence due to accumulation of fluorescein dye. The hyperfluorescence gradually gets brighter, but the **size stays the same**. Usually, a mild amount of fluorescence is seen, but it is never very bright. The optic disc always stains. Additionally, drusen and fibrosis will stain.
4. Window defect: Defect in the RPE allows transillumination of the choroidal hyperfluorescence. Remains **static in size and brightness** and becomes fluorescent with the choroidal phase before the arteries even fill in the early frames.

Leakage



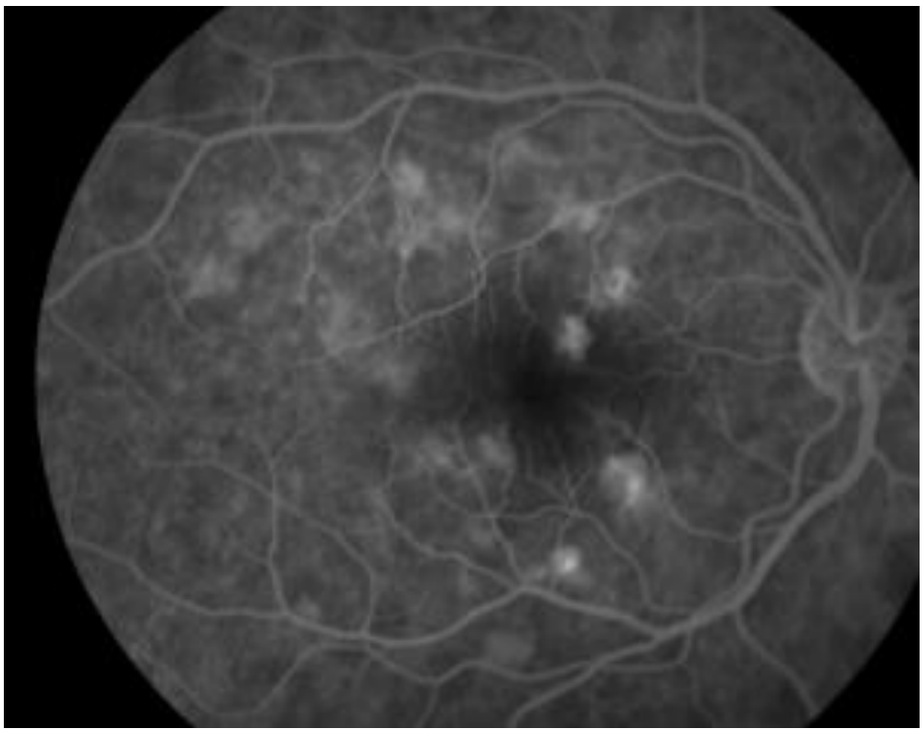
Petaloid leakage from cystoid macular edema

Pooling



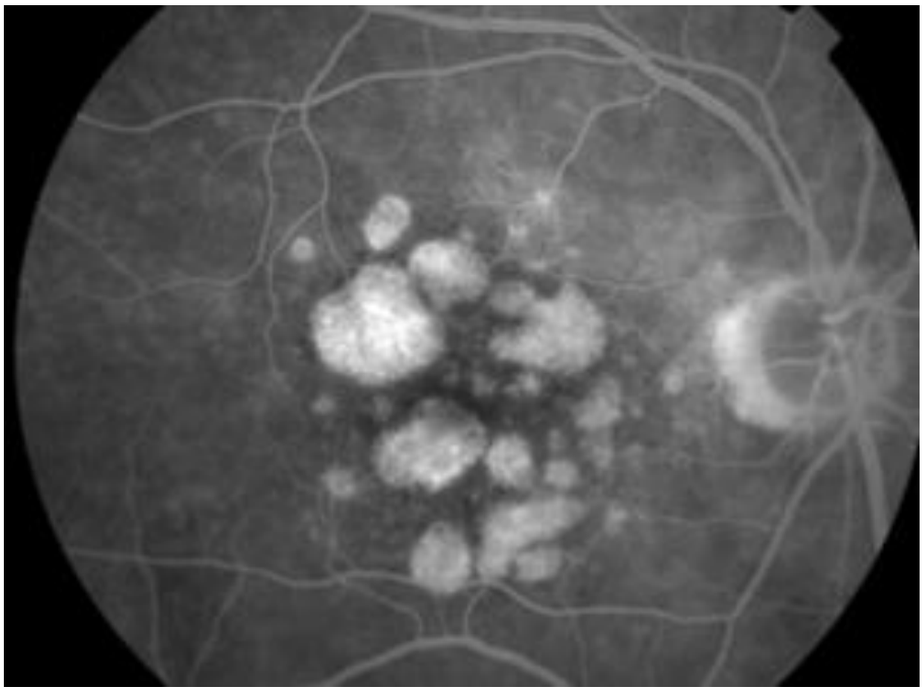
Pooling from a serous pigment epithelial detachment

Staining



Late staining of acute posterior multifocal placoid pigment epitheliopathy (APMPPE) lesions.

Window defect



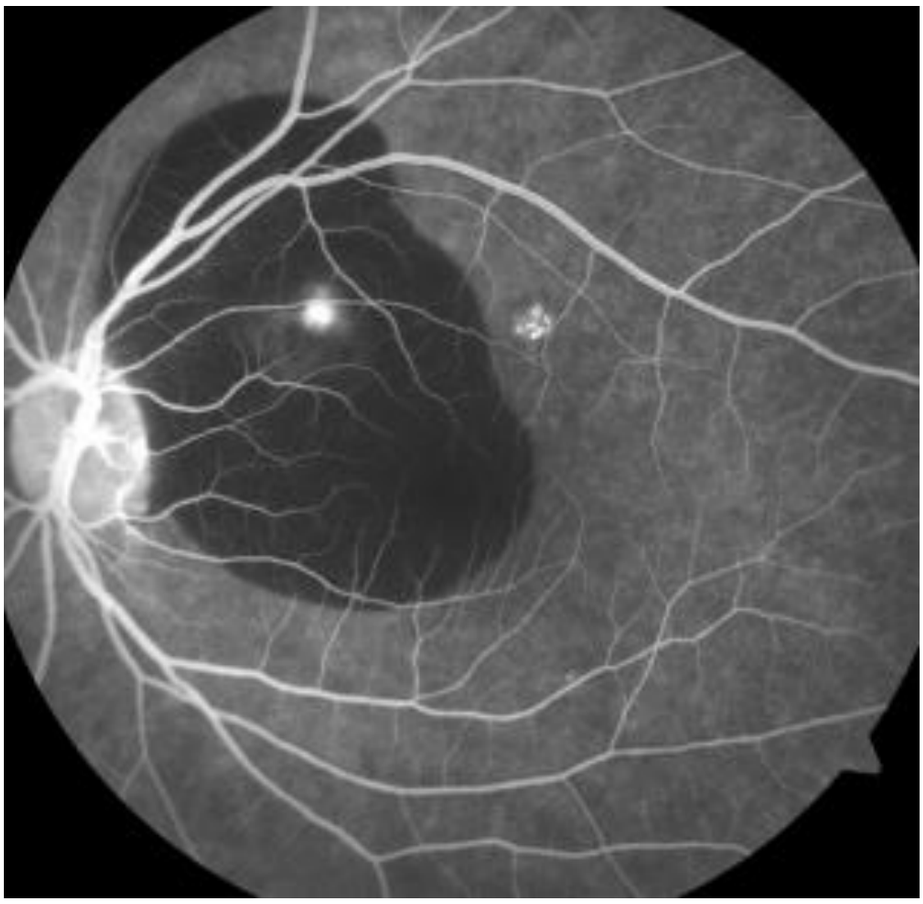
Window defect from geographic atrophy in AMD

Types of hypofluorescence

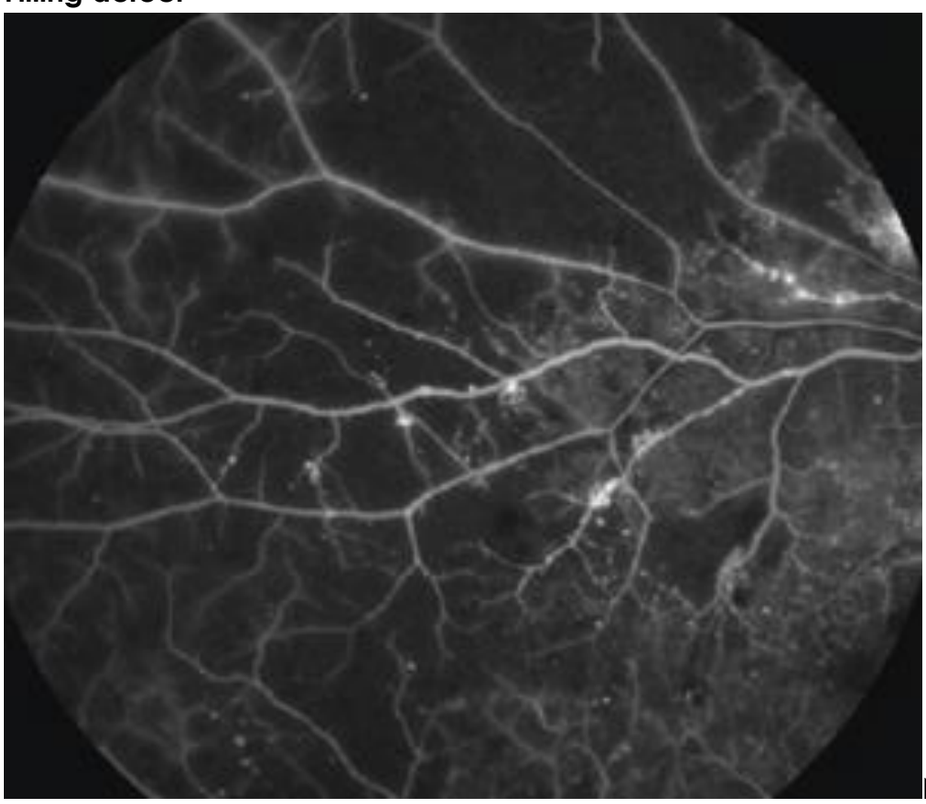
There are 2 major types of hypofluorescence:

1. Blocking: Blood or other opacities block the fluorescence. Blockage of the retinal fluorescence can happen due to preretinal or vitreous hemorrhage. Blockage of the choroidal fluorescence can happen due to nevi or melanomas, Stargardt's disease (lipofuscin blocking choroidal flush leading to a "dark choroid"), or subretinal blood.
2. Filling defect – lack of retinal perfusion due to capillary dropout, retinal artery occlusion and other causes.

Blocking


Blocking of choroidal hyperfluorescence from subretinal blood. You know it's subretinal because the retinal vessels are overlying the dark area.

Filling defect


Nonperfusion from diabetic capillary dropout.

Conclusion

1. Fluorescein angiography (FA) is a great way to evaluate retinal circulation.
2. Nowadays, OCT has greatly reduced the number of FAs performed, though FA still remains a very important modality for assessing many circulatory dysfunctions of the retina.
3. FAs can be evaluated based on distinct phases of dye circulation.
4. Various pathology can cause structures to be hyperflourescent or hypoflourescent. It is important to know generally what pathology correlates with what FA appearance.

A Reference Guide for OCT Angiography

OCT angiography (OCTA) is a noninvasive imaging technique that uses the principles of motion detection to reveal depth-resolved images of the retinal and choroidal vasculature, down to the capillary level.[1] OCTA has several advantages over traditional imaging techniques, including being noninvasive (no dye injection), depth resolved, and rapid. A key benefit of OCTA is its ability to distinguish the various vascular networks without obscuration by leakage, making it very helpful for characterizing retinal neovascularization and nonperfusion with precision beyond dye-based angiography.

Here, we detail several clinical scenarios in which OCTA can be a useful diagnostic tool and illustrate key imaging features. In general, absence of flow (nonperfusion) is best appreciated with en face images. The presence of abnormal flow is most accurately detected using a combination of en face imaging assisted by the OCT B-scan with flow overlay to pinpoint abnormal flow related to structural pathological changes.

The OCT B-scan with flow overlay is particularly useful in situations where the quality of the en face image is equivocal. These tools are complementary and, together, can provide the clinician with a wealth of knowledge. Although beyond the scope of this discussion, it is also important to be cognizant of the artifactual errors that can occur and influence image interpretation.[2,3] Examples include segmentation errors with en face images and projection artifacts with both en face images and B-scan flow overlay.[2,3]

DIABETIC RETINOPATHY

OCTA can be useful in evaluating nonperfusion and neovascularization, giving the clinician insight into the degree of ischemia and severity of retinopathy. Nonperfusion is more easily detectable on the en face images than the cross-sectional OCT B-scan (Figures 1-3).

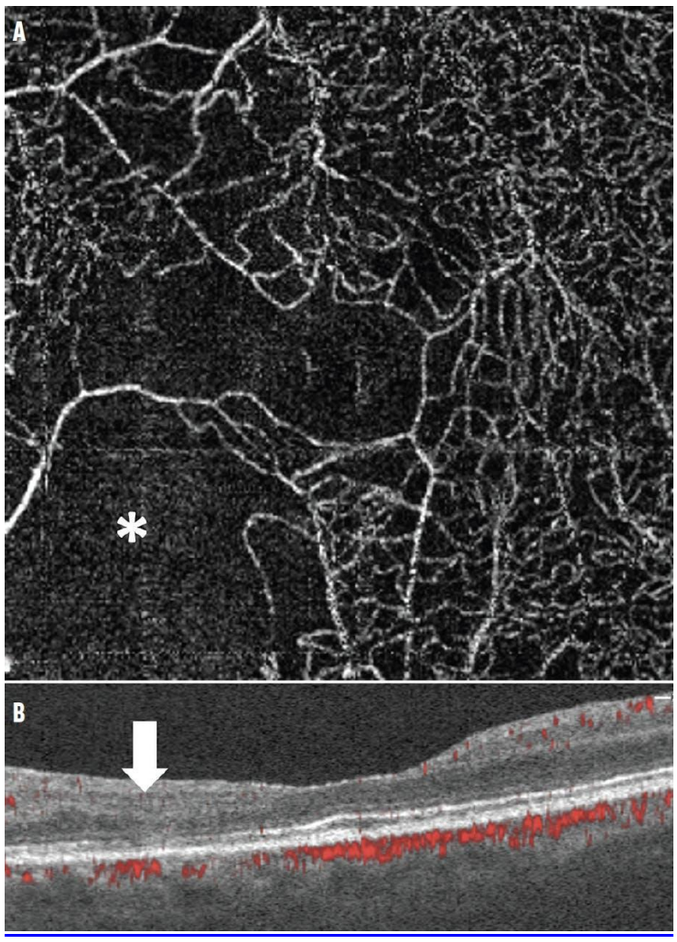


Figure 1. The en face OCTA deep capillary plexus slab of an eye of a 30-year-old woman with type 1 diabetes revealed significant areas of nonperfusion and capillary dropout (A, asterisk). The area of nonperfusion corresponds to a lack of flow seen on the OCT B-scan flow overlay (B, arrow). Note the asymmetry in flow between the temporal and nasal retina. There is also significant thinning of the fovea and temporal retina, including photoreceptor disruption, and disorganization of the retinal inner layers with distortion of the retinal layers on the OCT B-scan.

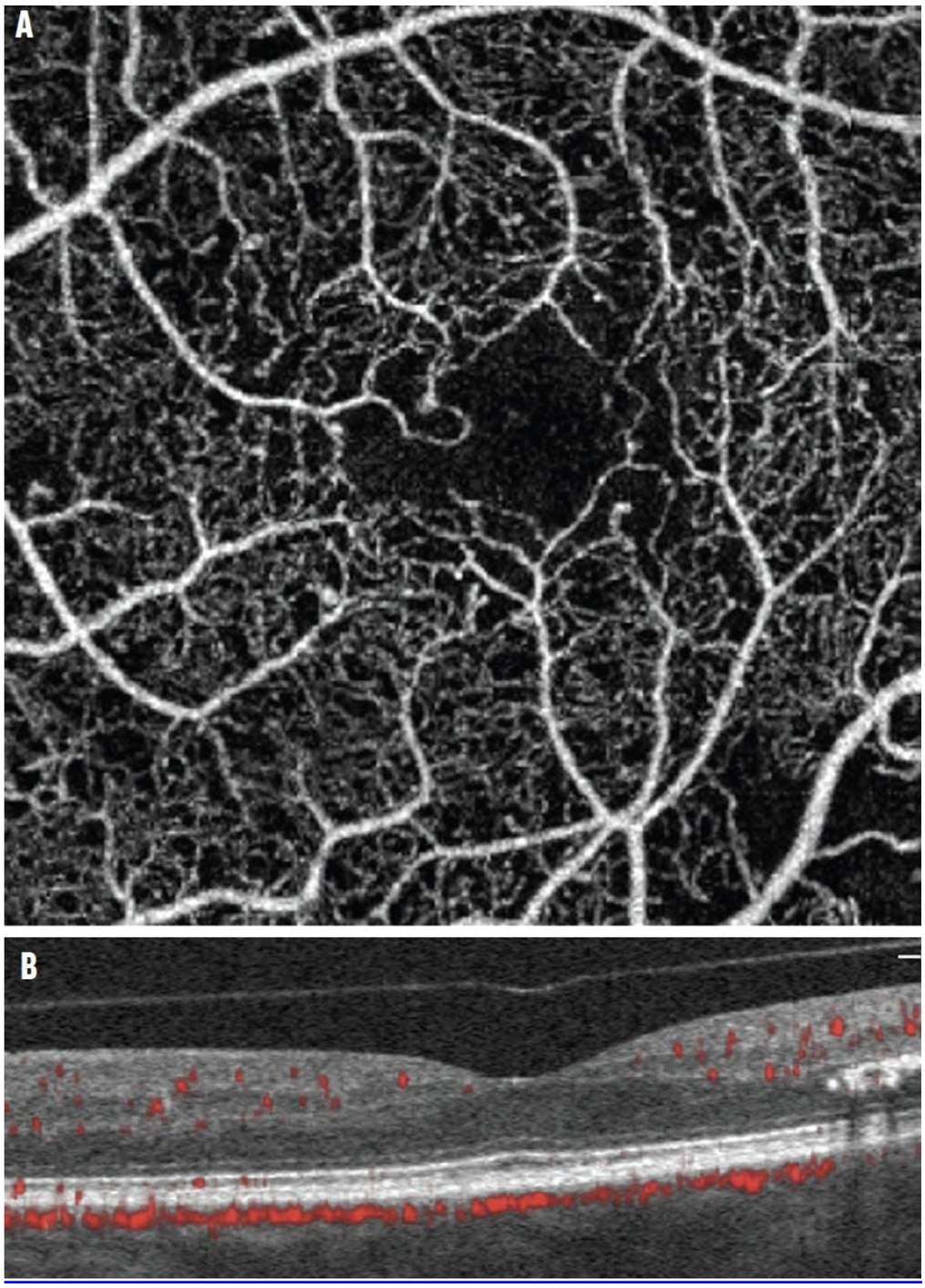


Figure 2. The full-thickness en face OCTA of the eye of a 36-year-old woman with type 1 diabetes showed an irregular, enlarged foveal avascular zone (FAZ) due to nonperfusion (A). Note the relatively normal retinal appearance on the OCT B-scan with flow overlay (B). In general, the full-thickness OCTA slab is the best approach for outlining the entire FAZ.

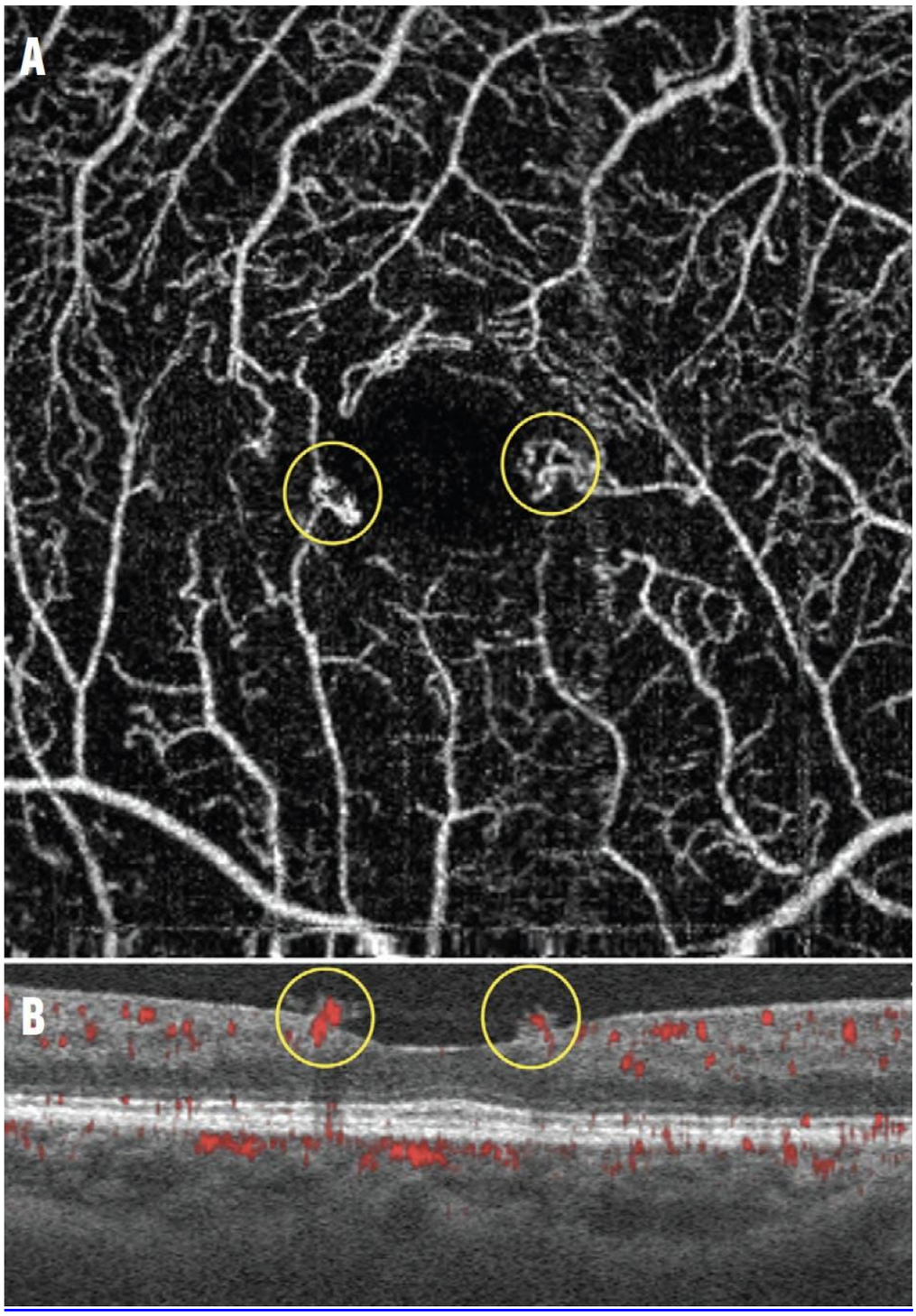


Figure 3. The en face superficial capillary plexus slab of an eye of a 48-year-old woman with type 2 diabetes illustrated abnormal blood vessels in the juxtafoveal region (A, circles). These abnormal vessels correspond to hyperreflective foci that project anterior to the internal limiting membrane on each side of the FAZ, with flow (B, circles, red overlay), consistent with neovascularization elsewhere, rather than intraretinal microvascular abnormalities.

AMD (Age Related Macular dystrophy)

OCTA is typically used in the setting of AMD to confirm the presence of neovascularization prior to treatment. It is particularly useful in cases of type 1 neovascularization, where sub-retinal pigment epithelium (RPE) neovascularization (also known as *subclinical* or *nonexudative* AMD) can develop without active exudation (Figure 4). OCTA can also be used to pinpoint the exact location of new blood vessel growth in cases of type 3 neovascularization (Figure 5).

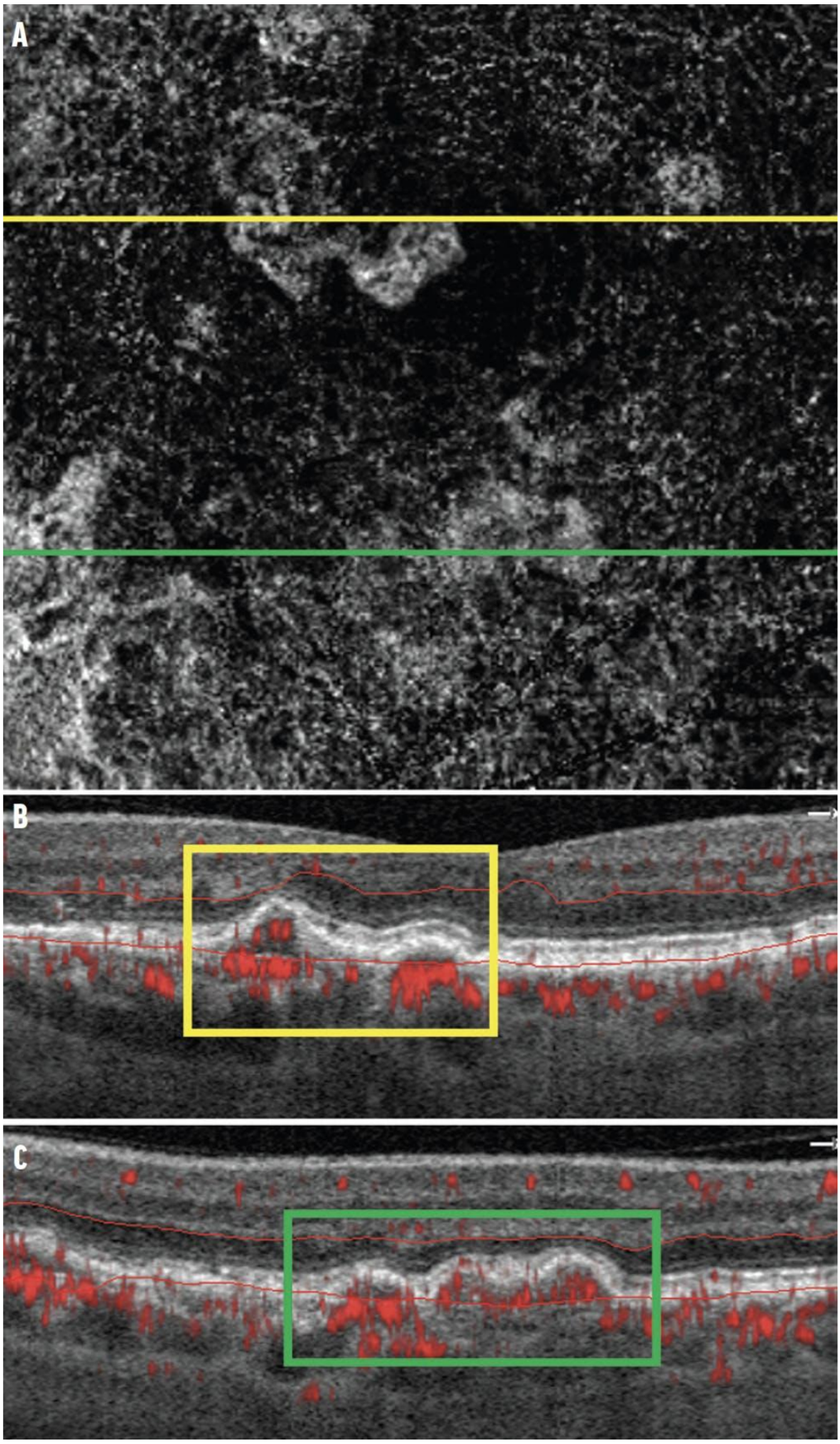


Figure 4. The en face outer retina slab of an eye of a 64-year-old woman with a history of nonexudative AMD showed several areas suspicious for neovascular networks (A). The colored lines correspond to the colored boxes in the OCT B-scans with flow overlay (B and C), where multiple areas of flow are present within the shallow pigment epithelial detachment and above Bruch membrane, consistent with a type 1 neovascular membrane. In these situations, the OCTA distinguishes drusen or drusenoid pigment epithelial detachments from subclinical neovascularization.

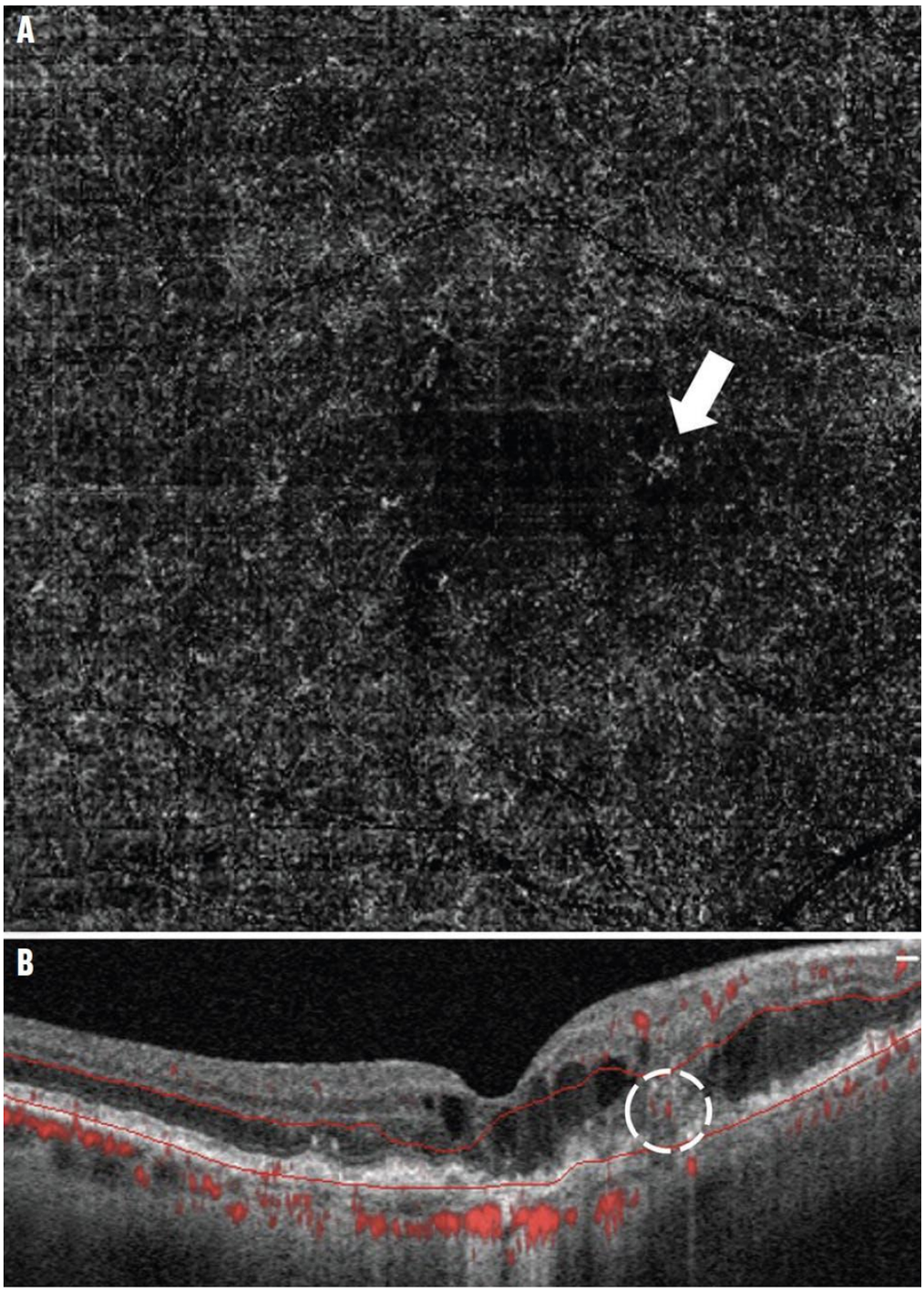


Figure 5. The en face deep capillary plexus slab of the eye of a 77-year-old man with AMD showed a subtle area of possible neovascularization in the outer retinal slab, consistent with possible type 3 neovascularization in AMD (A, arrow). By looking at the cross-section with flow overlay (B), an area of definite abnormal flow with surrounding outer retinal hyperreflectivity confirms the neovascular lesion (circle). The OCT B-scan with flow overlay was useful to confirm the presence of neovascularization due to the poor quality of the en face image. The B-scan can also be helpful in situations where the area of neovascularization may be too small or inconclusive on the en face slab.

POLYPOIDAL CHOROIDAL VASCULOPATHY (PCV)

PCV is traditionally diagnosed via the identification of polyps or branching vascular networks using ICG angiography, which can be time-consuming and difficult to obtain.[4] However, OCTA in combination with structural OCT can be used to identify flow features consistent with PCV (Figure 6). In polyps, flow is present at the top of the pigment epithelial detachment and seen in the outer retina slabs, while branching vascular networks show flow between the RPE and Bruch

membrane.[5] Cross-sectional OCTA may be sensitive in detecting polyps on en face segmentation.[6] Occasionally, the flow within a polyp may be too slow to detect using OCTA.

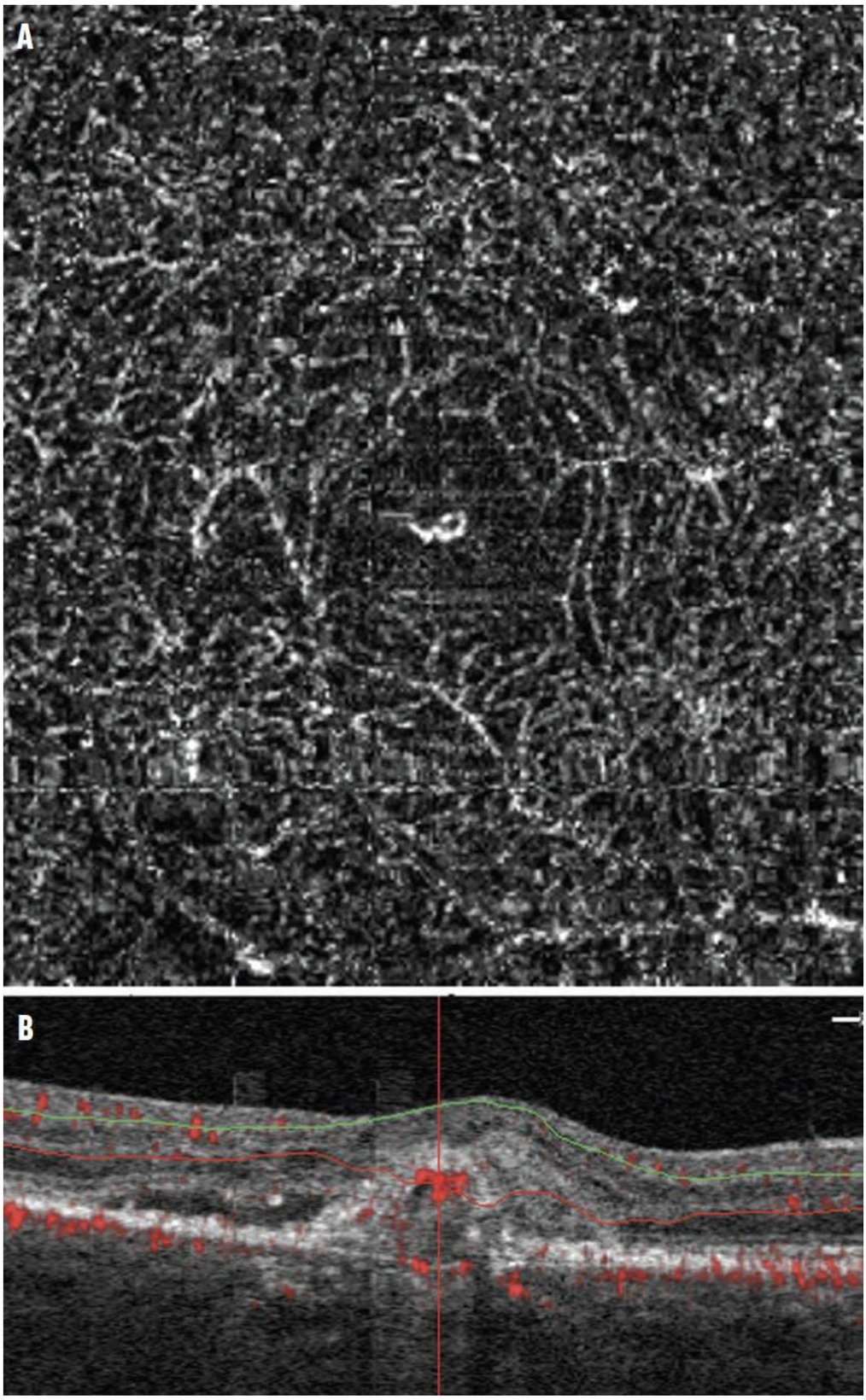


Figure 6. In the eye of a 67-year-old man with PCV, the en face deep capillary plexus slab showed the anterior projection of a central polyp within the FAZ (A). The OCT B-scan with flow overlay confirmed the presence of flow within a hyporeflective ring-like lesion between the RPE and Bruch membrane, consistent with a polyp (B).[6]

NEOVASCULARIZATION IN MULTIFOCAL CHOROIDITIS

The use of OCTA in inflammatory conditions, such as neovascularization in multifocal choroiditis or punctate inflammatory choroidopathy, can help clinicians distinguish choroidal neovascular membranes from inflammatory lesions (Figure 7).

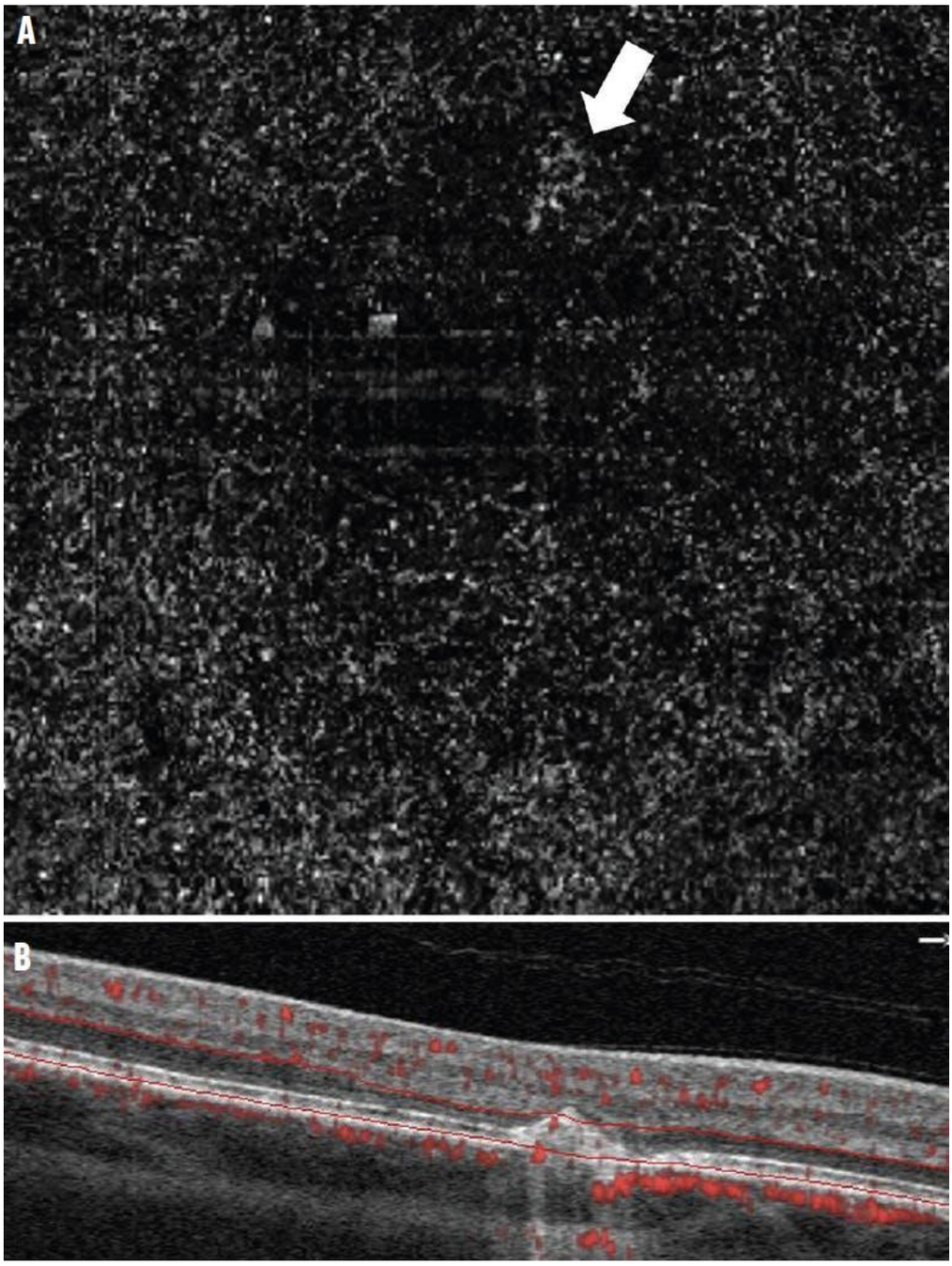


Figure 7. The en face OCTA outer retina slab of the eye of a 34-year-old woman with myopia and a history of multifocal choroiditis showed a neovascular network (A, arrow) that corresponds with several areas of flow under the RPE and above Bruch membrane on the OCT B-scan (B). In this case, OCTA was helpful in distinguishing choroidal neovascular membranes from a new inflammatory lesion, which ultimately favored treatment with injections of anti-VEGF over steroid. This patient responded well to a limited series of anti-VEGF injections.