

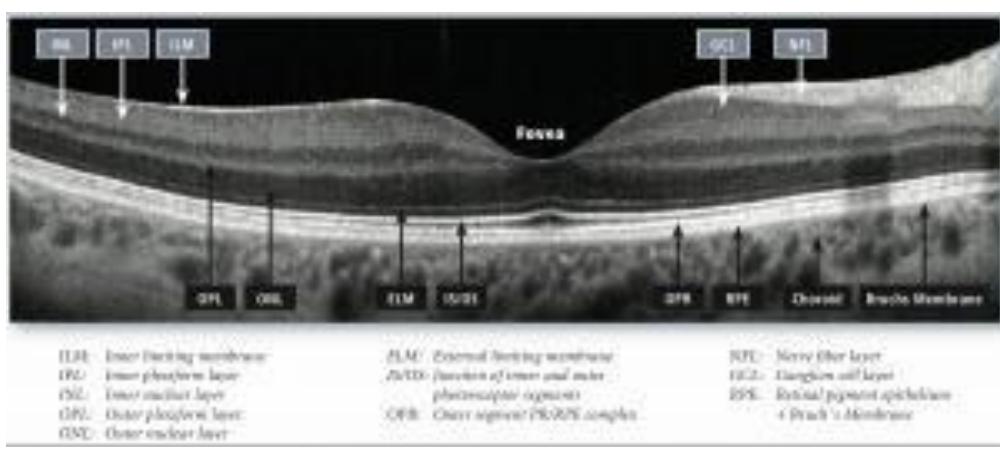
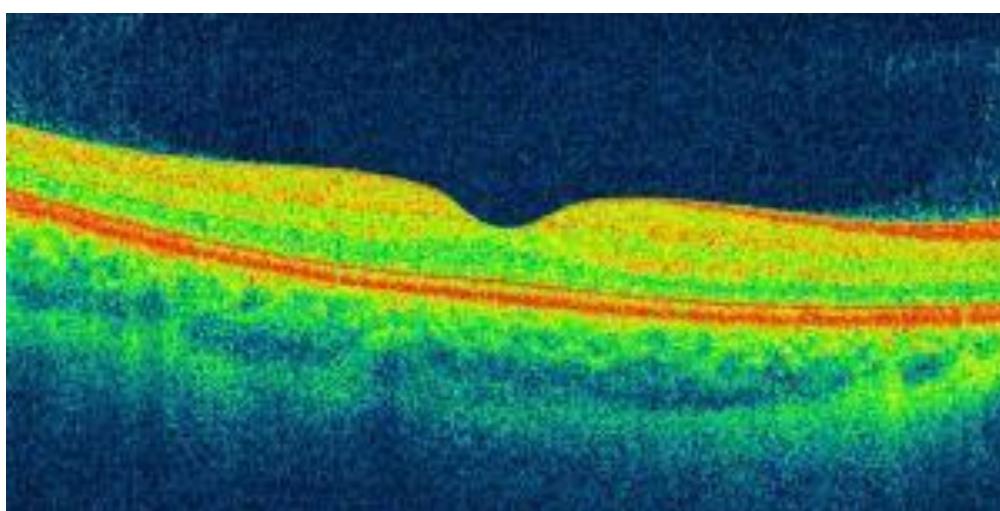
1. How to read OCTs: 8 fundamental diseases

Listed here are 80-90% of the OCTs that you are going to be seeing. Most OCTs 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.

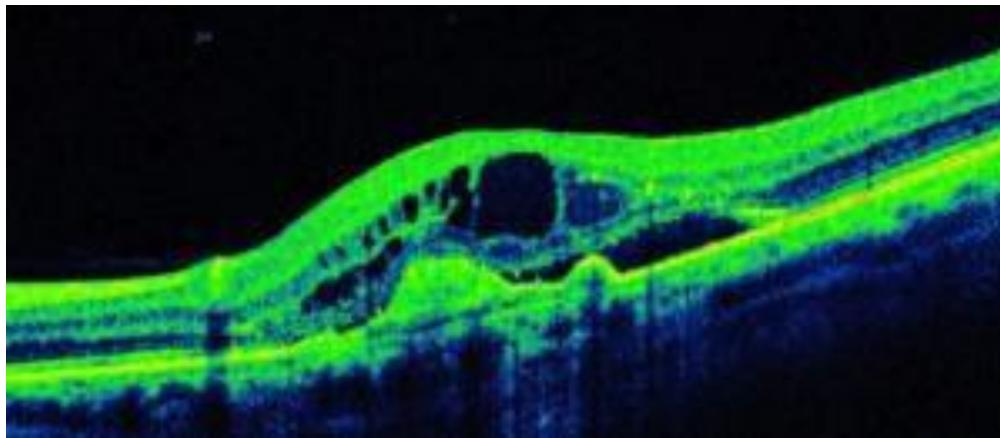
View of the normal retina with OCT



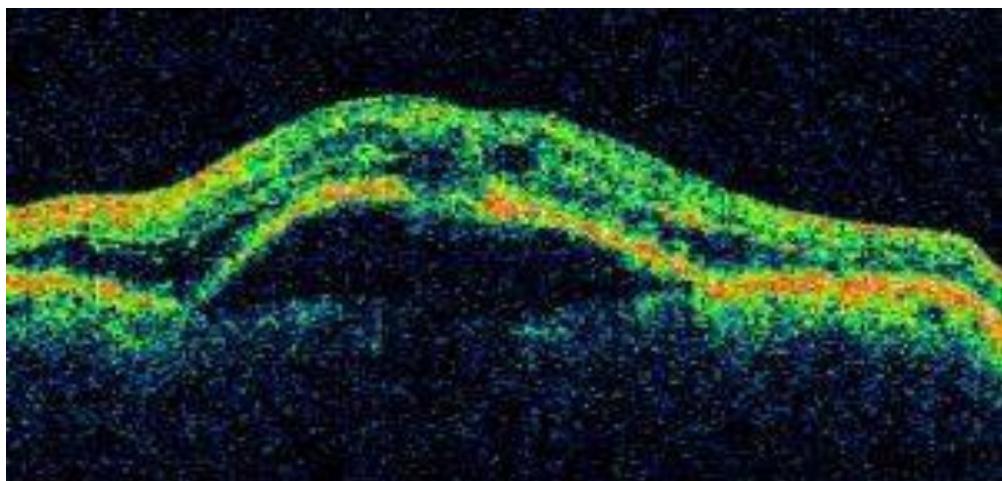
The macular OCT can be used to evaluate premacular vitreous, macula, and choroid. We'll look at OCT through several common diseases.

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

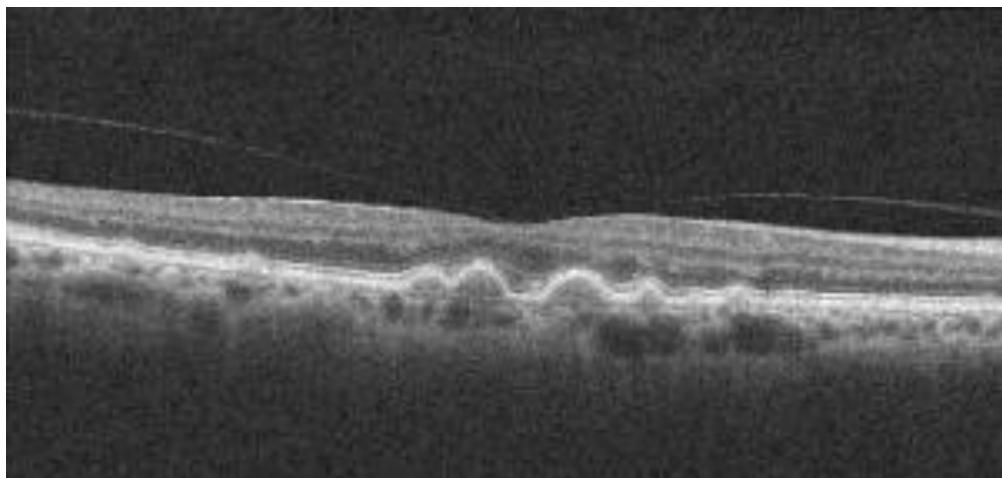
View of the retinal pathologies with OCT Age-related macular degeneration (AMD)



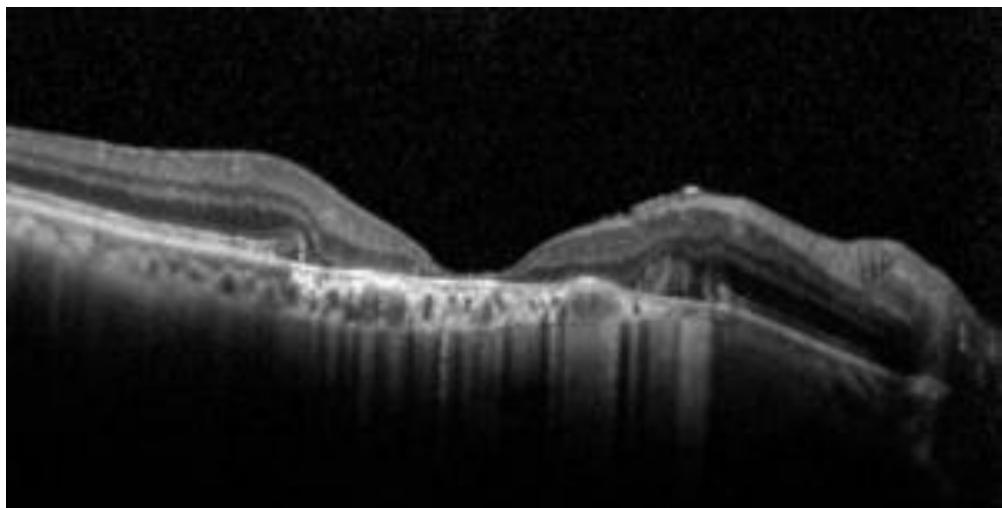
Wet AMD leads to intraretinal fluid (IRF) and subretinal fluid (SRF) accumulation. The choroidal neovascular membrane (CNV) can be visualized.



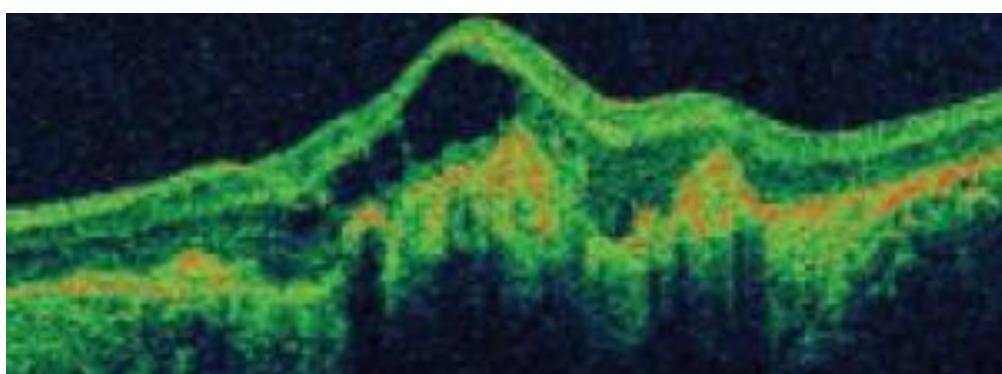
This is an OCT of a pigment epithelial detachment (PED) in wet AMD with some adjacent subretinal fluid (SRF) and an overlying area of focal intraretinal fluid (IRF).



Drusen: Lumps of deposits under the RPE.

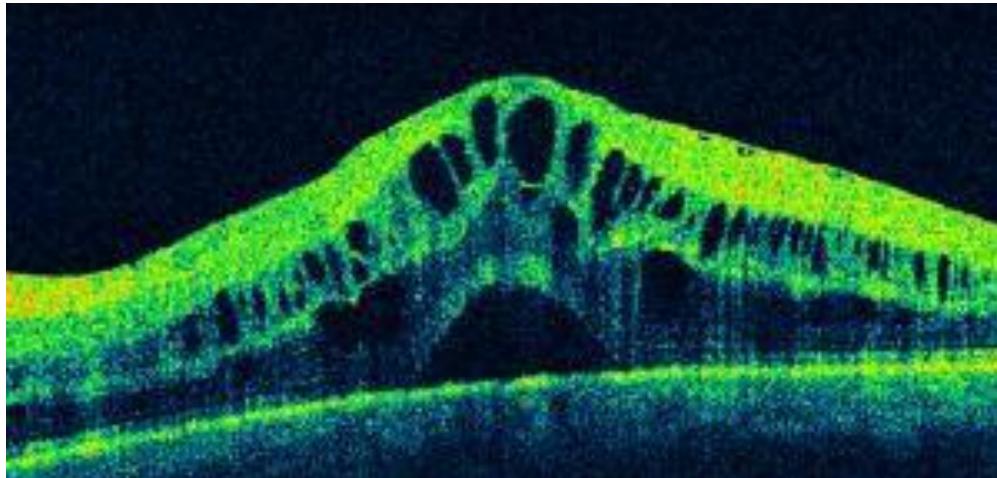


Geographic atrophy: Atrophy of the outer retinal layers with OCT signal penetrating deeper into the choroid.



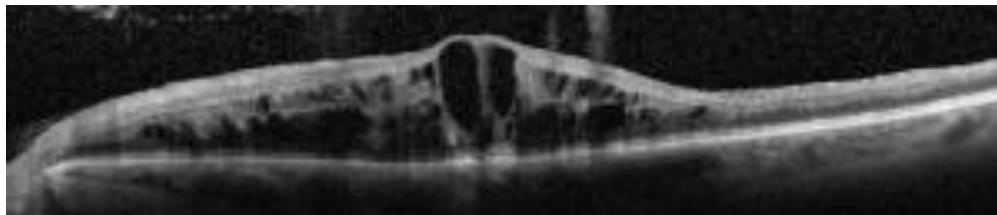
Another example of wet AMD: Eyes show fibrovascular pigment epithelial detachments (PEDs), neovascular membranes and subretinal fibrosis along with fluid.

Diabetic macular edema (DME)

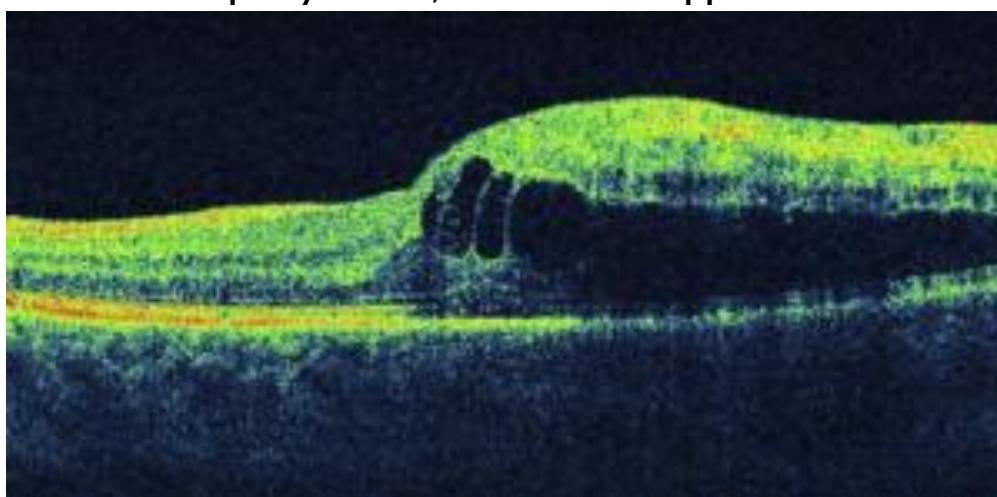


This is classic DME with cystoid intraretinal fluid pockets in the outer plexiform layer (OPL). Subretinal fluid (SRF), which is present in severe DME, is also seen here.

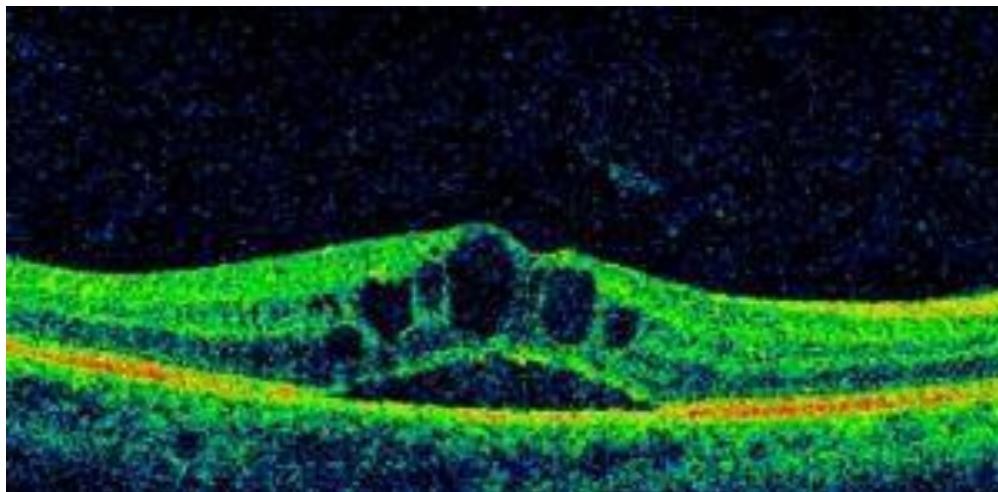
Retinal vein occlusions (RVOs)



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.

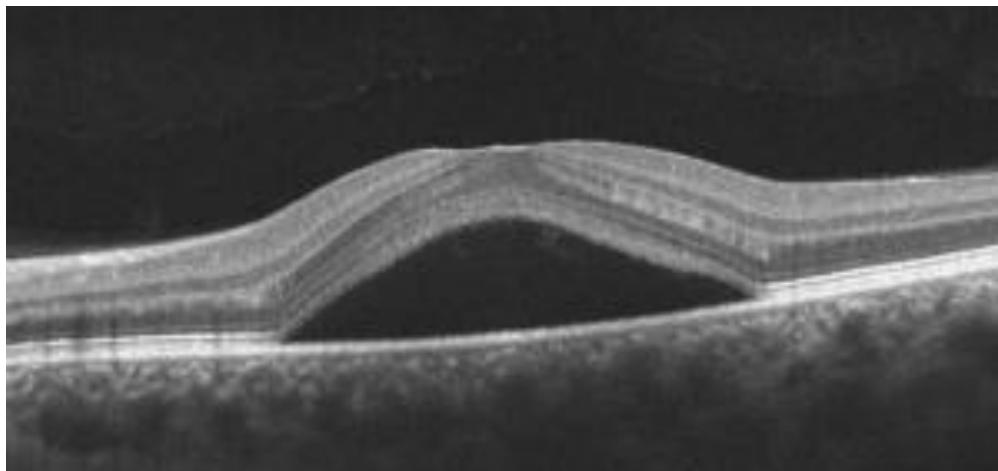


In comparison to CRVO, this branch retinal vein occlusion (BRVO) shows retinal edema on the temporal side of the macula, which is a more common finding in BRVO. You know it's the temporal side because the nasal side of the OCT has a thicker retinal nerve fiber layer (RNFL).

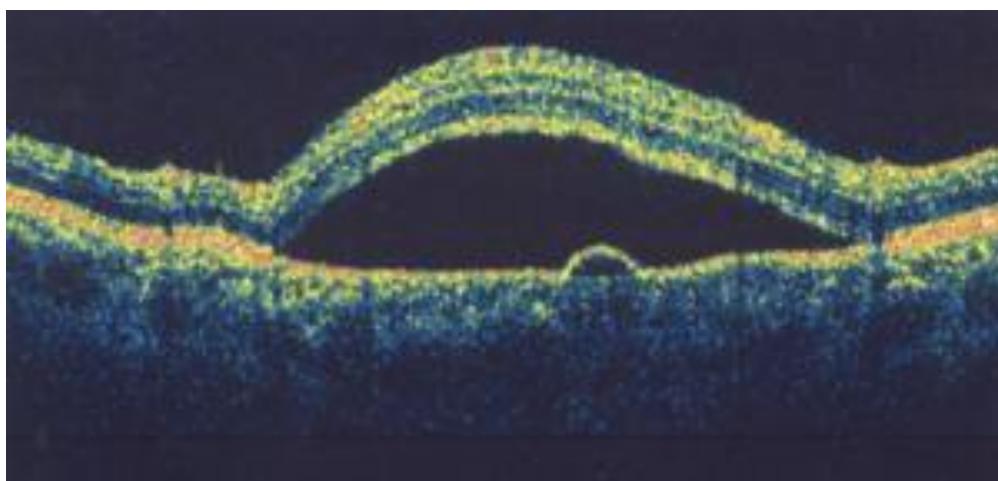


Here is a BRVO with central macular edema. Chronic RVOs lead to inner retinal atrophy, which is also characteristic of the disease.

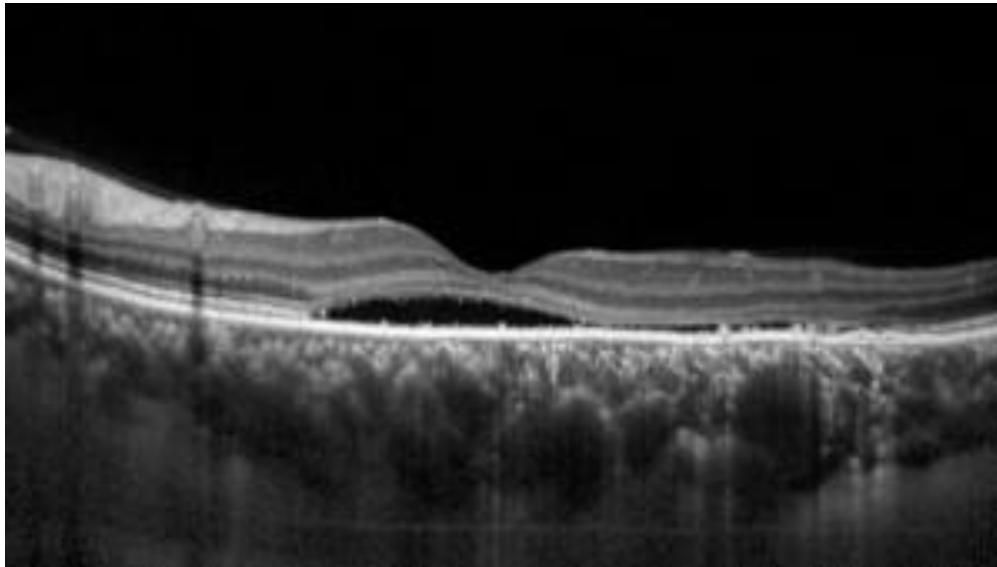
Central serous chorioretinopathy (CSR)



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

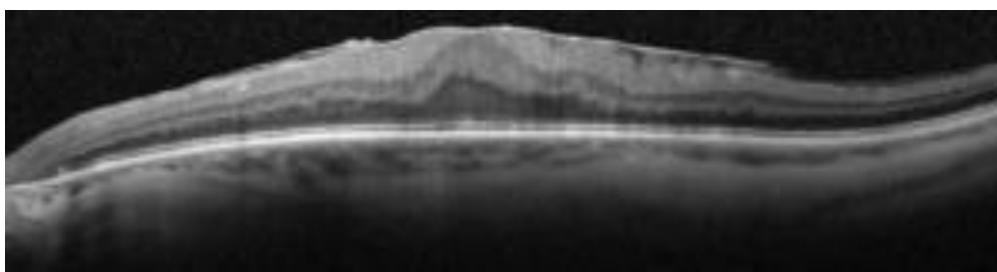


With CSR, there can often be a component of pigment epithelial detachment (PED) inside the area of serous detachment. These PEDs can be quite large.

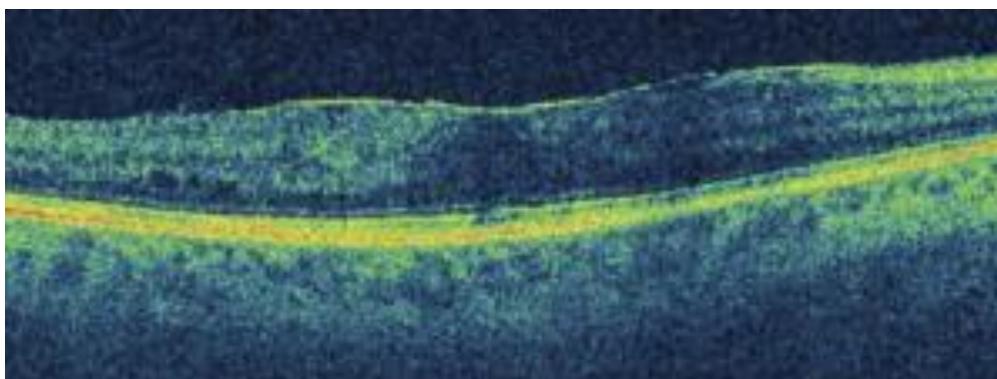


This example of CSR displays a very thick choroid.

Epiretinal membrane (ERM)

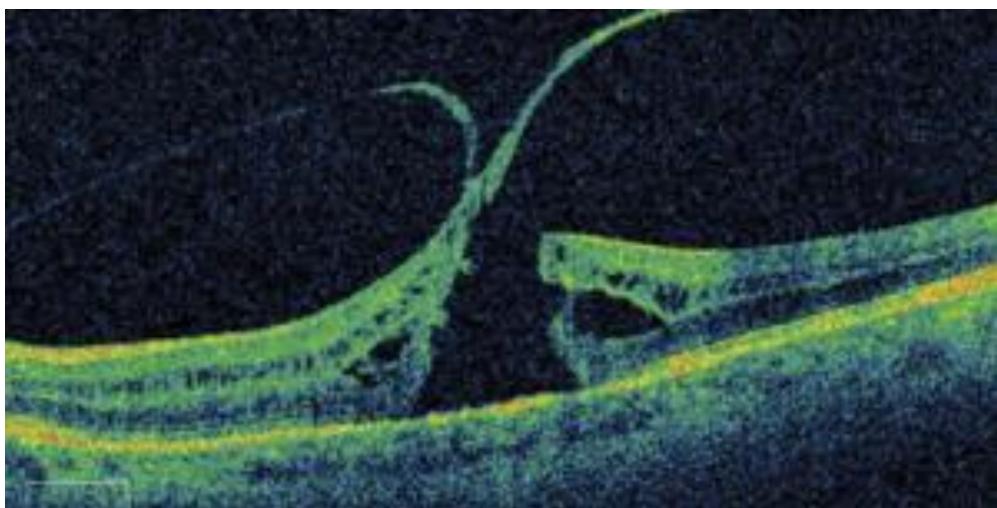


A dense epiretinal membrane (ERM) can be seen here leading to inner retinal wrinkling and distortion of the foveal contour. A severe ERM can also be associated with cystoid macular edema.



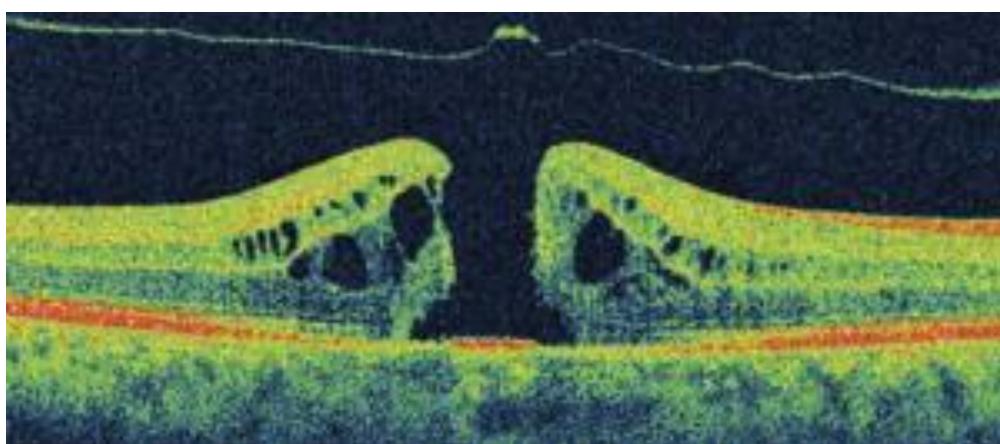
A mild-moderate ERM.

Macular Hole (MH)



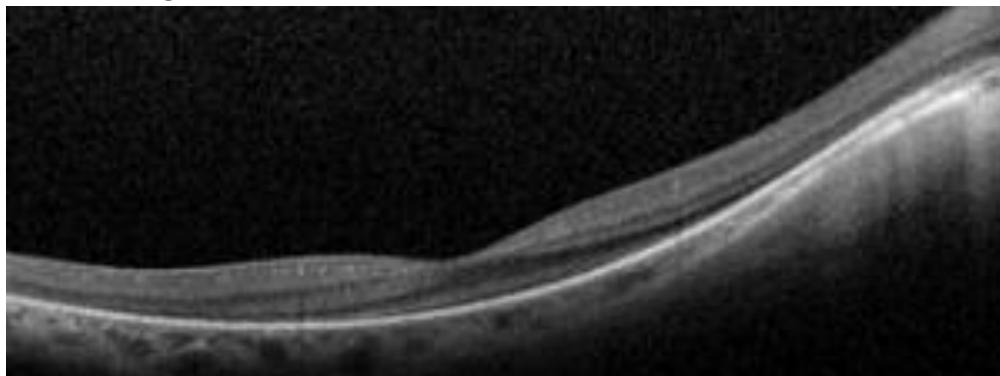
Full-thickness macular holes (FTMH) are very easy to diagnose with OCT. They are

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.

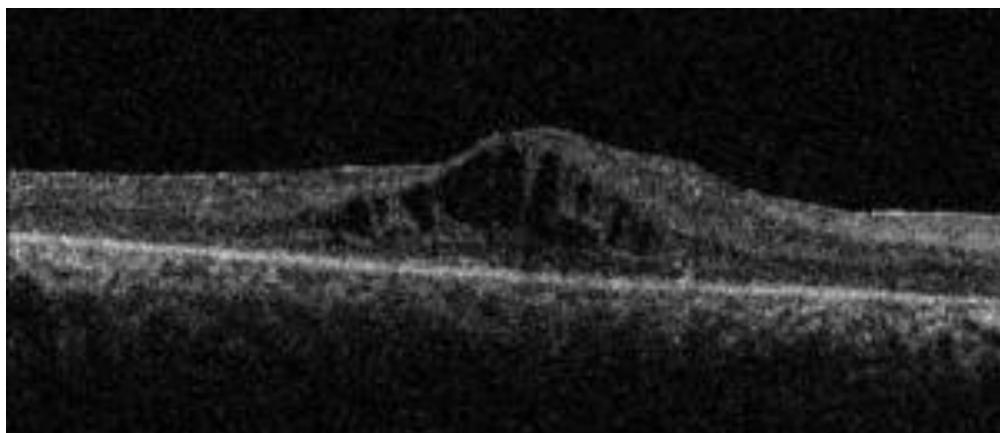


Here, the posterior hyaloid has separated, leaving a central operculum and a full thickness defect.

Retinitis pigmentosa (RP)

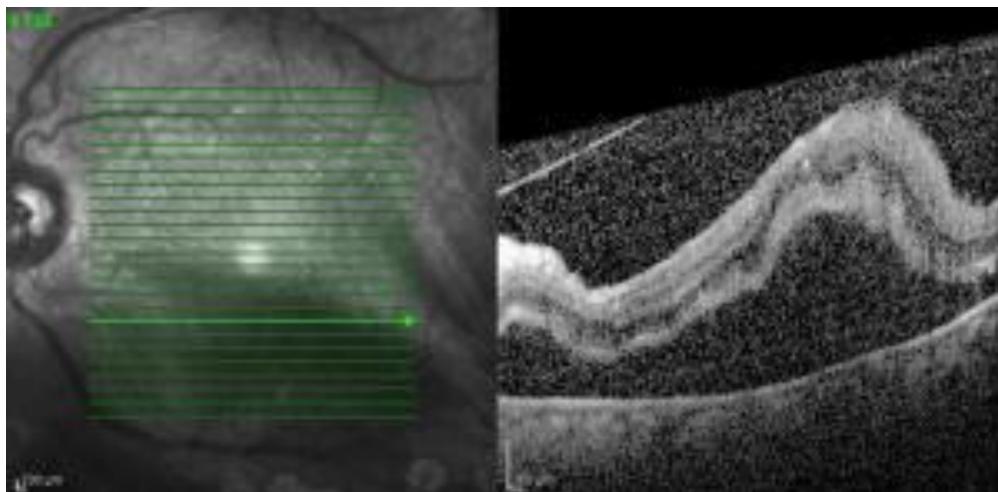


RP is a rod-cone dystrophy. The photoreceptor layer is completely lost except for a central island. Along with it comes thinning of the outer nuclear layer (ONL), which is where the cell bodies of the photoreceptor cells reside.



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.

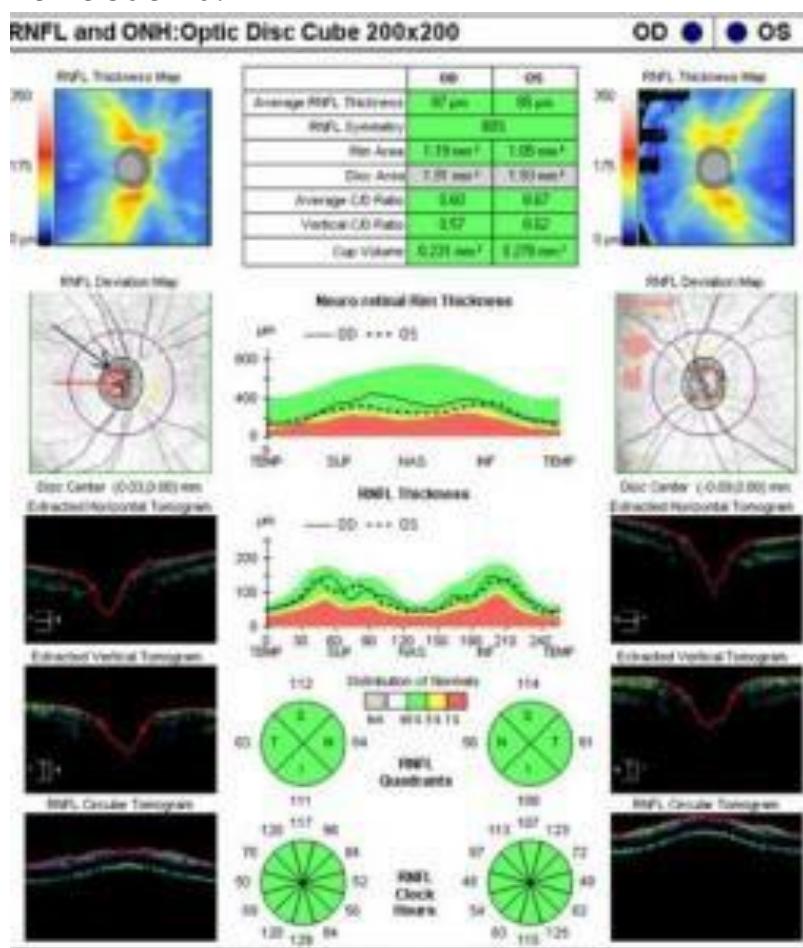
Retinal detachment

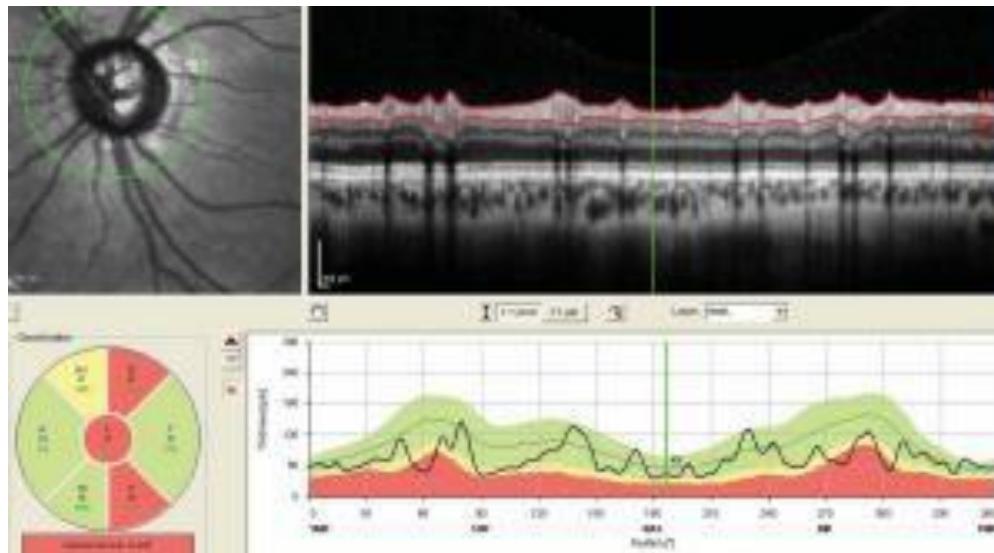


A retinal detachment is usually diagnosed clinically and with examination, but shallow macular detachments are sometimes hard to appreciate early on. If any doubt, a retinal OCT can demonstrate detachment easily.

Optic nerve OCT

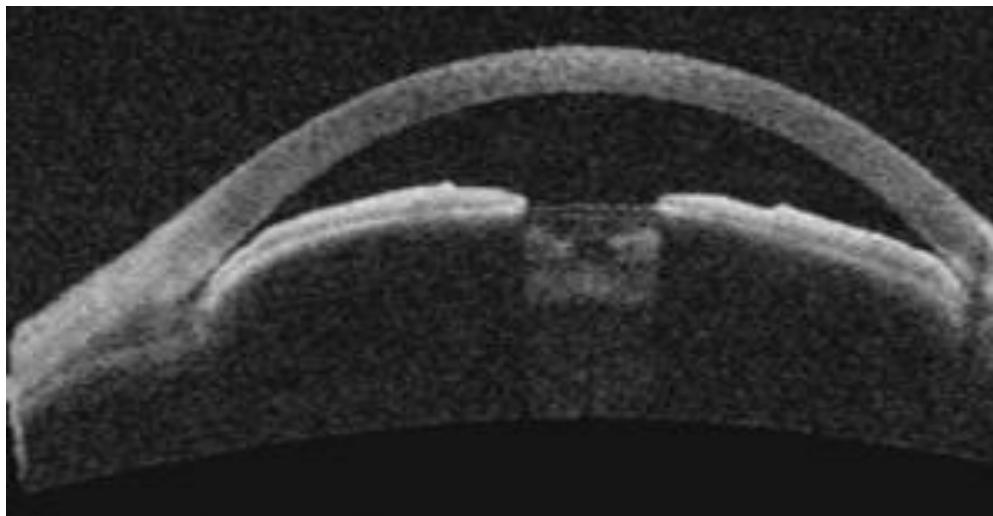
Optic nerve and nerve fiber layer OCT helps in the management of glaucoma. The OCT machines provide automated, serial analysis of the nerve fiber layer thickness, cup-to-disc ratio, and other measurements. They can compare the patient's optic nerve and nerve fiber measurements against age-matched normal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

2. 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 **topography** 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

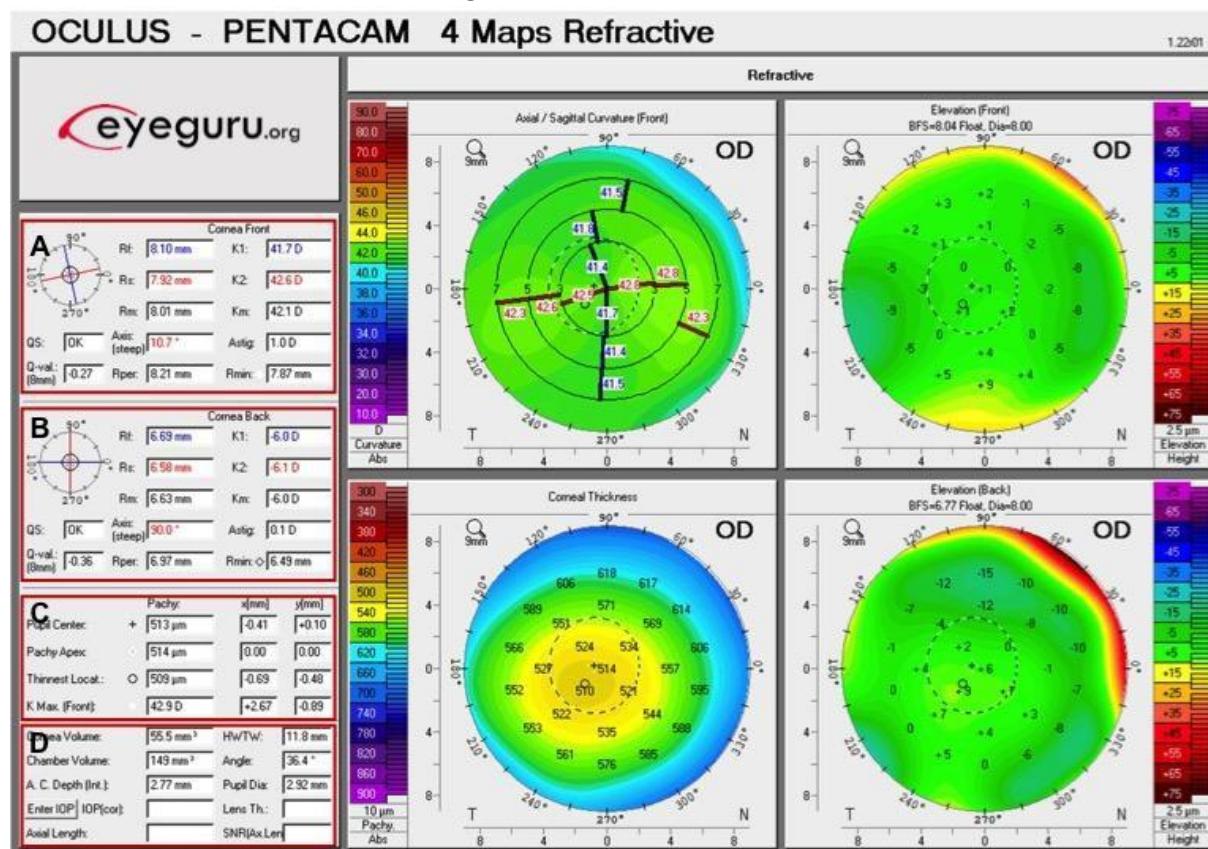
Colored Maps: You will see a rainbow of colors on every topographic map. These range from warm colors (red, orange, yellow) to neutrals (green) to cool colors (blue, purple). On our representative Pentacam images below, you will see four different types of maps.

- 1) Axial map (top left)
 - Useful for assessing irregularity of astigmatism and planning suture removal after PK
 - **Warm** colors = steep (think "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.



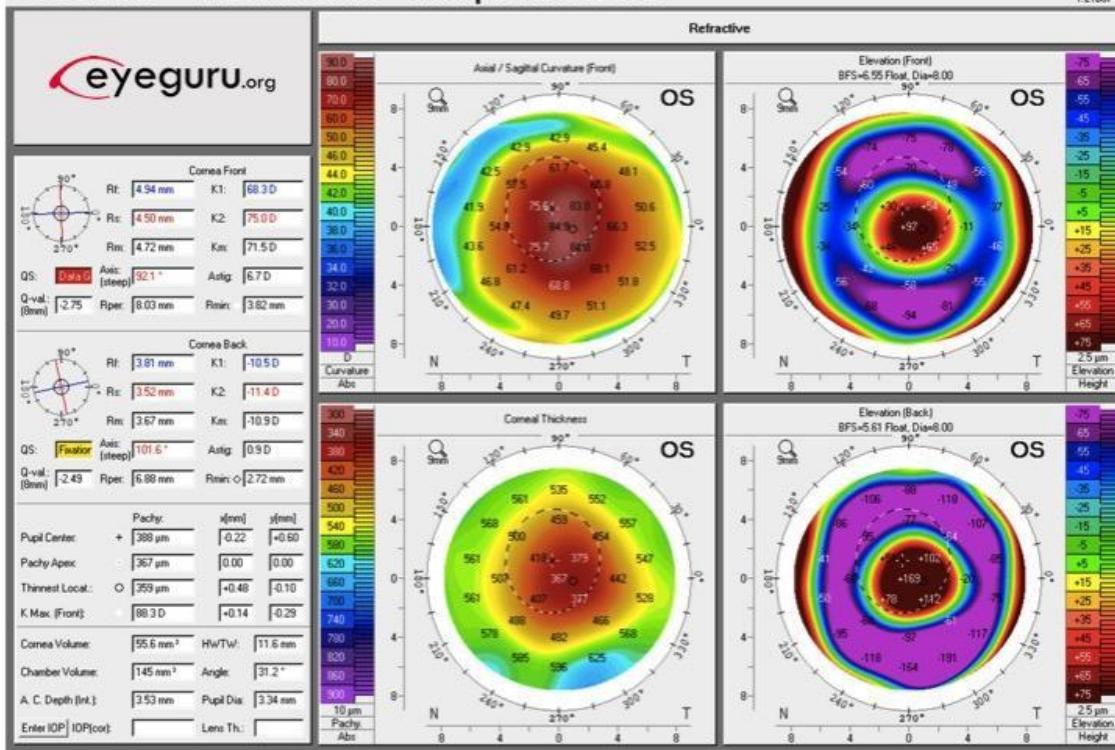
Interpreting Pentacam Values¹

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

OCULUS - PENTACAM 4 Maps Refractive

1.2167



- 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.

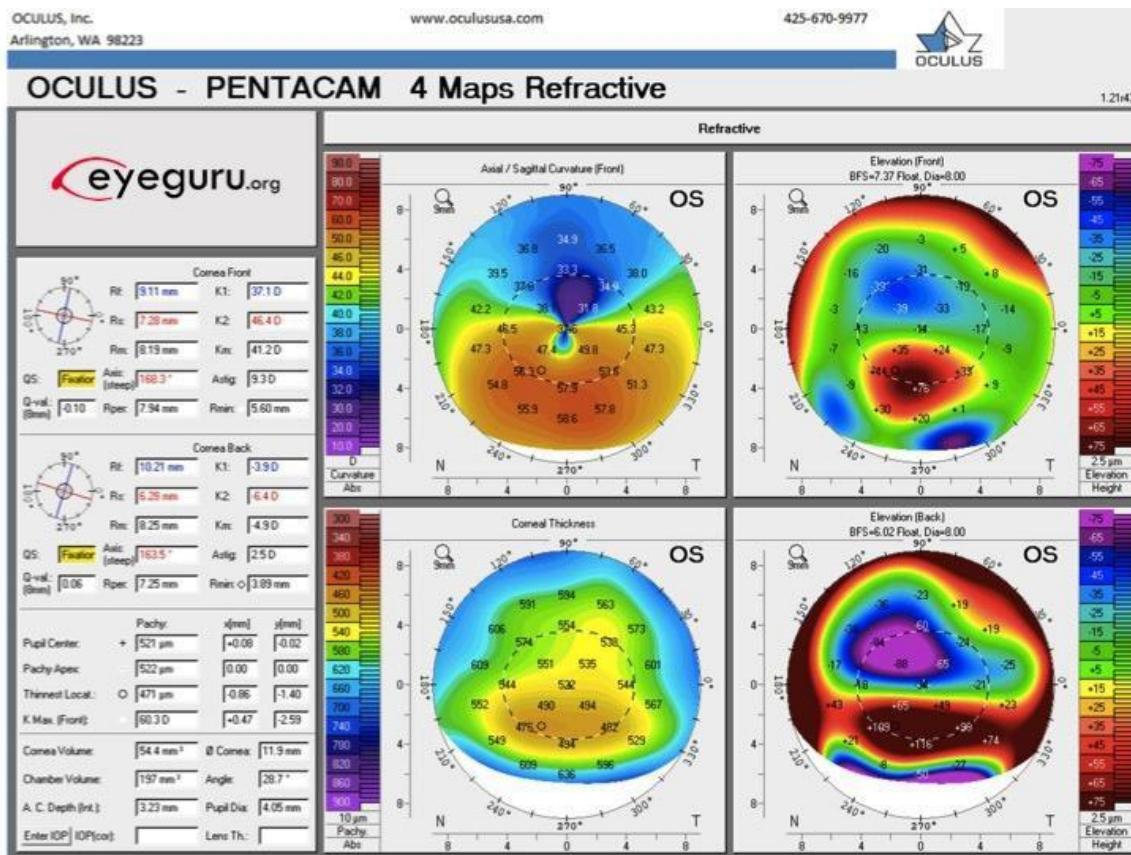
Expected topography: inferior steepening on anterior axial map and corresponding thinning on pachymetry map. There are many systems to grade keratoconus. Here are some examples of various systems, but these are not necessarily the only criteria by which to rule in or rule out keratoconus.

	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



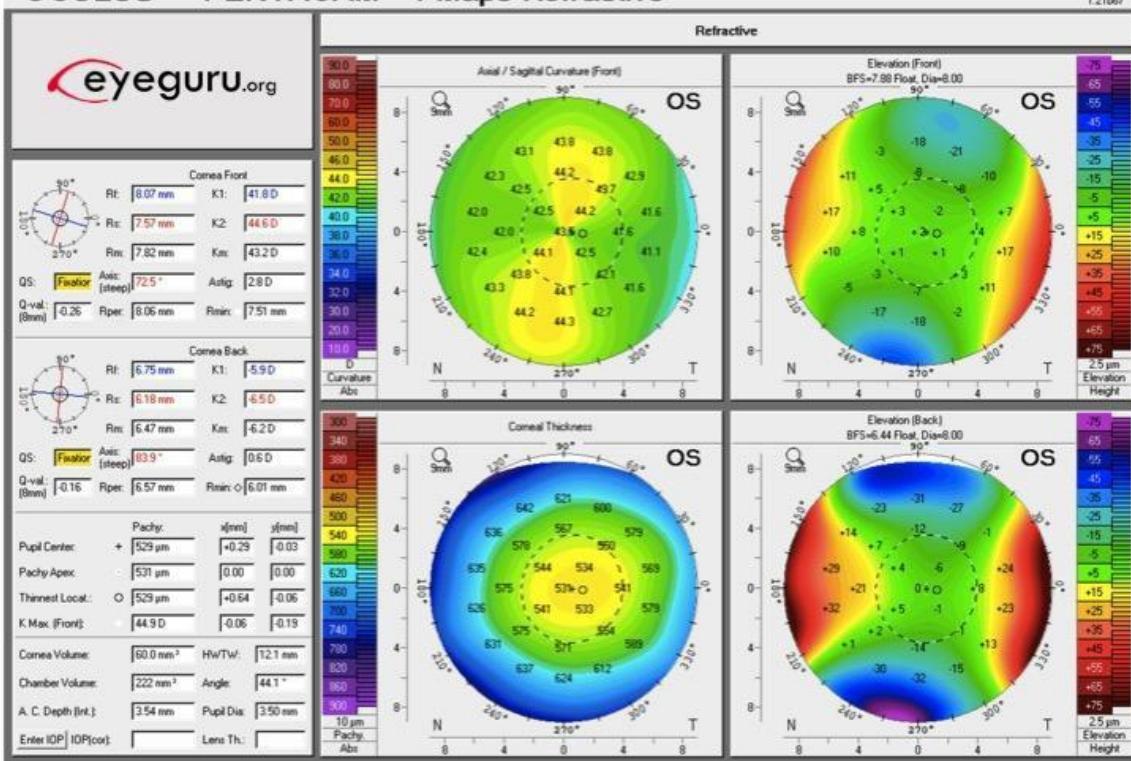
3) Astigmatism

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

OCULUS - PENTACAM 4 Maps Refractive

1.21b67

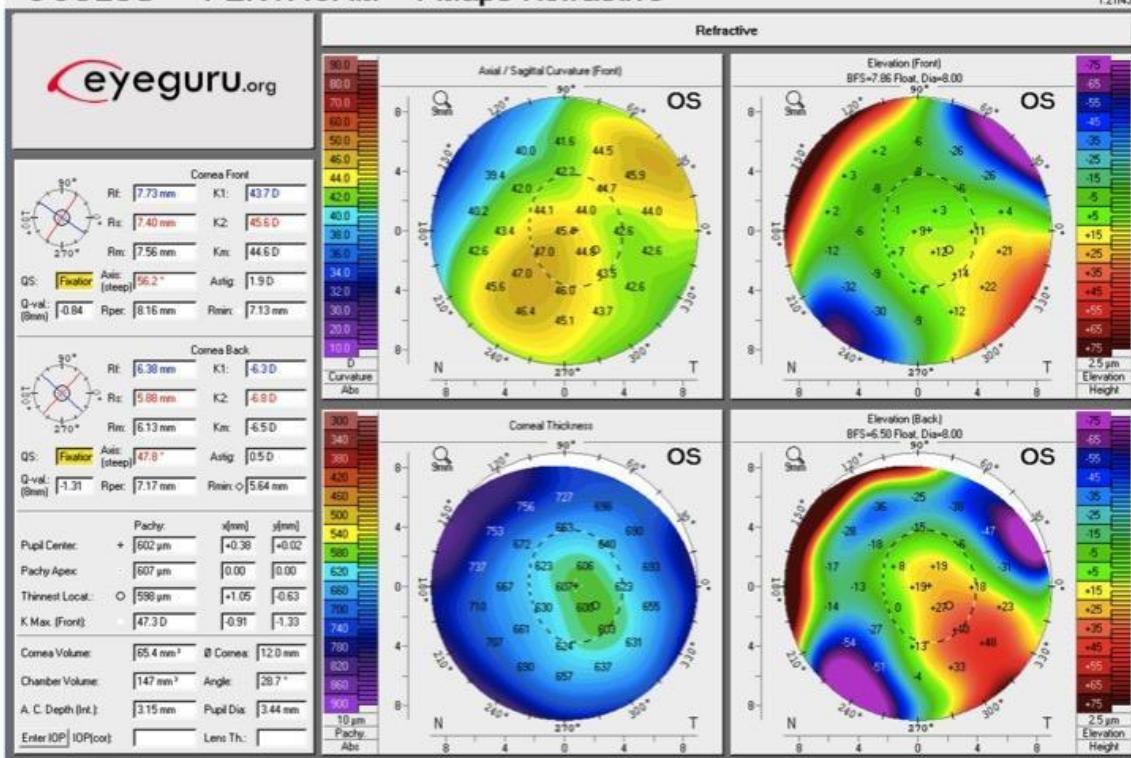


Irregular astigmatism: nonuniform steepening that cannot be corrected by cylindrical lens (BCVA of 20/50 or worse due to irregular astigmatism).

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

OCULUS - PENTACAM 4 Maps Refractive

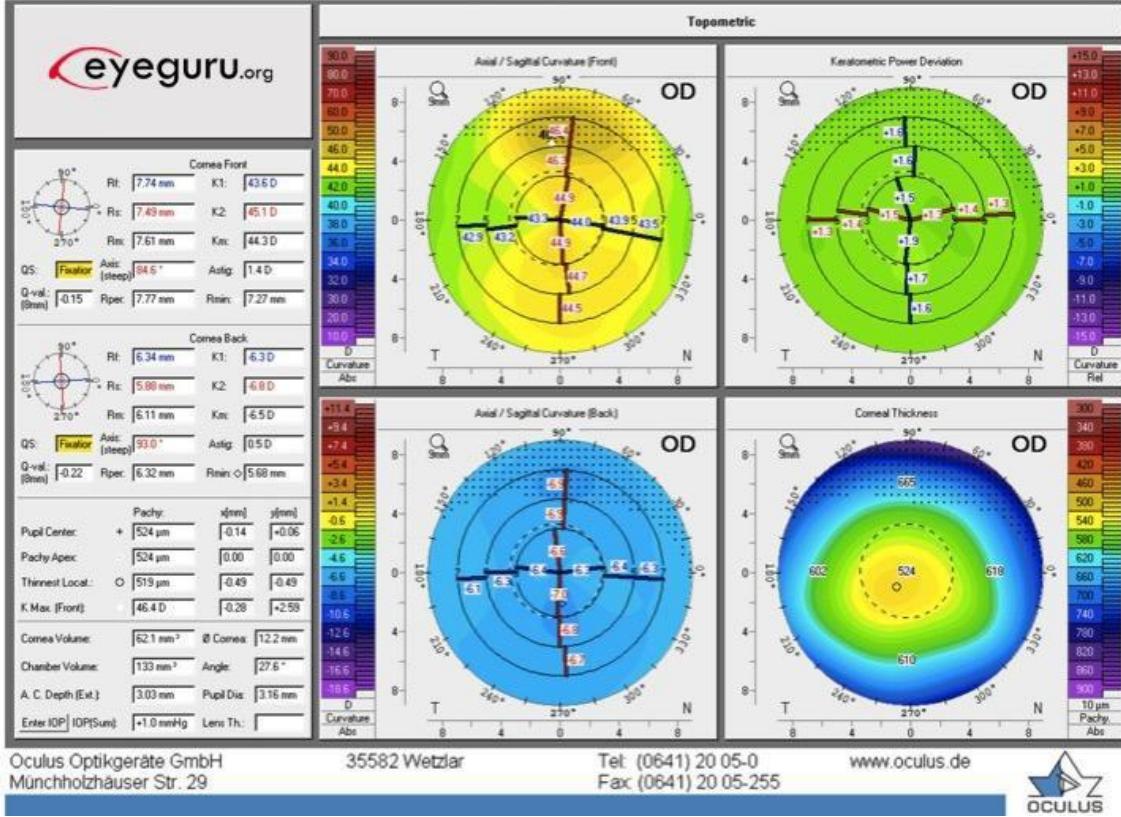
1.21i43



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

OCULUS - PENTACAM 4 Maps Topometric

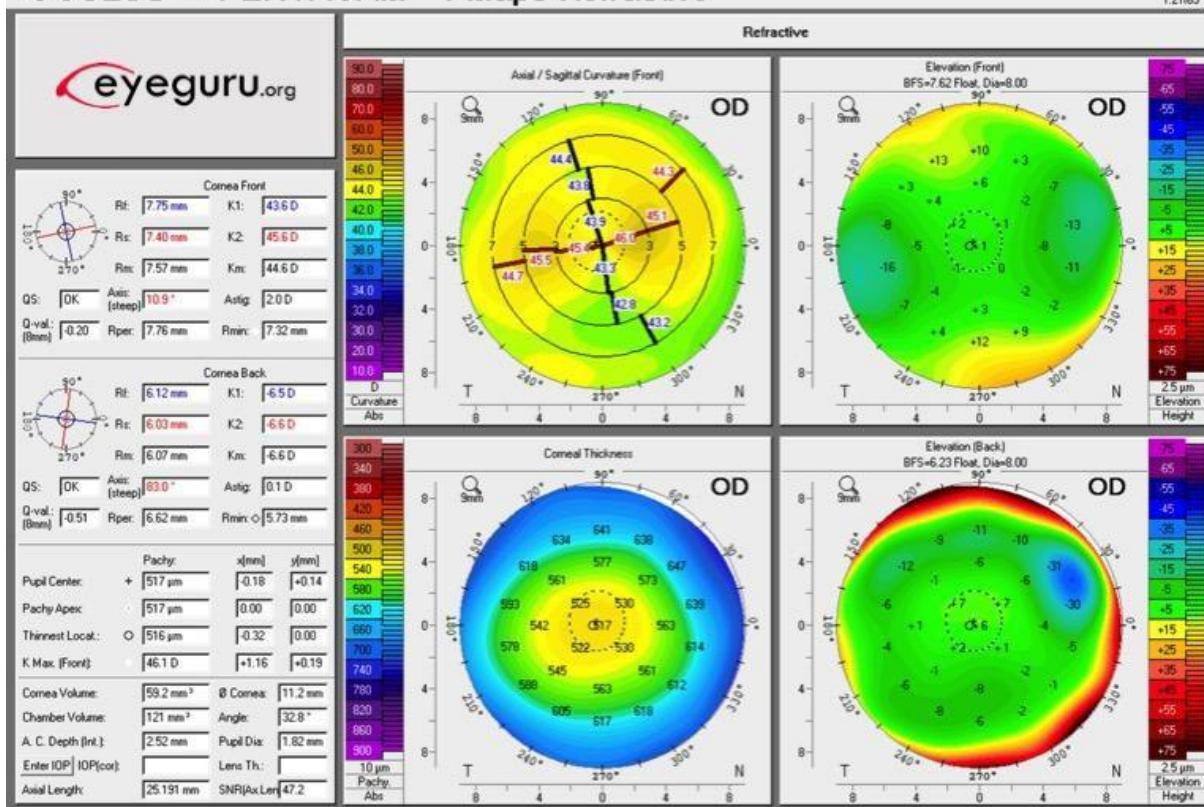
1.2143



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

OCULUS - PENTACAM 4 Maps Refractive

1.2165



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 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

$$\text{PTA} = (\text{FT} + \text{AD})/\text{CCT}$$

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.

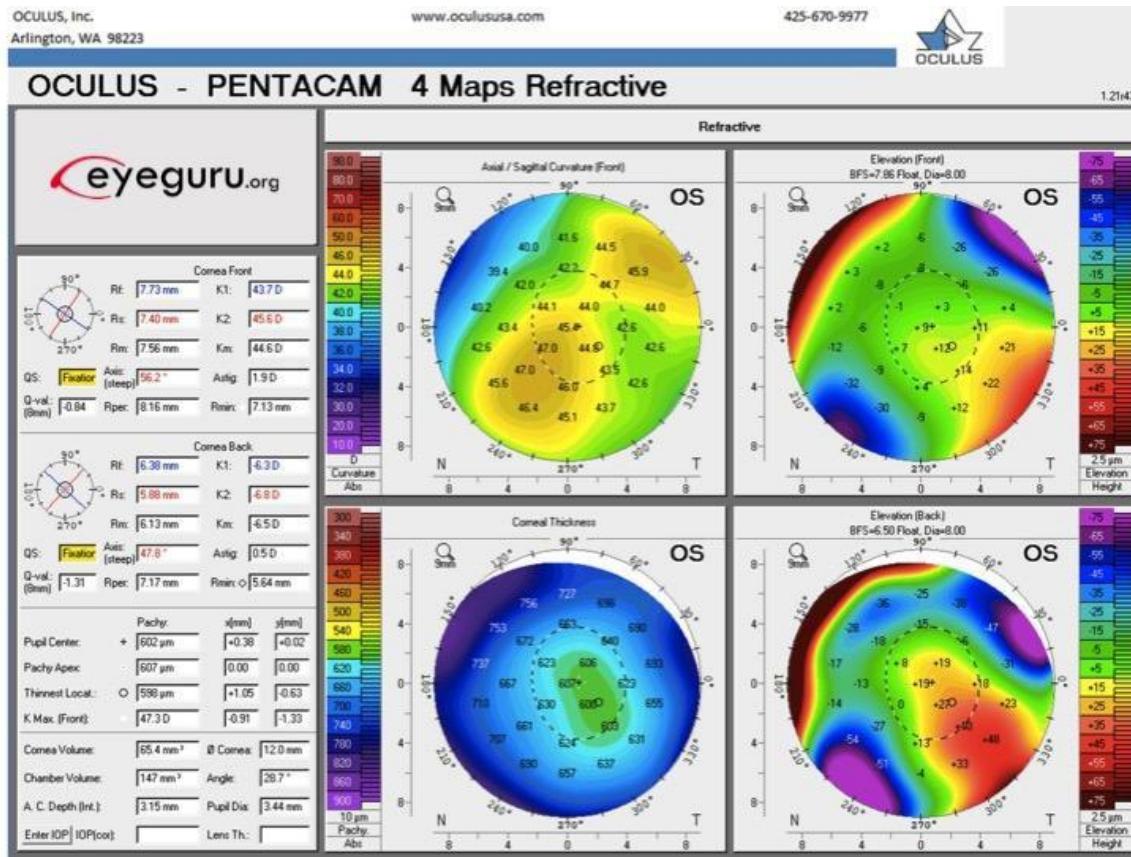
Quick Tips for Clinic

- 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,

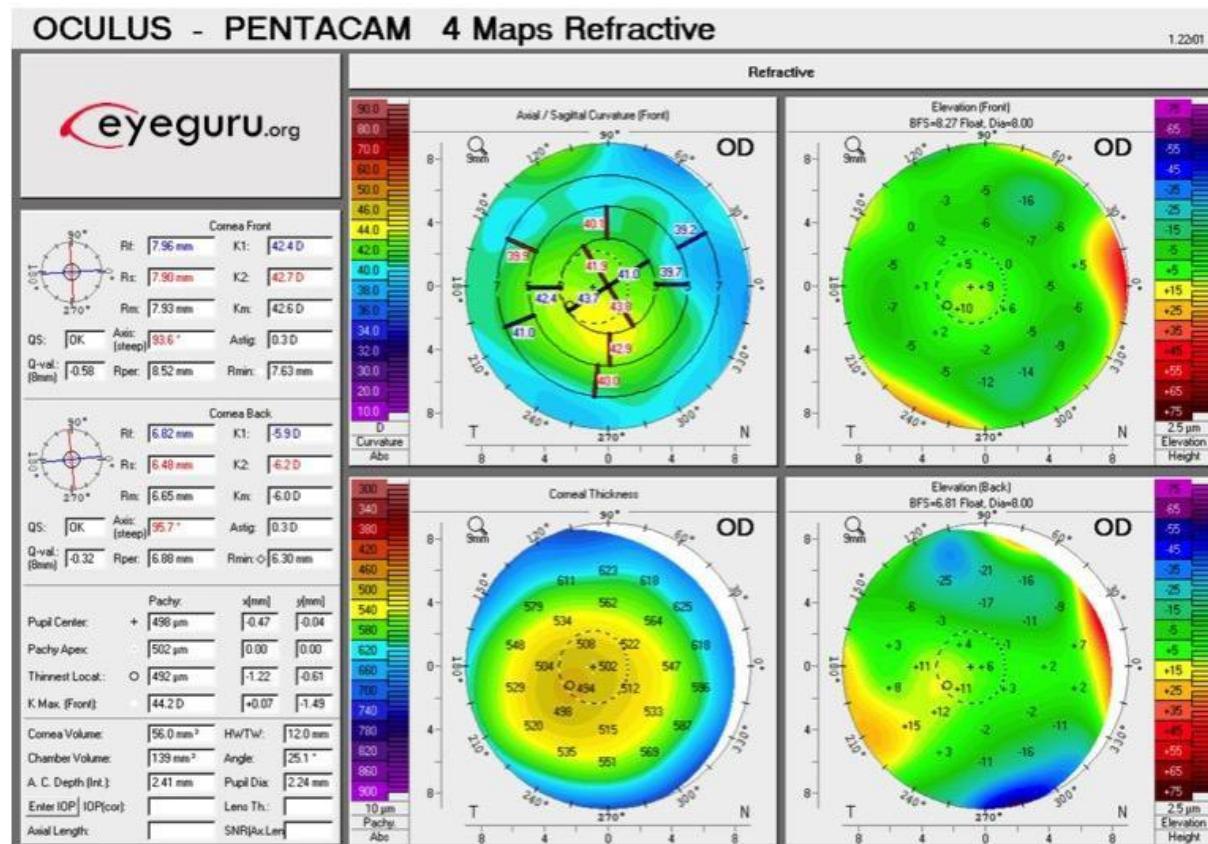
Review Questions

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**.

3. 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

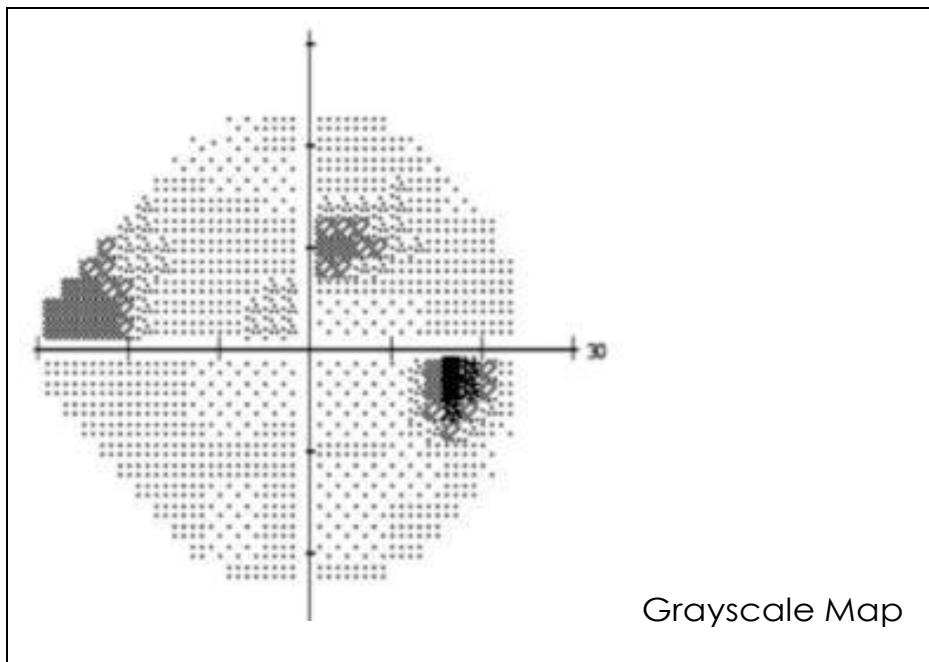
including plaqenil toxicity exams also need 10-2.

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.



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!

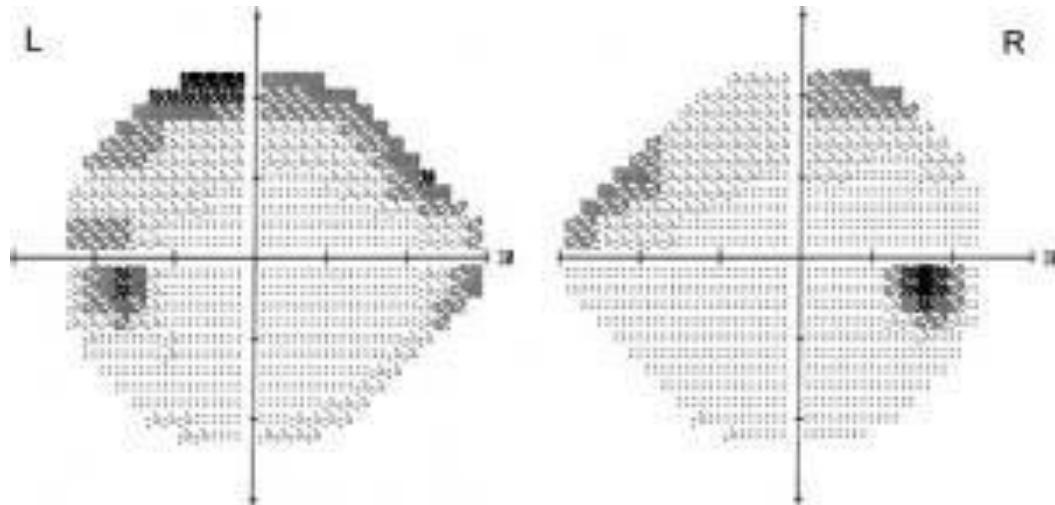
Top 5 most common visual field patterns

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.

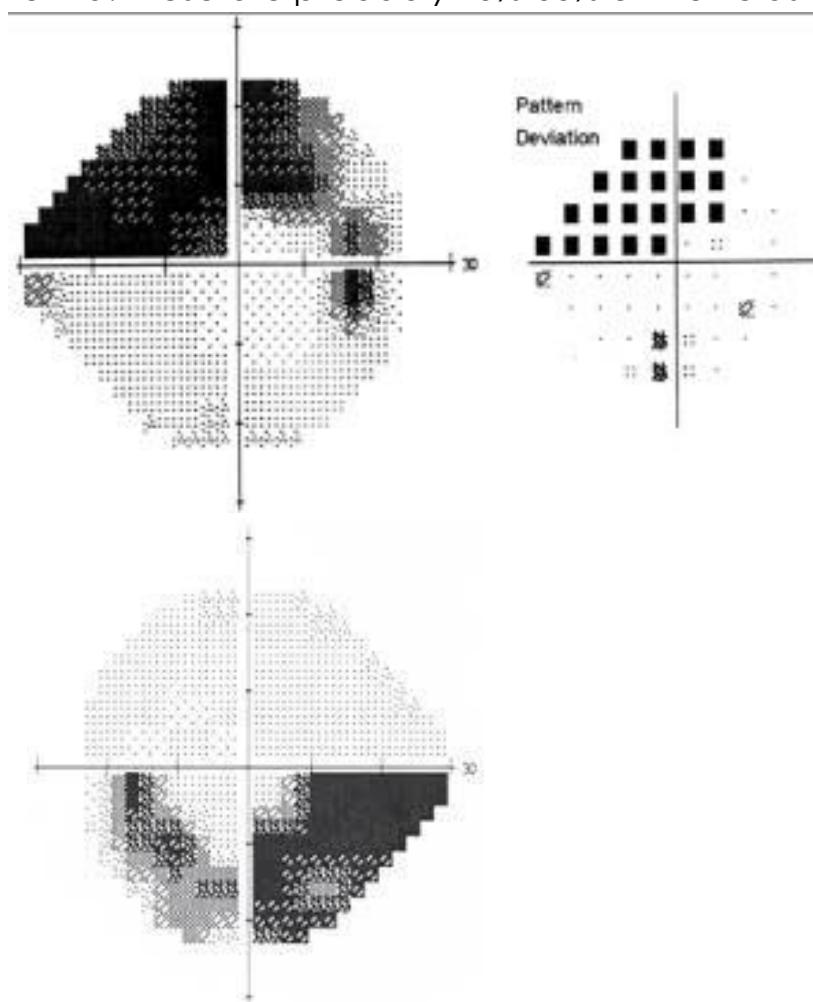
These types of inattention errors will usually register as high fixation losses, false positives, or false negatives. Or, the visual field could just be patchy all over.

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).



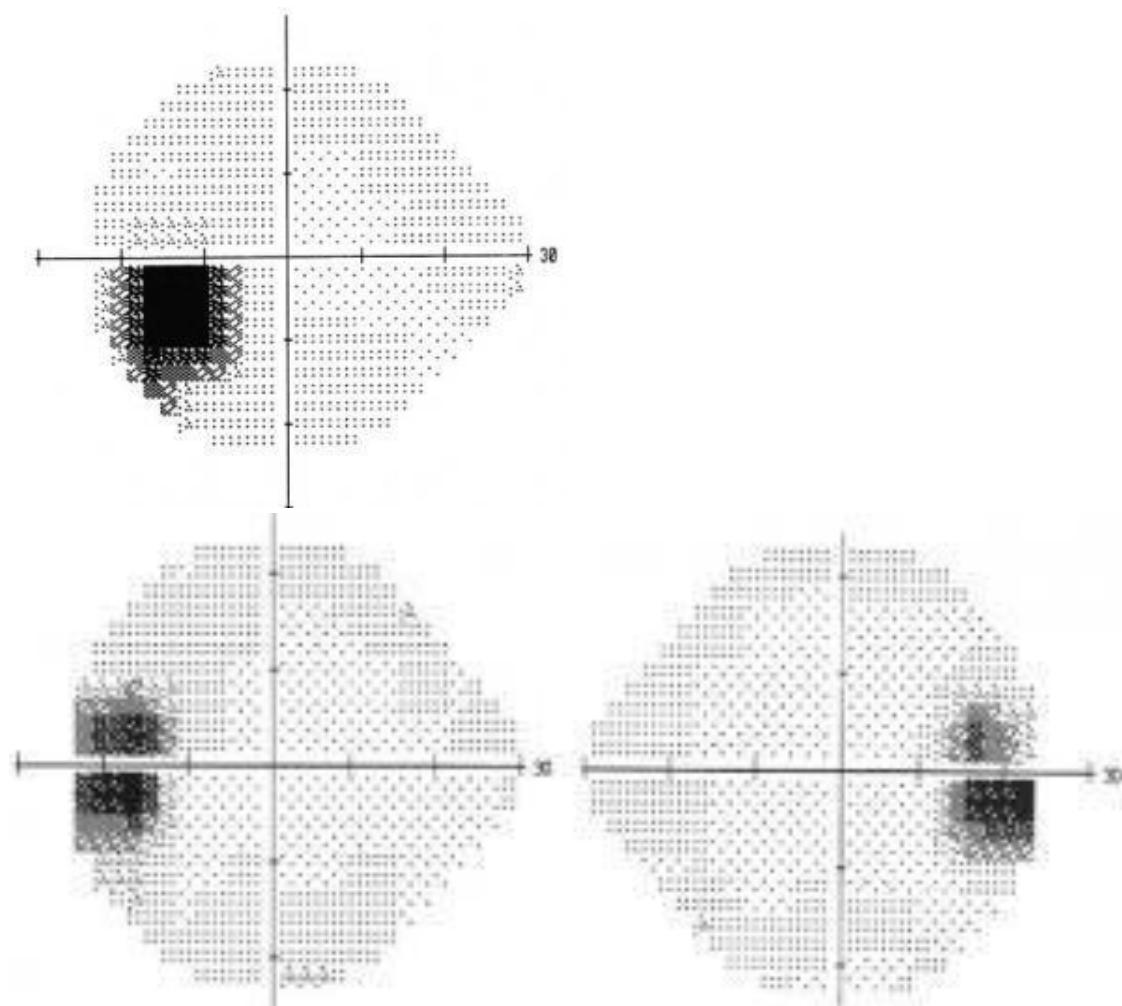
2) Superior / inferior arcuate defect

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.



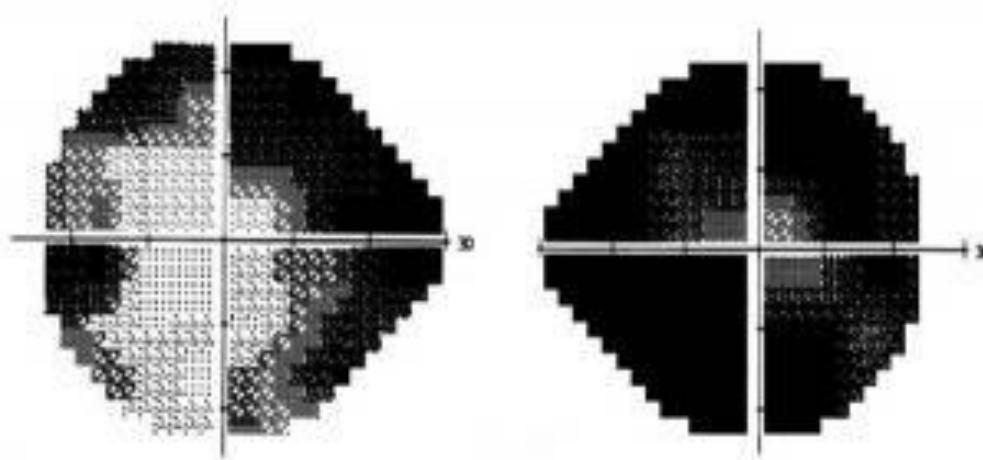
3) Blind spot enlargement

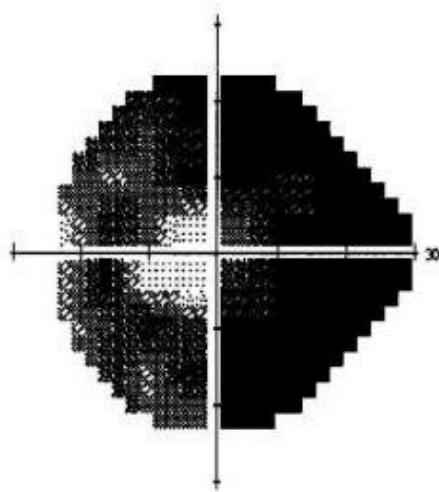
This can be seen in glaucoma but also can occur with papilledema and optic nerve head swelling. This would likely be seen in patients with idiopathic intracranial hypertension (aka pseudotumor cerebri).



4) Severe constriction with a central island

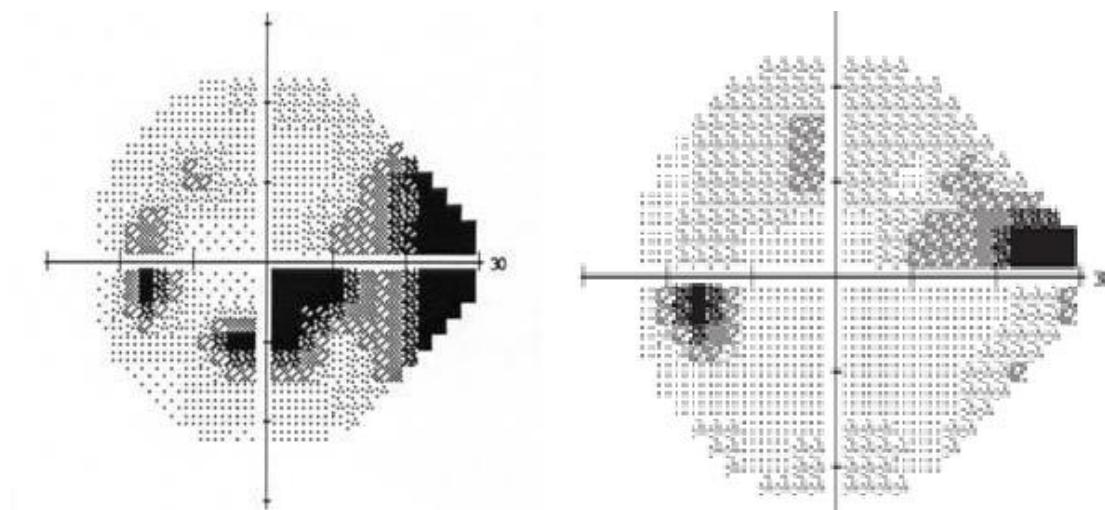
Unfortunately, this is end stage glaucoma. At this point, many patients still have great central vision of 20/20 to 20/50, but peripheral vision is nearly gone. Here, we switch patients over to an HVF 10-2 to better follow their progression.





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

4. 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.

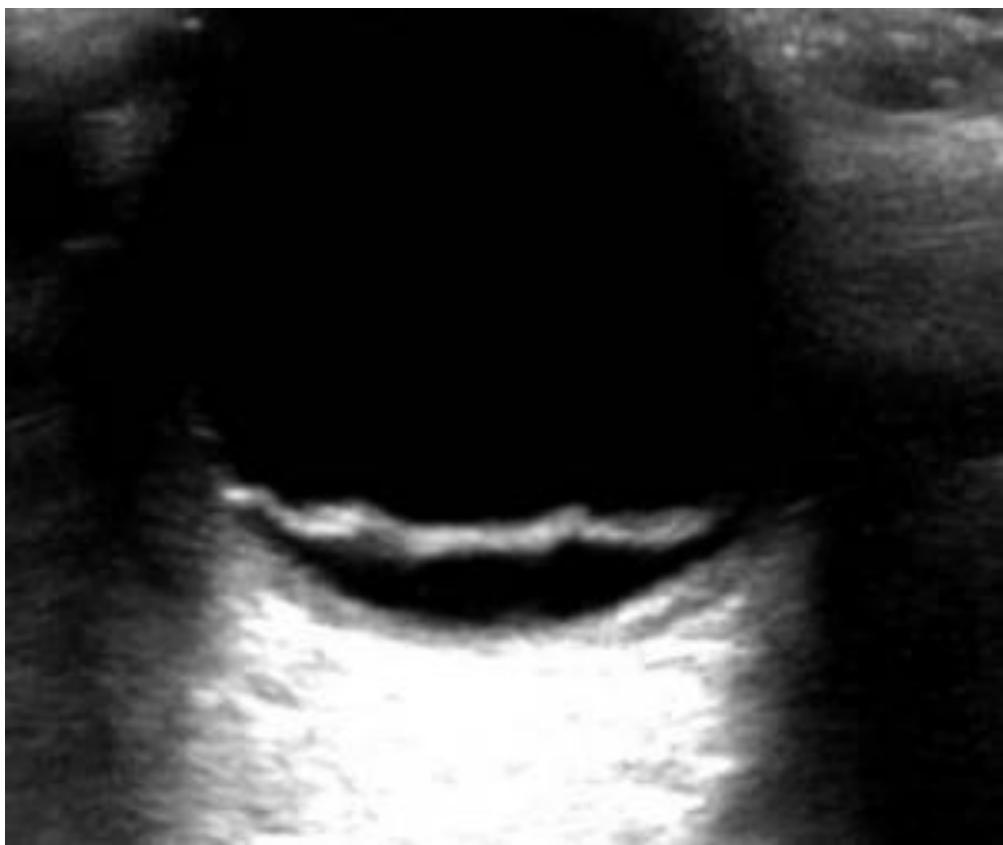
Dynamic scans

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

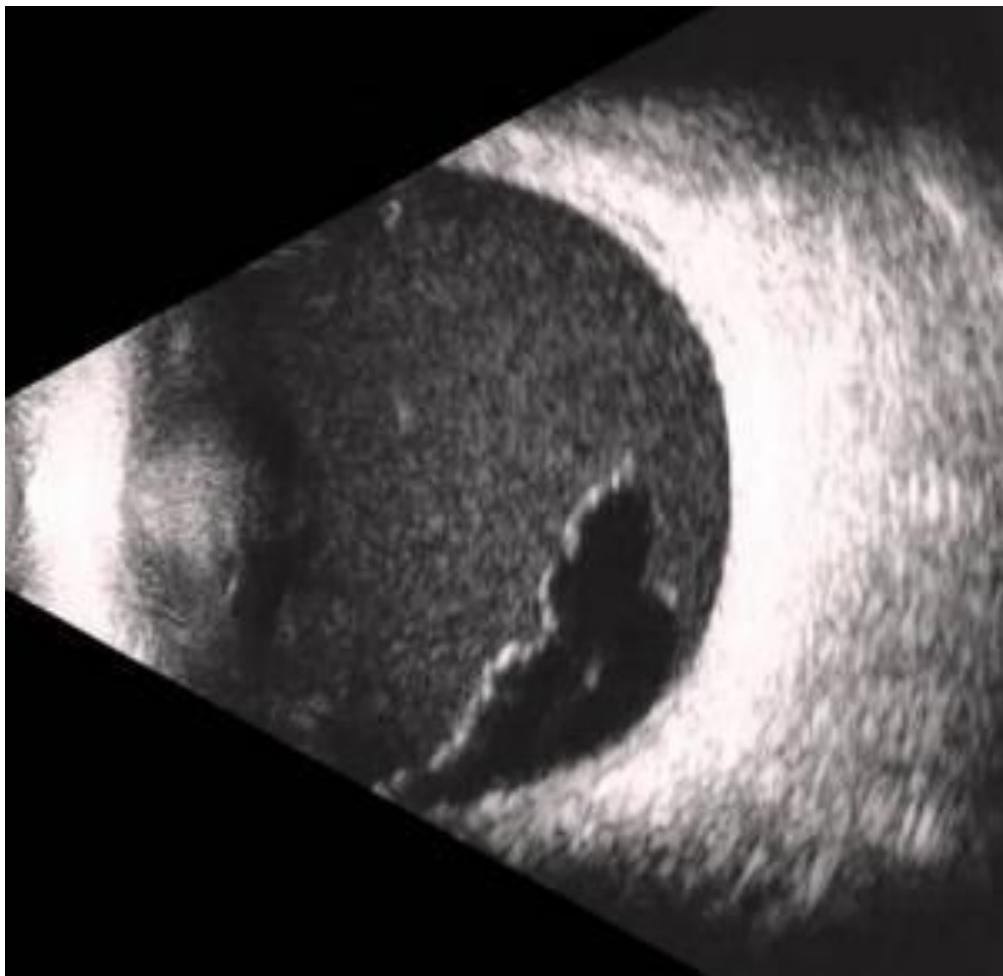
Retinal detachments have a characteristic undulating movement of the retina with dynamic scans. The retina moves at a slower speed than the posterior hyaloid and its reflectivity is higher. You can use ultrasound using the axial, transverse and longitudinal views to delineate where the retina has detached.



Vitreous hemorrhage

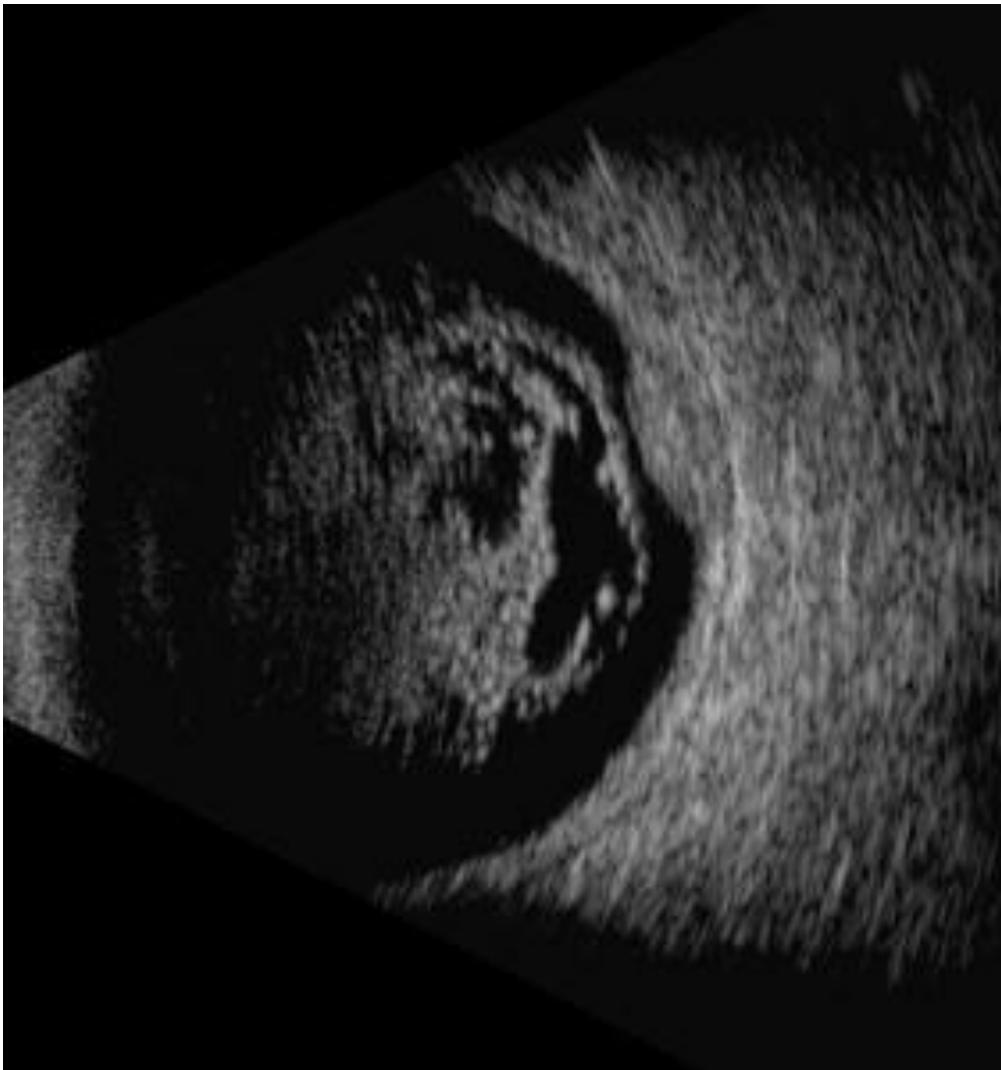
Vitreous hemorrhages are seen commonly in the setting of acute vision loss in one eye.

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



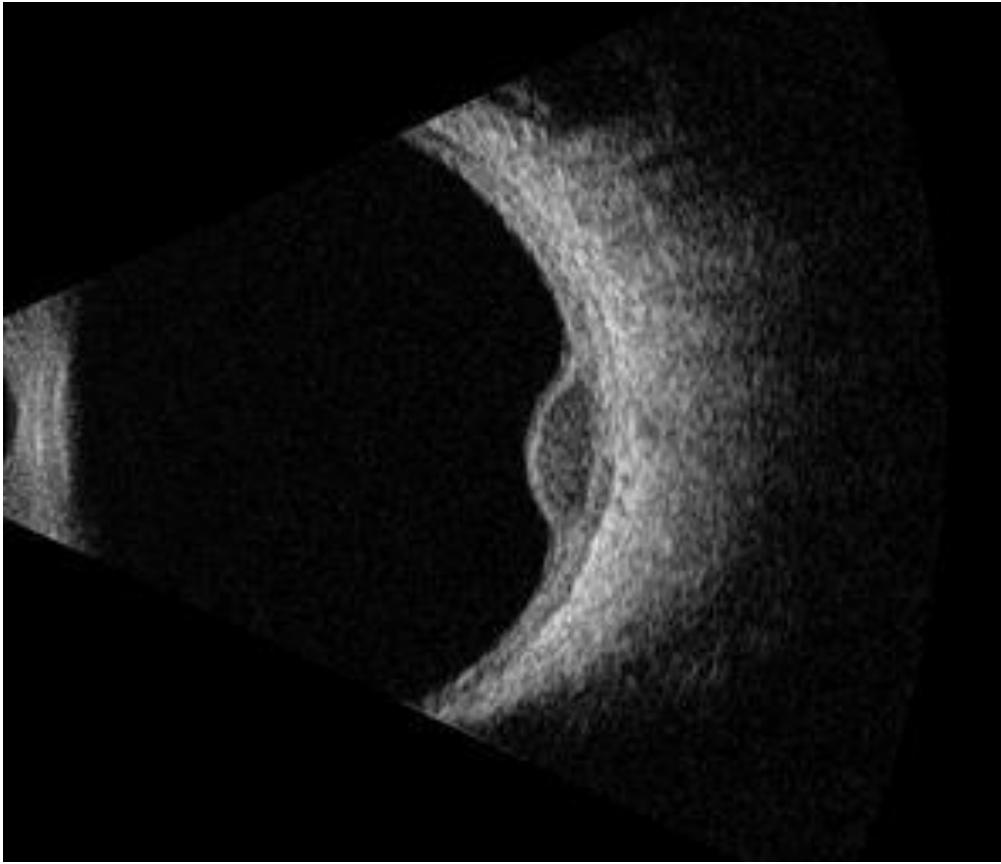
Choroidal nevus

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



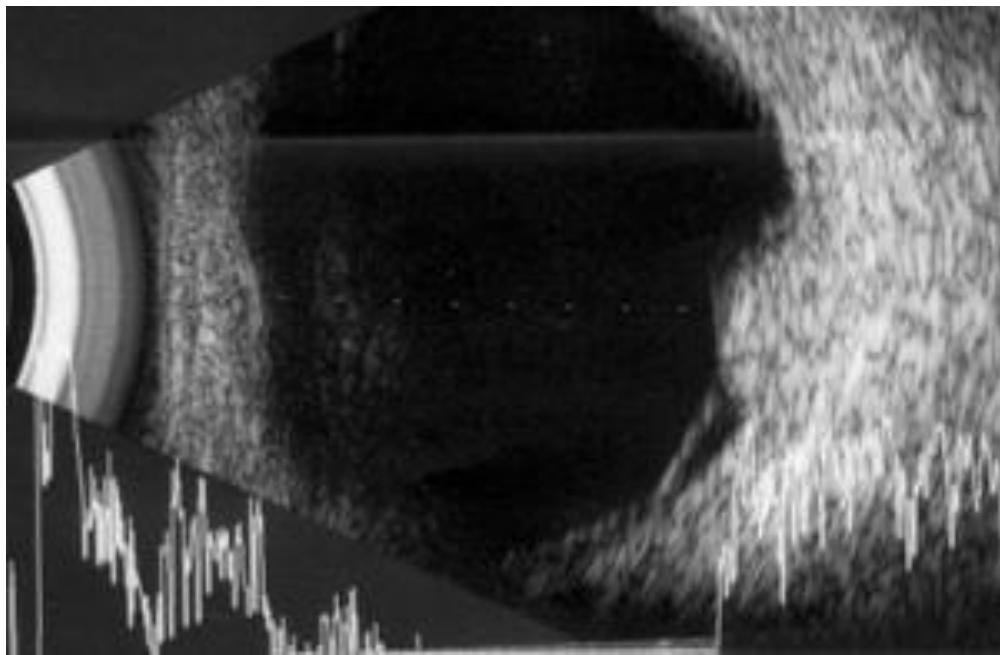
Choroidal melanoma

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.



5. 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.

- 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:

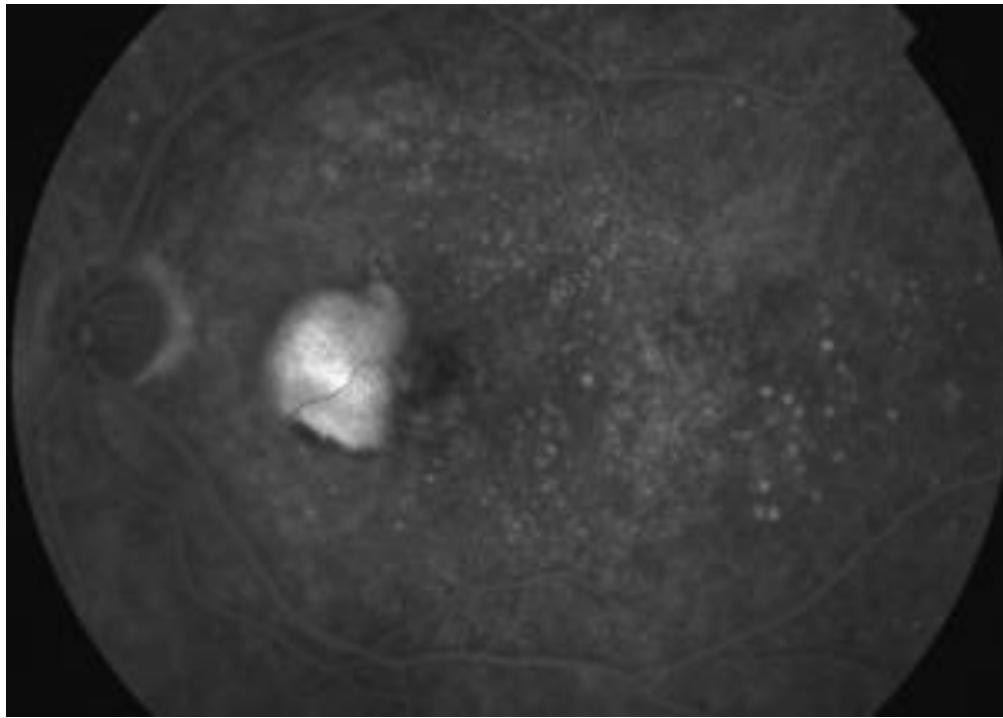
- Leakage: Hyperfluorescence **progressively enlarges** with fuzzy borders. The dye permeates out of leaky, incompetent blood vessels in the setting of neovascularization, retinal vasculitis, vascular malformations, tumours, or disc oedema (dye leaks from prepapillary capillaries).
- Pooling: Hyperfluorescence 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).
- 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.
- 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



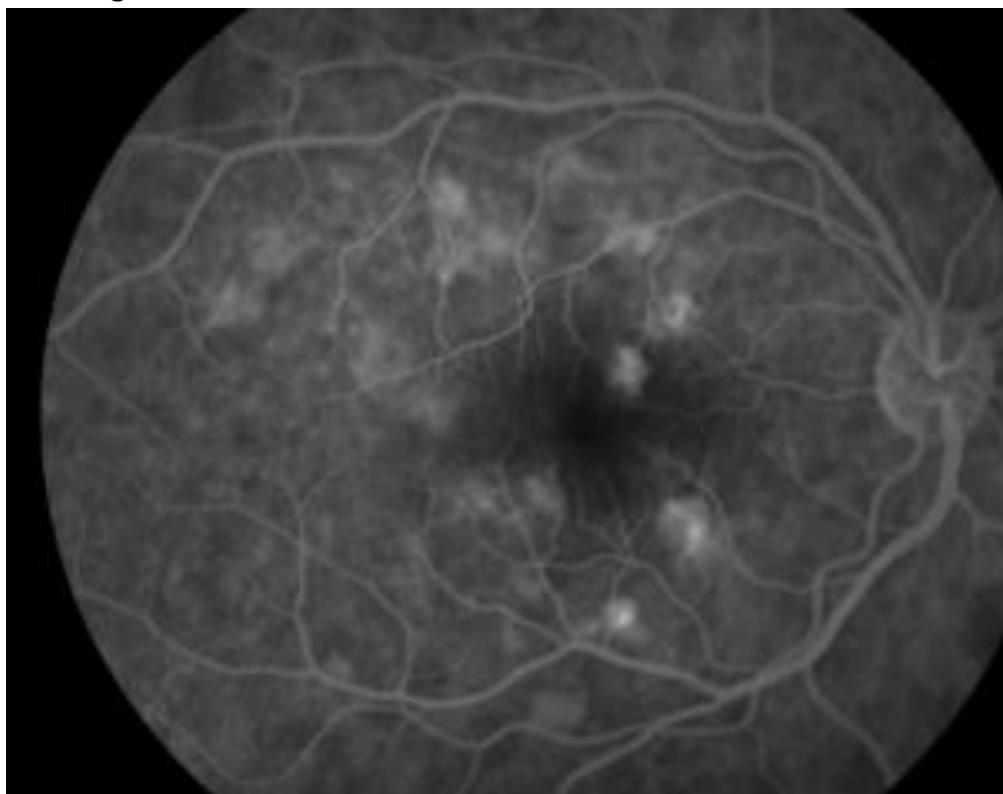
Petaloid leakage from cystoid macular edema

Pooling



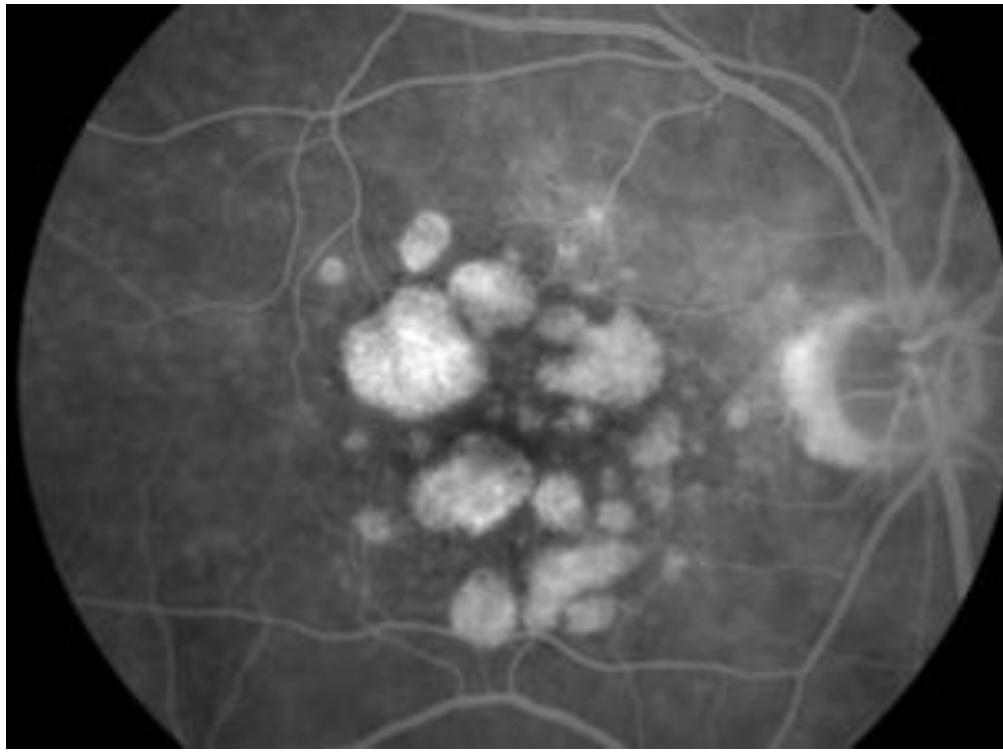
Pooling from a serous pigment epithelial detachment

Staining



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

Window defect



Window defect from

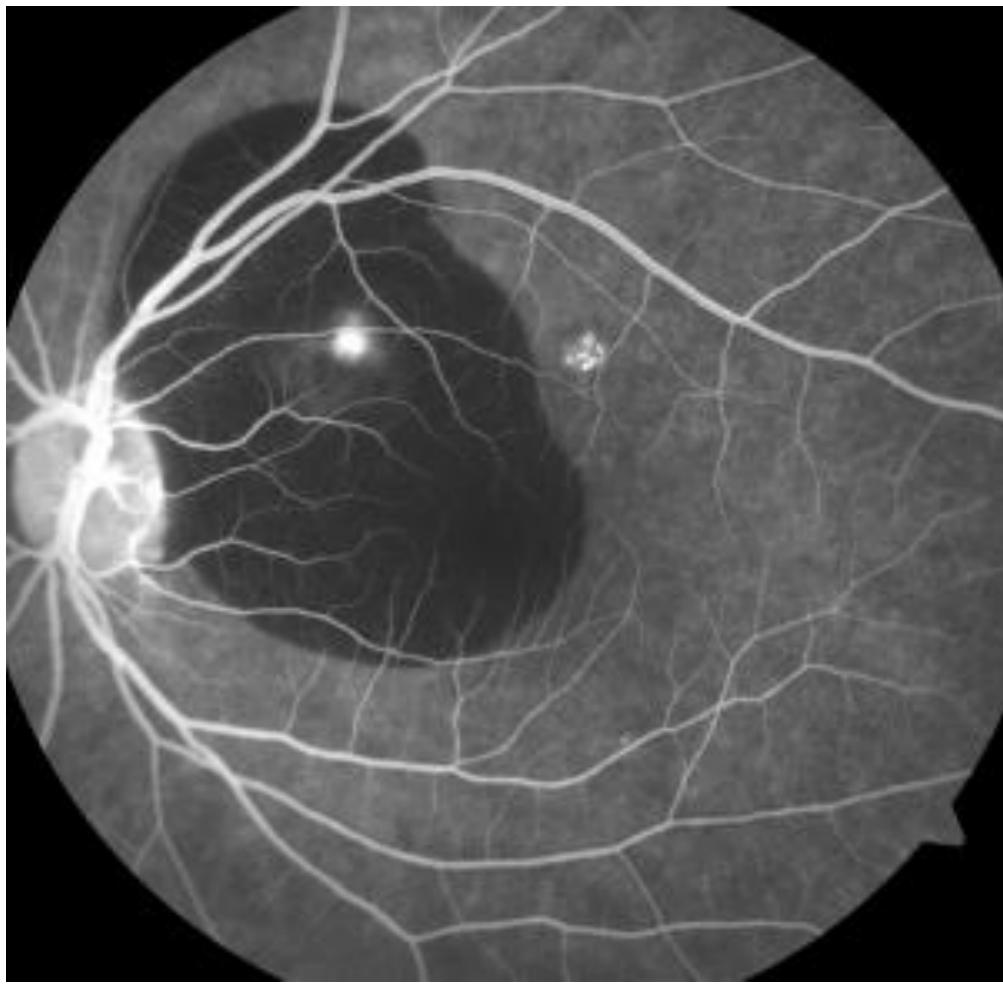
geographic atrophy in AMD

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.

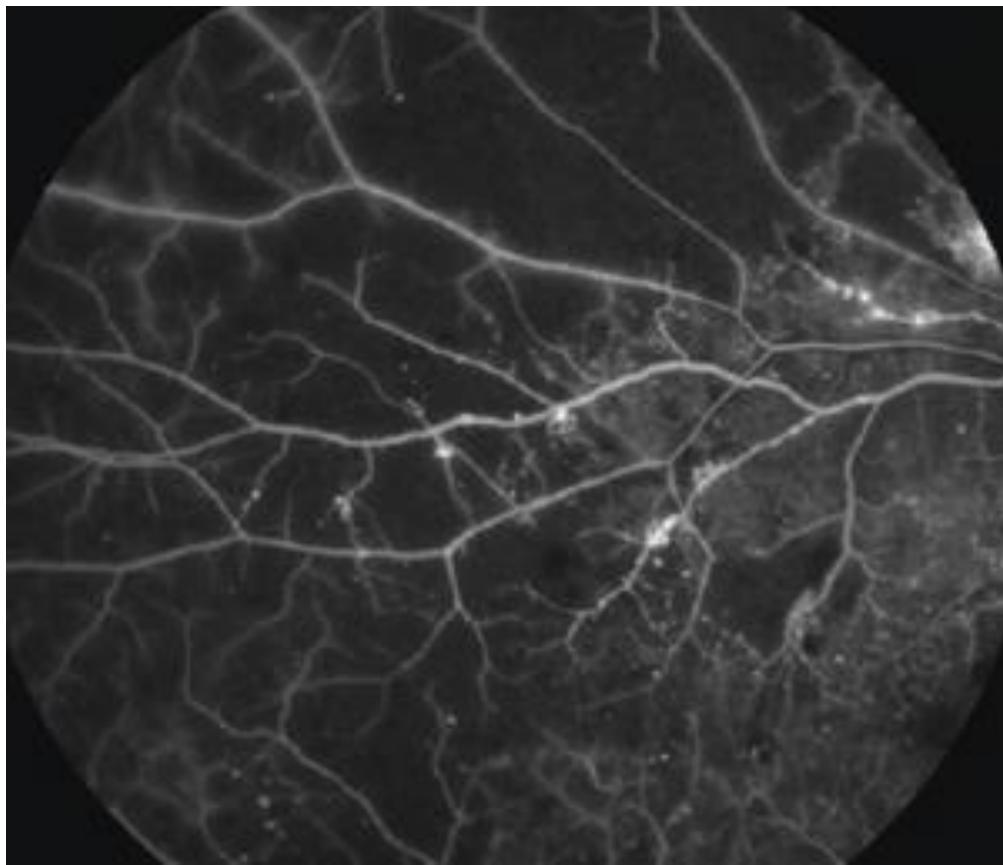
Blocking



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 hyperfluorescent or hypofluorescent. It is important to know generally what pathology correlates with what FA appearance.

6. 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).

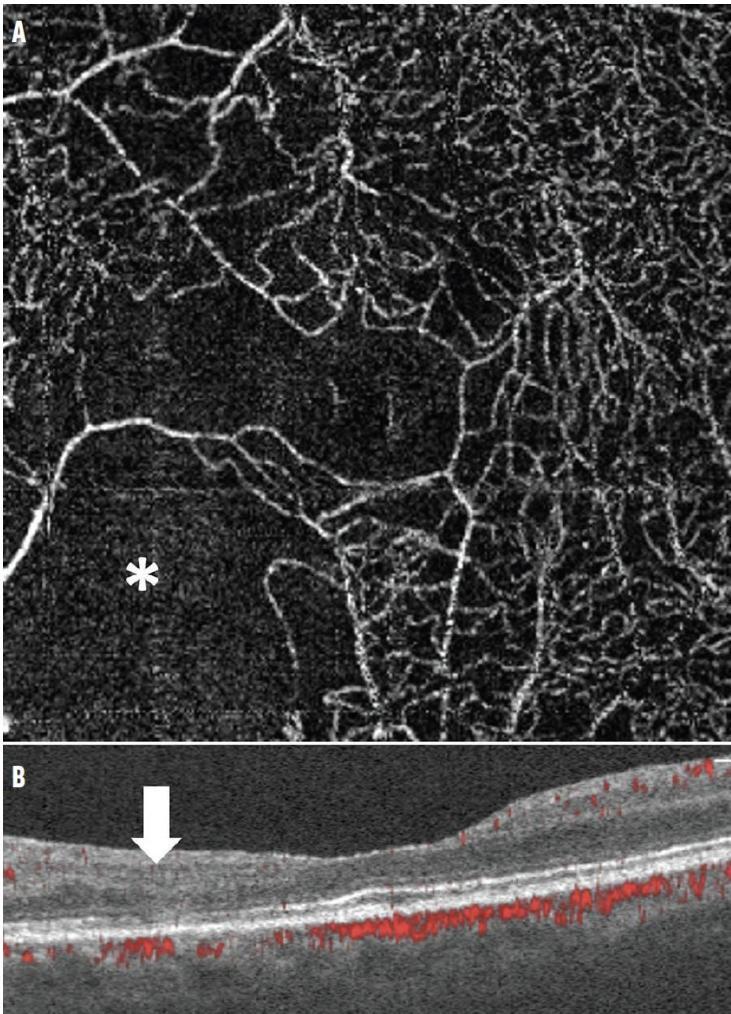


Figure 1. The en face OCTA deep capillary plexus slab of an eye of a 30-year-old woman with type 1 diabetes revealed significant areas of nonperfusion and capillary dropout (A, asterisk). The area of nonperfusion corresponds to a lack of flow seen on the OCT B-scan flow overlay (B, arrow). Note the asymmetry 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.

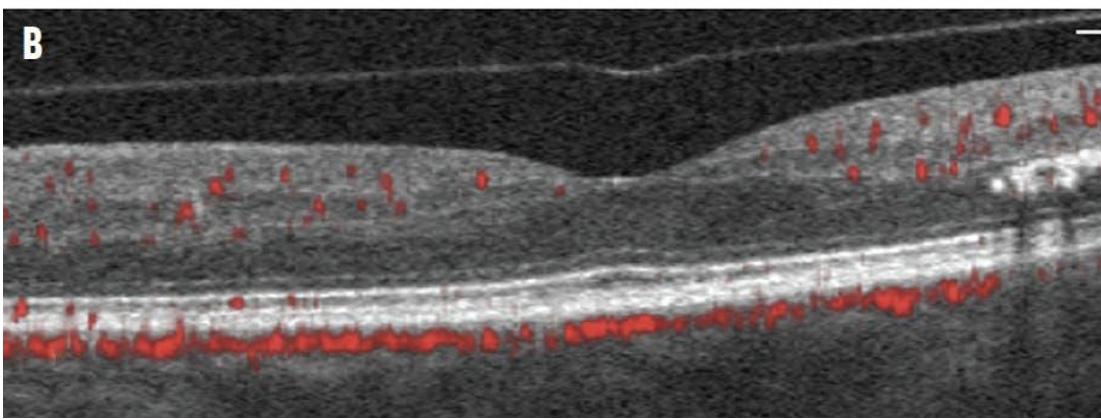
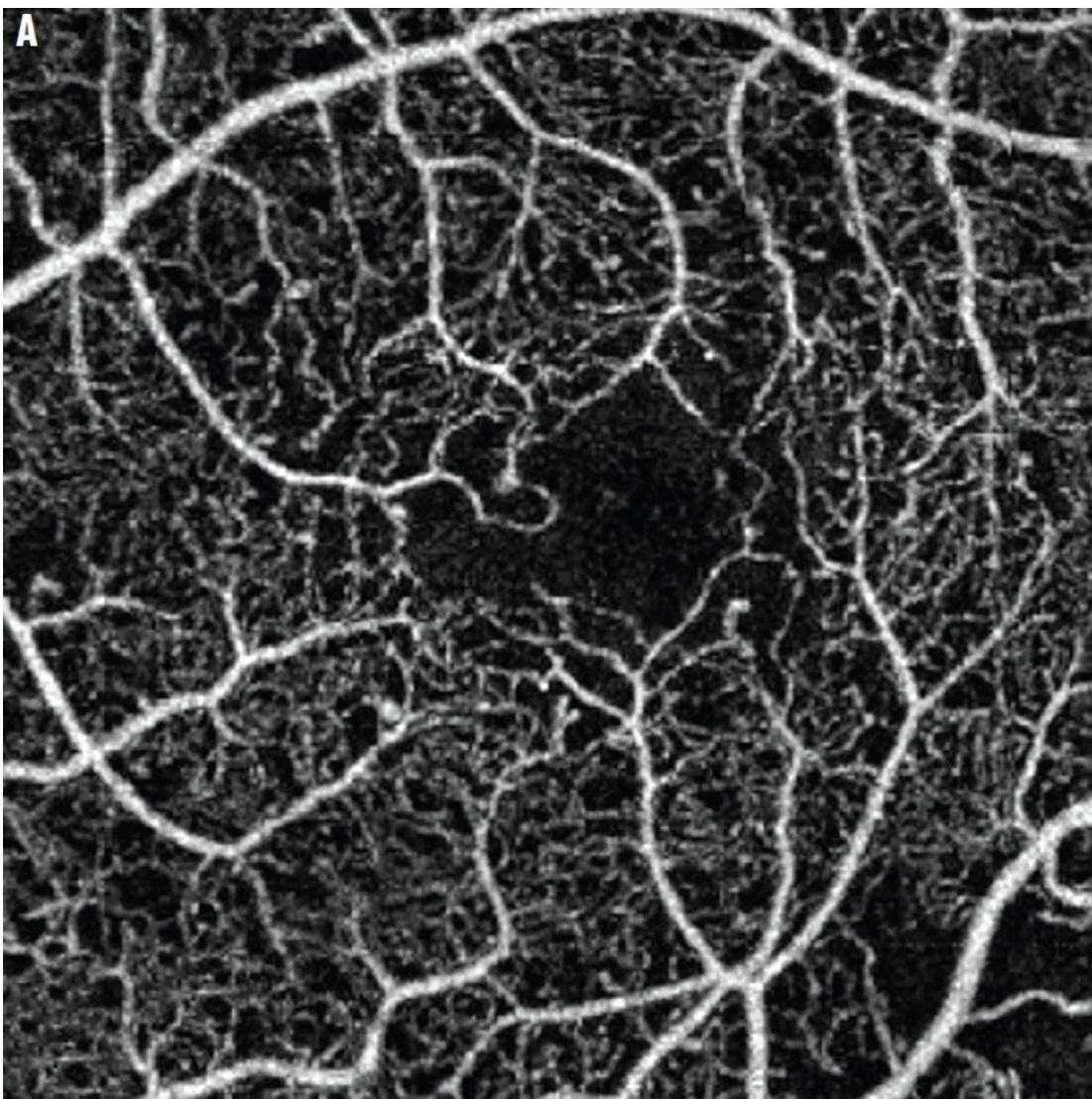


Figure 2. The full-thickness en face OCTA of the eye of a 36-year-old woman with type 1 diabetes showed an irregular, enlarged foveal avascular zone (FAZ) due to nonperfusion (A). Note the relatively normal retinal appearance on the OCT B-scan with flow overlay (B). In general, the full-thickness OCTA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

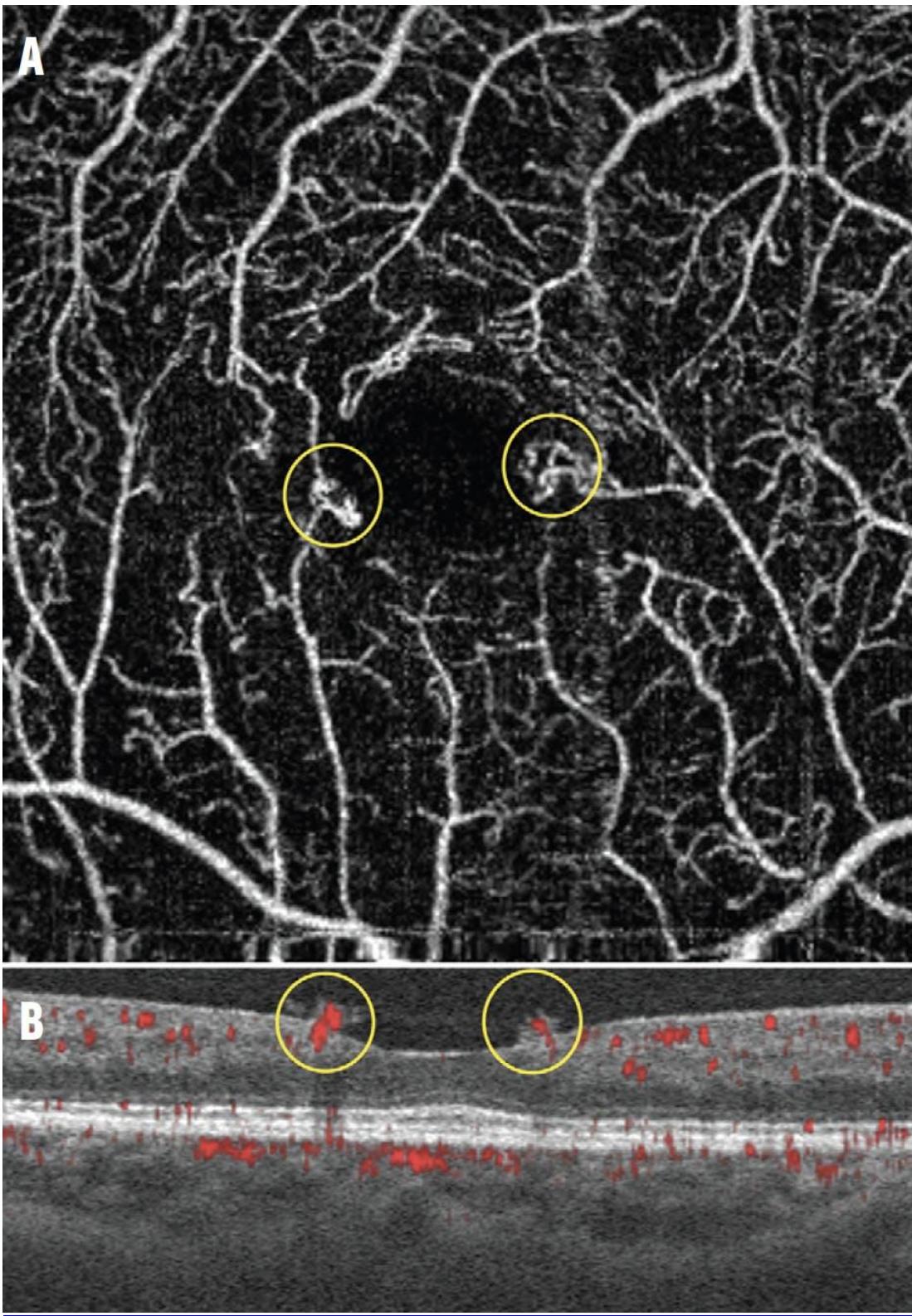


Figure 3. The en face superficial capillary plexus slab of an eye of a 48-year-old woman with type 2 diabetes illustrated abnormal blood vessels in the juxtafoveal region (A, circles). These abnormal vessels correspond to hyperreflective foci that project anterior to the internal limiting membrane on 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).

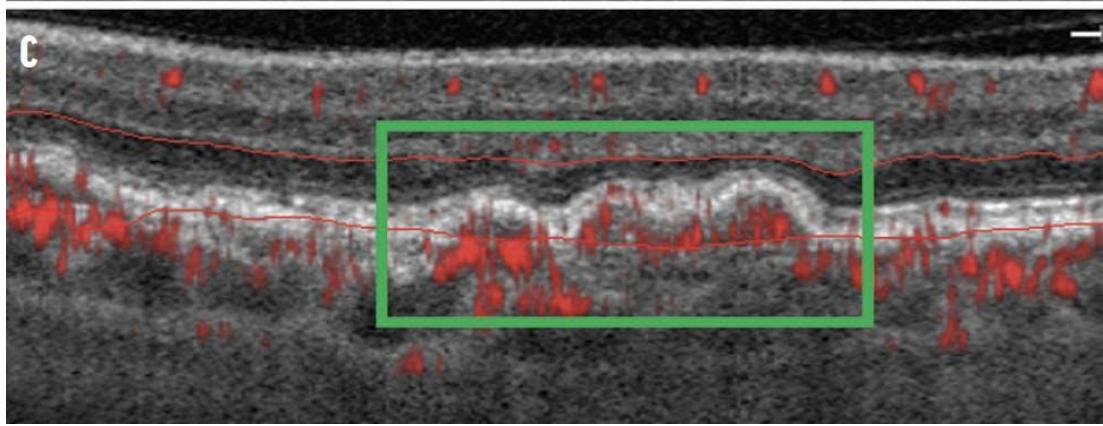
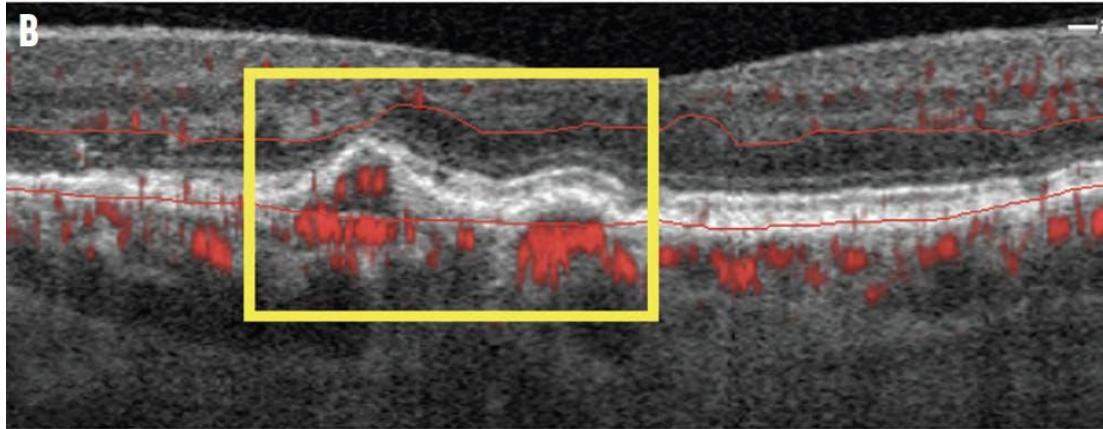
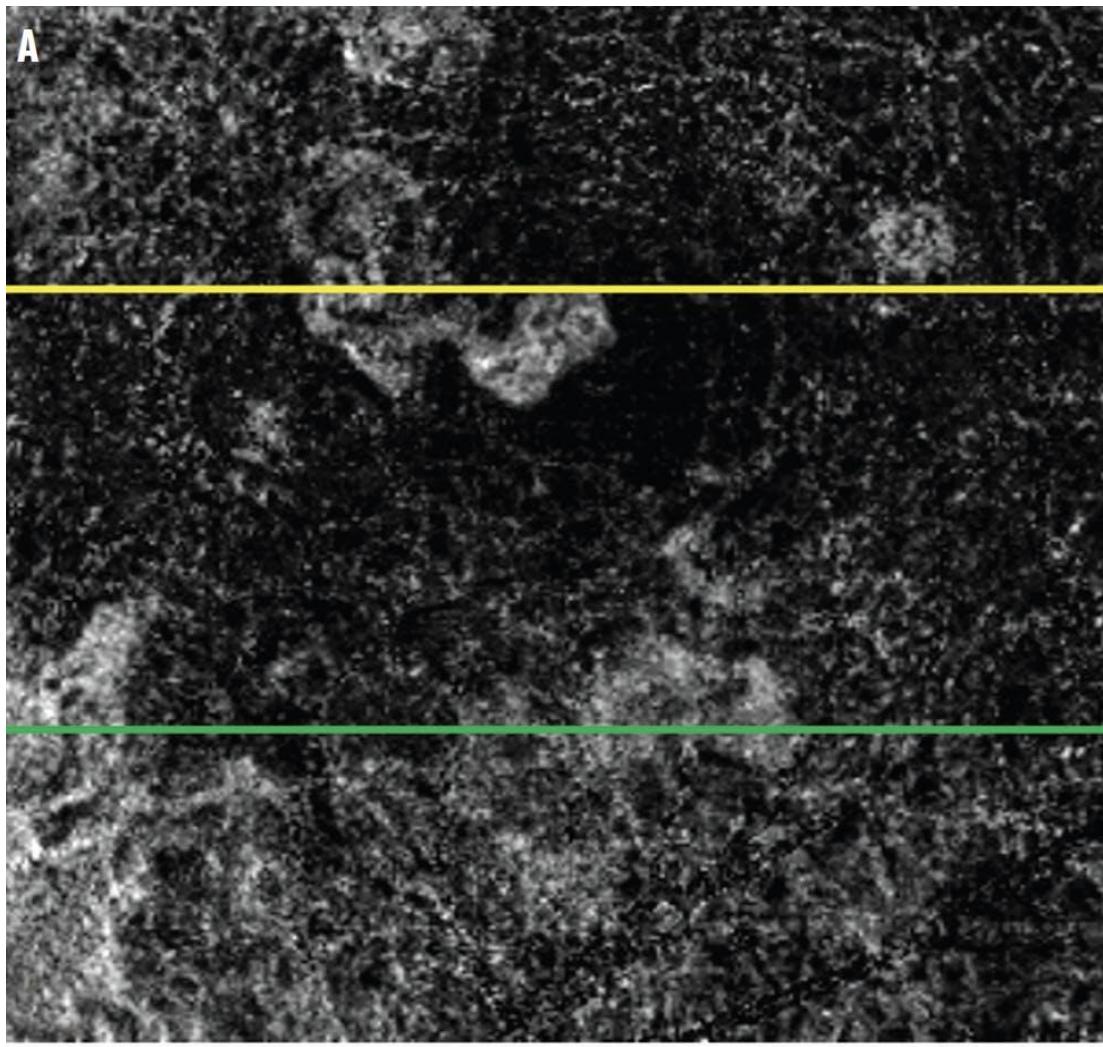


Figure 4. The en face outer retina slab of an eye of a 64-year-old woman with a history of nonexudative AMD showed several areas suspicious for neovascular networks (A). The colored lines correspond to the colored boxes in the OCT B-scans with flow overlay (B).

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.

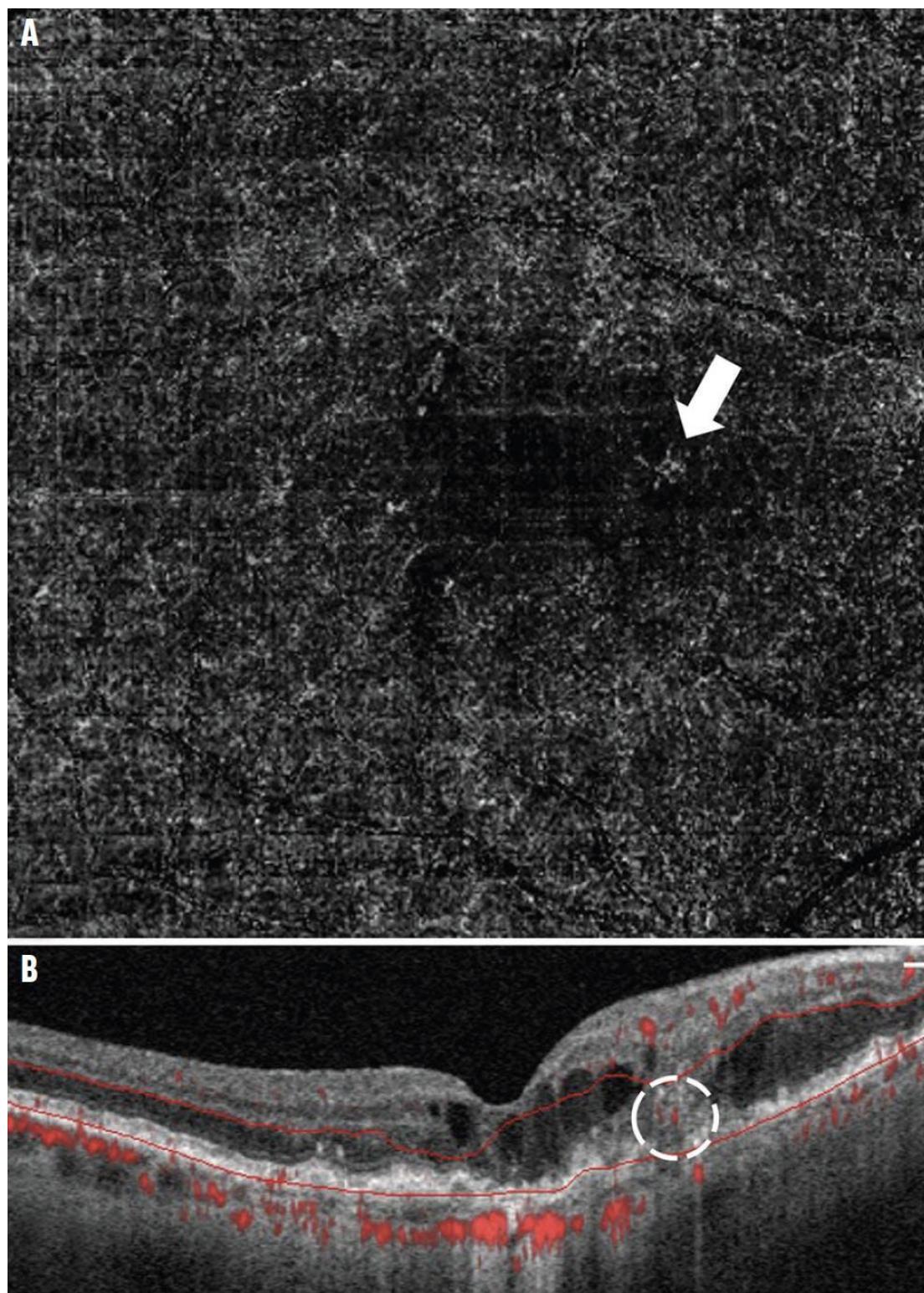


Figure 5. The en face deep capillary plexus slab of the eye of a 77-year-old man with AMD showed a subtle area of possible neovascularization in the outer retinal slab, consistent with possible type 3 neovascularization in AMD (A, arrow). By looking at the cross-section with flow overlay (B), an area 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.

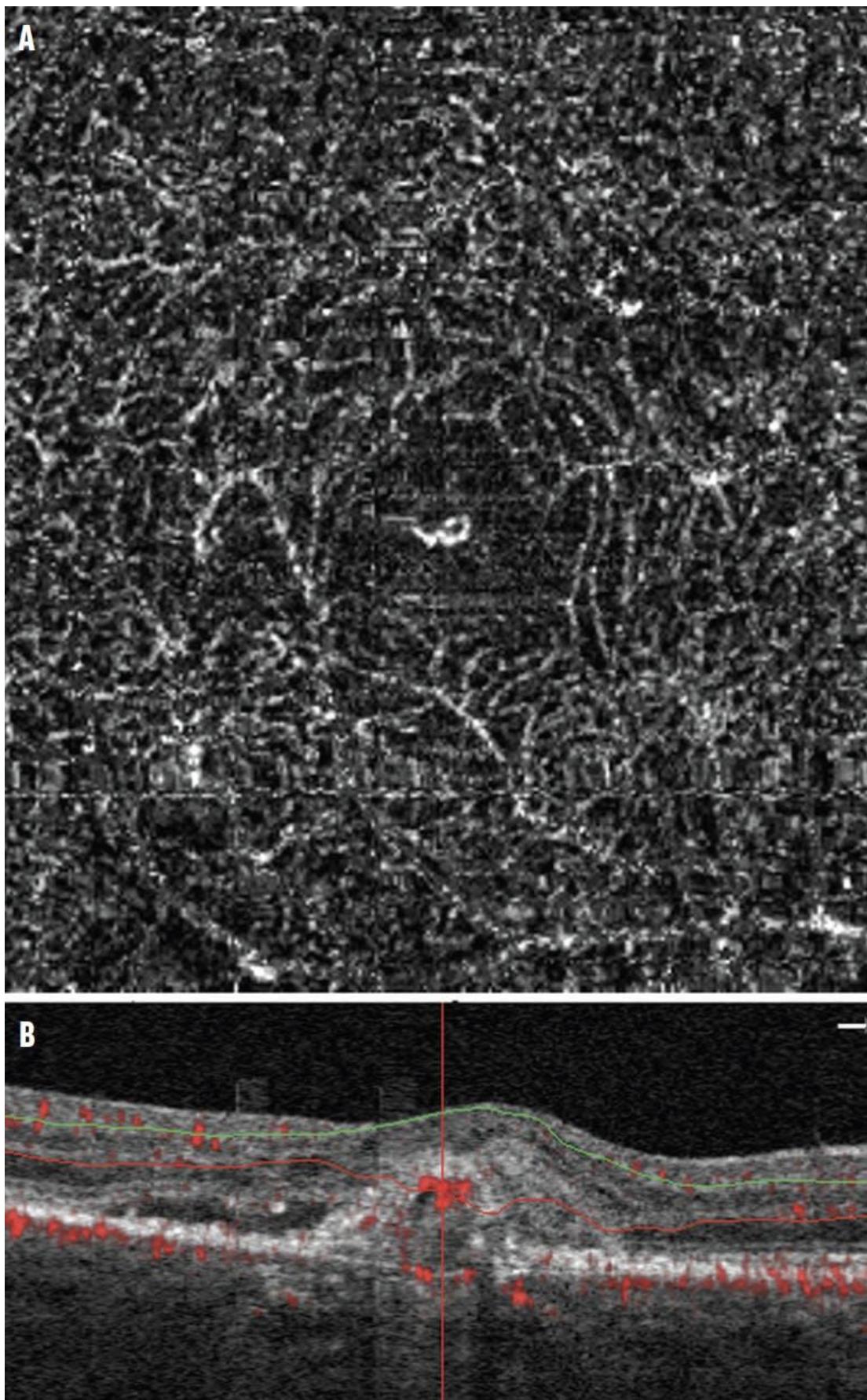


Figure 6. In the eye of a 67-year-old man with PCV, the en face deep capillary plexus slab showed the anterior projection of a central polyp within the FAZ (A). The OCT B-scan with flow overlay confirmed the presence of flow within a hyporeflective ring-like lesion between the RPE and Bruch membrane,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

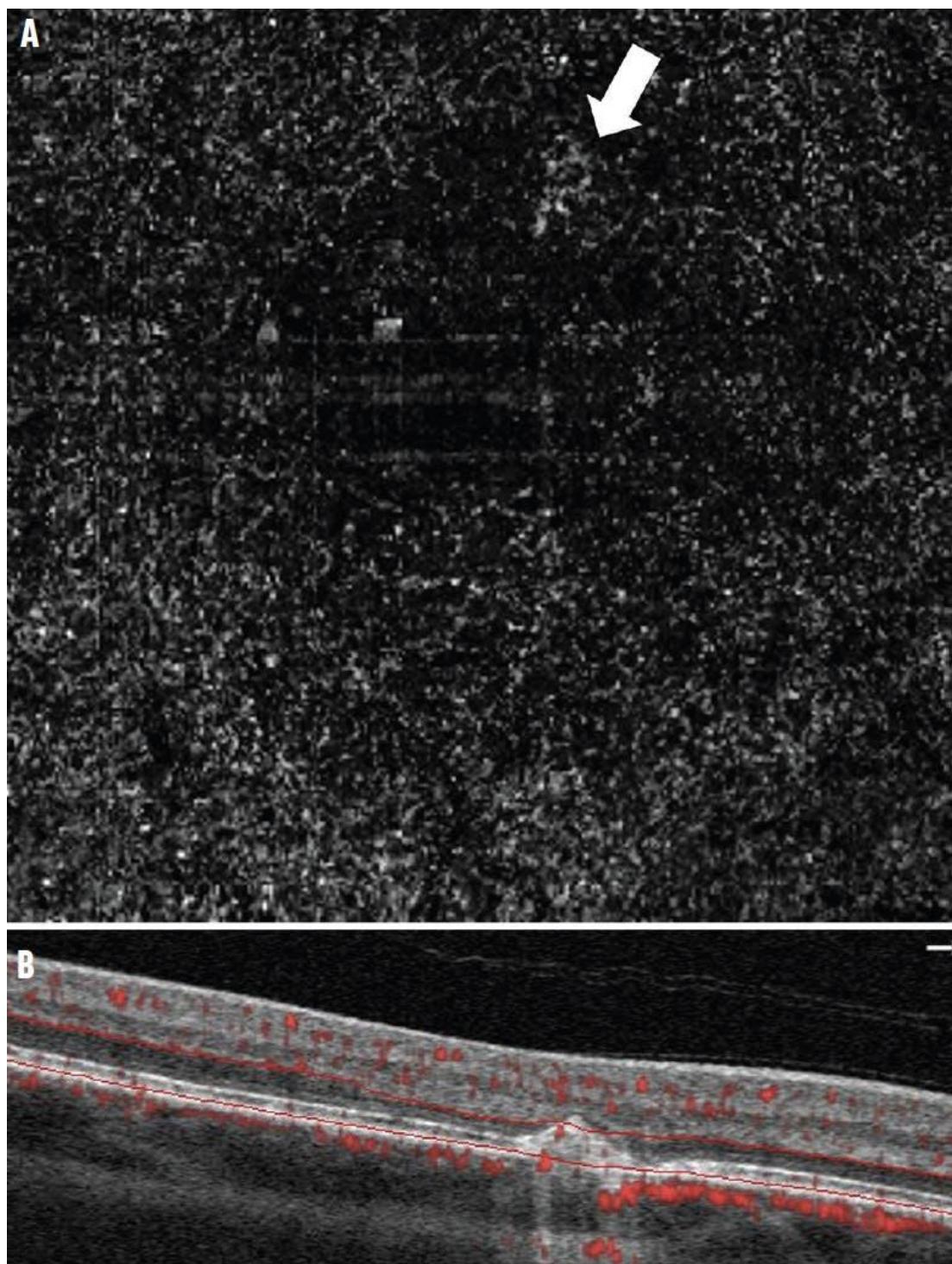


Figure 7. The en face OCTA outer retina slab of the eye of a 34-year-old woman with myopia and a history of multifocal choroiditis showed a neovascular network (A, arrow) that corresponds with several areas of flow under the RPE and above Bruch membrane on the OCT B-scan (B). In this case, OCTA was helpful 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.

MultiColor scanning laser imaging is an innovative technology for fundus imaging offering detail and clarity not available from traditional fundus photography.

This guide will help you to systematically evaluate MultiColor images and describe clinical observations visualized by such images in a straight-forward and efficient manner.



Fig. 1: MultiColor image of a healthy eye (left) compared to a fundus photo (right) of the same patient.

MultiColor images are captured by simultaneously scanning with three individual laser wavelengths: **infrared (IR)**, **green (GR)**, and **blue (BR)**. Each wavelength penetrates the tissue at a different depth (Fig. 2), providing structural information for different layers within the retina. The high-resolution, detailed MultiColor images can show structures and pathologies not visible on ophthalmoscopy and fundus photography.

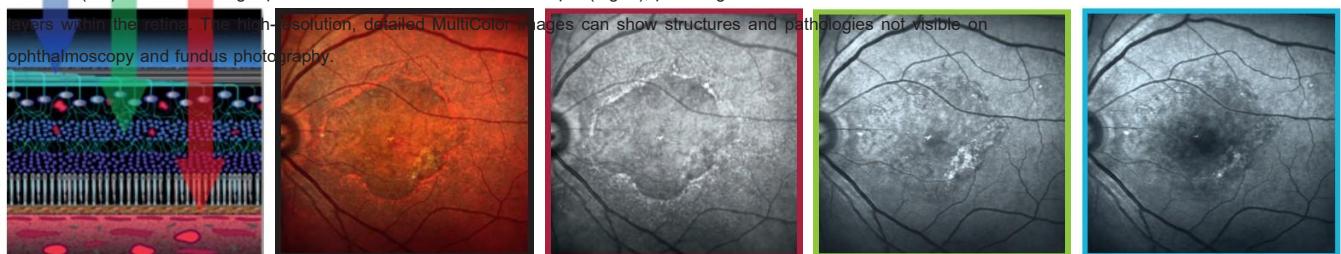


 Fig. 2: MultiColor image composed of three simultaneously acquired color laser images.

The IR, BR and GR images will be identified by frames in the respective colors throughout this document.

Interpreting MultiColor Images in 3 Steps



MultiColor Image Interpretation



Fovea: The fovea typically appears orange-red. The surrounding retina generally appears in a lighter pink-orange color.

Optic nerve head (ONH)/Retinal nerve fiber layer (RNFL): RNFL is best seen in the BR and GR images and is often especially easy to see temporal to the ONH in both superior and inferior regions. The ONH generally appears as a dark zone and may have a green appearance.

Retinal blood vessels: The retinal blood vessels appear dark. Well-focused MultiColor images show the double contour of the blood vessels, also observed in infrared reflectance images. Special attention should be paid to the course of the retinal blood vessels and the foveal avascular area.

Pattern of changes: Many interpretation patterns learned from evaluating fundus photographs can also be applied to MultiColor images. For example, distorted blood vessels may suggest an epiretinal membrane. Flame-shaped hemorrhages may correlate with the path of the retinal nerve fibers in cases with a branch retinal vein occlusion.

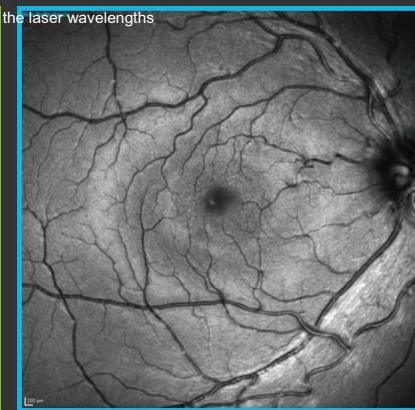


Selective Information Shown in Individual Reflectance Images

The three reflectance images offer unique details due to the different penetration depths and reflectance properties of the laser wavelengths used (infrared, green, and blue).



The three reflectance images offer unique details due to the different penetration depths and reflectance properties of the laser wavelengths used (infrared, green, and blue).



The IR image shows deeper structures in the choroid and the retinal pigment epithelium (RPE).

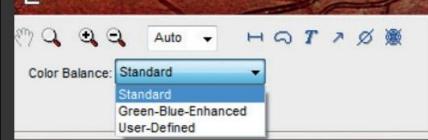
The GR image is useful for examining blood vessels, and exudates.

The BR image is best for spotting changes in superficial retinal structures, like epiretinal membranes.



Image Enhancement

The SPECTRALIS viewing module offers a number of image enhancement options including contrast, brightness, and color balance. When viewing MultiColor images, adjusting the color balance setting can often be helpful.



The default color balance setting is <>Standard>>, which is close to a natural fundus appearance. This setting is optimized to highlight retinal and choroidal changes. To emphasize inner retinal layers and the blood vessels, the <>Green-Blue-Enhanced>> option is recommended.



<>Standard>> setting <>Green-Blue-Enhanced>> setting



MultiColor Image Interpretation



Fovea:

No obvious changes visible.

ONH/RNFL:

The reflectivity of the retinal nerve fiber layer appears normal.

Retinal blood vessels:

No obvious changes visible.

Pattern of changes:

Reticular drusen are seen with the <<Standard>> color balance setting as bright greenish spots surrounded by a dark ring. The retinal changes are associated with pigment migration to the layers of the outer retina.

Fig. 3: MultiColor image, grid-like visible reticular drusen



Selective Information Shown in Individual Reflectance Images

Reticular drusen can be observed most clearly in the GR image.



Fig. 4: Individual reflectance images, grid-like visible reticular drusen



Image Enhancement



To enhance the contrast of reticular drusen, change the color balance setting to <<Green-Blue-Enhanced>>.

Fig. 5: Image with <<Green-Blue-Enhanced>> setting, grid-like visible reticular drusen



MultiColor Image Interpretation



Fig. 6: MultiColor image, subretinal hemorrhage

Fovea:

The fovea looks blurred due to an underlying choroidal neovascularisation (CNV) which leads to a protrusion of the fovea.

ONH/RNFL:

The reflectivity of the retinal nerve fiber layer appears normal.

Retinal blood vessels:

Blood vessels are not covered by the bleeding. Therefore, the bleeding must be subretinal.

Pattern of changes:

Blood appears red in MultiColor images. Very dense subretinal hemorrhages can also occur as dark areas.

The bright orange area around the fovea is caused by a **CNV**.



Selective Information Shown in Individual Reflectance Images

The hemorrhage can be observed most clearly and with greatest contrast in the GR image. The same distribution pattern of blood is detectable in the BR image but with lower contrast. In IR images the hemorrhage stays relatively transparent.

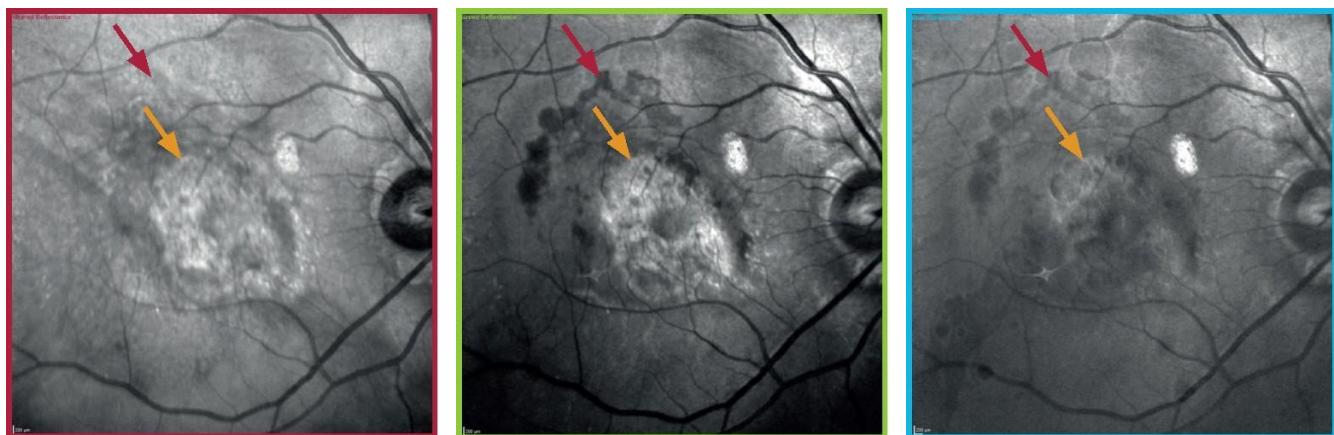


Fig. 7: Individual reflectance images, subretinal hemorrhage



Image Enhancement



To enhance the contrast of the hemorrhage, change the color balance setting to <<Green-Blue-Enhanced>>.

Fig. 8: Image with <<Green-Blue-Enhanced>> setting, subretinal hemorrhage



MultiColor Image Interpretation

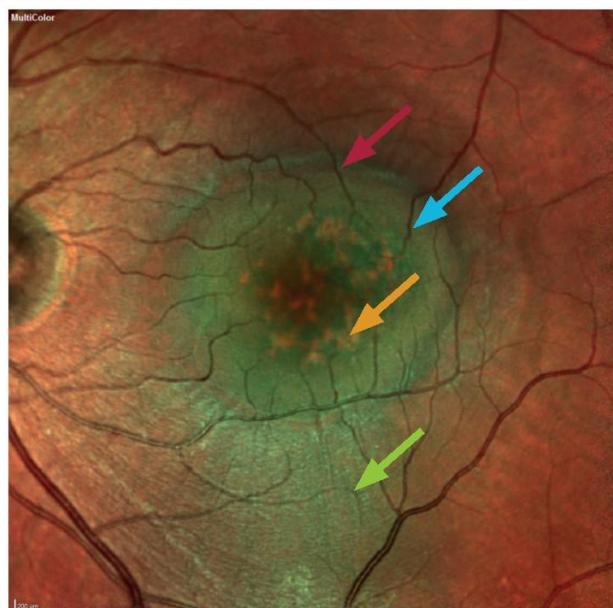


Fig. 9: MultiColor image, PED with subretinal fluid

Fovea:

The fovea appears blurred, which may indicate a foveal shift and/or a missing foveal dip.

ONH/RNFL:

No obvious changes visible.

Retinal blood vessels:

The blood vessels show a **change in direction** at the outer margin of the green parafoveal reflective ring.

Pattern of changes:

The presence of **sub-neuroretinal fluid/sub-RPE fluid** is usually indicated by a green shift in MultiColor images.

A foveal and parafoveal **migration of RPE cells** is observed.



Selective Information Shown in Individual Reflectance Images

The migration of RPE cells is best visible in the IR image, whereas the sub-neuroretinal and sub-RPE fluid seems more prominent in the GR and BR image.

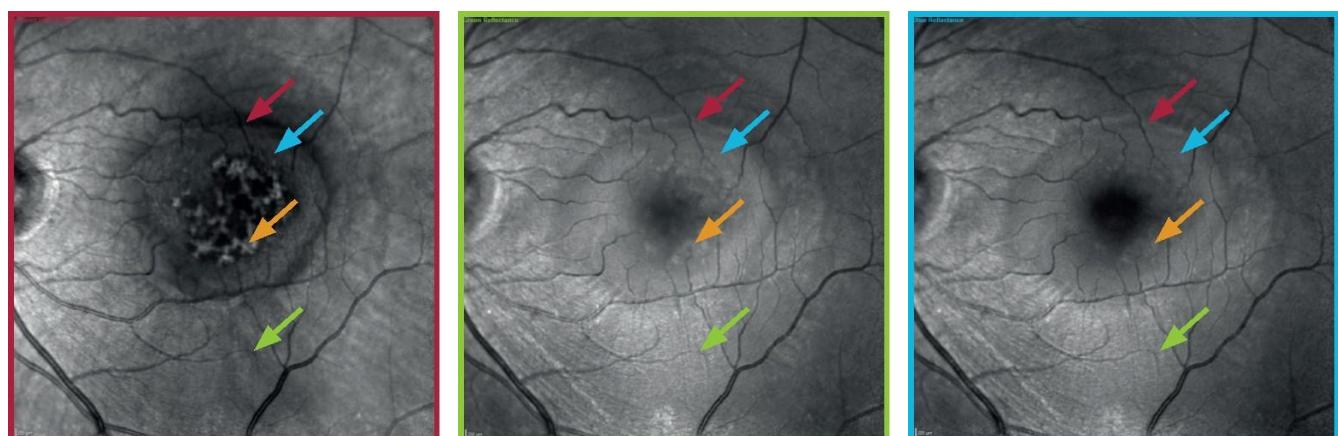
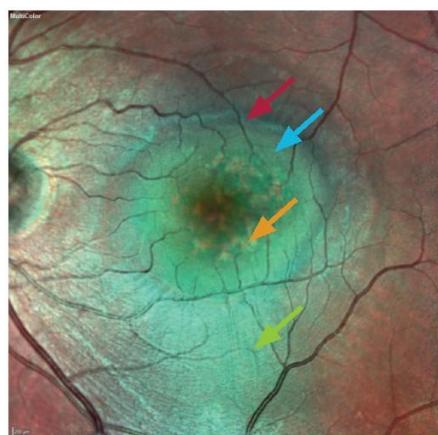


Fig. 10: Individual reflectance images, PED with subretinal fluid



Image Enhancement

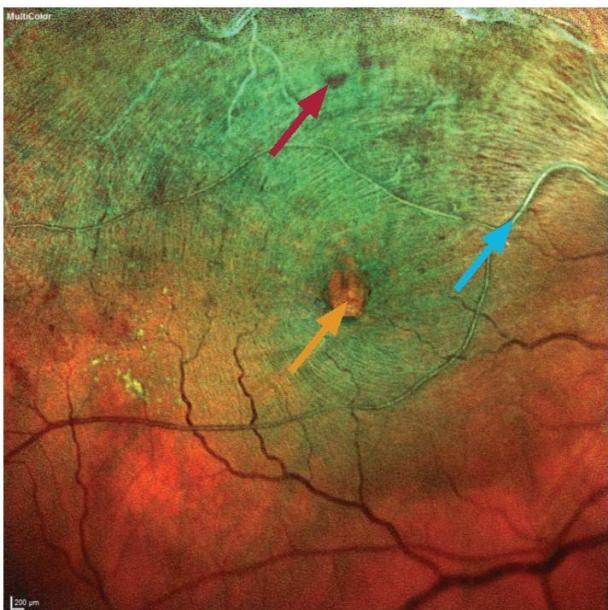


To enhance the contrast of detached areas, change the color balance setting to <>Green-Blue-Enhanced>>.

Fig. 11: Image with <>Green-Blue-Enhanced>> setting, PED with subretinal fluid



MultiColor Image Interpretation



Fovea:

Retinal edema caused by branch retinal vein occlusion is visible as a green ring surrounding the macular area which extends superiorly. In the foveal region, a large cyst causes a window defect, increasing reflectance from the RPE and resulting in an orange color shift.

ONH/RNFL:

RNFL arcuate bundles appear green in the superior hemisphere and around the fovea due to intraretinal and RNFL edema.

Retinal blood vessels:

Some of the retinal veins show a green shift which is a clear sign of the [opacification of the blood vessel wall](#).

Pattern of changes:

Multiple brown/red spots lie between the arcuate pattern of the retinal nerve fibers in the upper hemisphere of the MultiColor image. These can be interpreted as hemorrhages.

Fig. 12: MultiColor image, branch retinal vein occlusion



Selective Information Shown in Individual Reflectance Images

The retinal edema is located in the inner retinal layers. This is visible on the monochromatic BR and GR images. The macular RPE is clearly visible in the IR image as a hyperreflective spot.

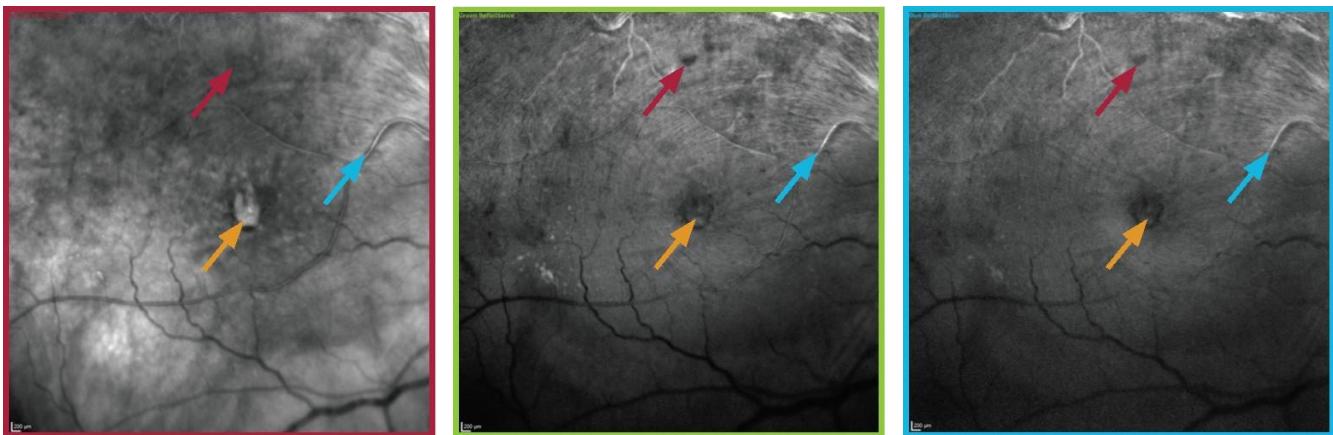
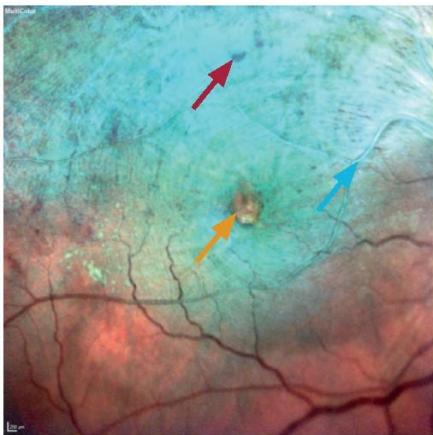


Fig. 13: Individual reflectance images, branch retinal vein occlusion



Image Enhancement



In case of an acute branch retinal vein occlusion, the <>Green-Blue-Enhanced<> color balance setting is usually overexposed due to the distinct swelling.

Fig. 14: Image with <>Green-Blue-Enhanced<> setting, branch retinal vein occlusion



MultiColor Image Interpretation



Fig. 15: MultiColor image, diabetic retinopathy

Fovea:

No obvious changes visible.

ONH/RNFL:

The reflectivity of the retinal nerve fiber layer appears normal.

Retinal blood vessels:

Some **intraretinal hemorrhages** close to the small blood vessels appear as brownish dots.

Pattern of changes:

A beginning **epiretinal membrane** is visible as a green speckled area in the superior hemisphere.

Laser spots as well as other atrophies of the retinal pigment epithelium appear orange in the MultiColor image.



Selective Information Shown in Individual Reflectance Images

Small hemorrhages appear as hyporeflective dots in all monochromatic images. The best contrast to detect small hemorrhages is achieved by the GR image. Atrophic areas are highly reflective in the IR image and less reflective in BR and GR images.

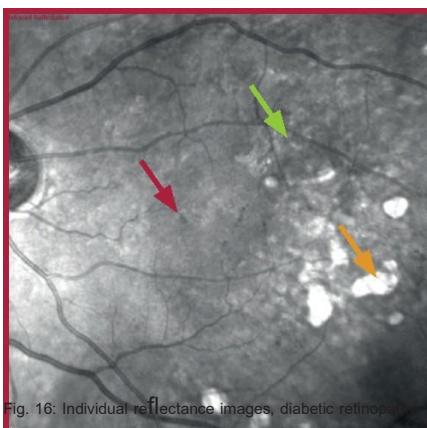


Fig. 16: Individual reflectance images, diabetic retinopathy

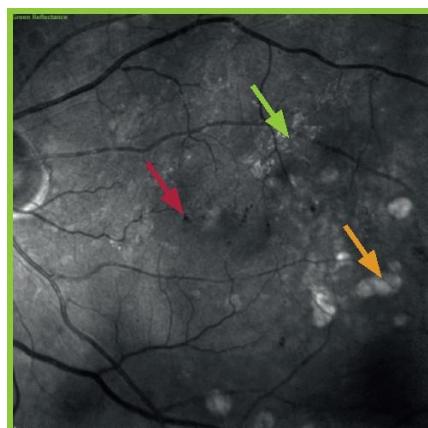


Image Enhancement



To enhance the contrast of epiretinal glial cells and microaneurysms, change the color balance setting to <>Green-Blue-Enhanced<>.

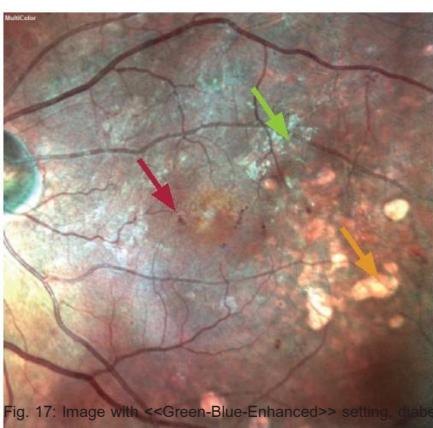


Fig. 17: Image with <>Green-Blue-Enhanced<> setting, diabetic retinopathy



MultiColor Image Interpretation



Fovea:

The fovea shows an **irregular color gradient**. The brownish base is spotted by green areas, which shows retinal edema.

ONH/RNFL:

The **reflectivity** of the retinal nerve **fiber layer** appears normal.

Retinal blood vessels:

The small blood vessels close to the fovea show **microaneurysms** and hemorrhages.

Pattern of changes:

Exudates, which are close to the small superior branch vein, appear as green shifted spots. The presence of exudates indicates chronic leakage of a microaneurysm. The large orange spots in the inferior retinal hemisphere are **atrophic areas after laser therapy**.



Selective Information Shown in Individual Reflectance Images

Among all monochromatic images, hard exudates appear **hyperreflective**, small hemorrhages **hyporeflective**. Both have their best contrast in GR images.



Image Enhancement



To enhance the contrast of exudates and microaneurysms, change the color balance setting to <>Green-Blue-Enhanced<>.



MultiColor Image Interpretation

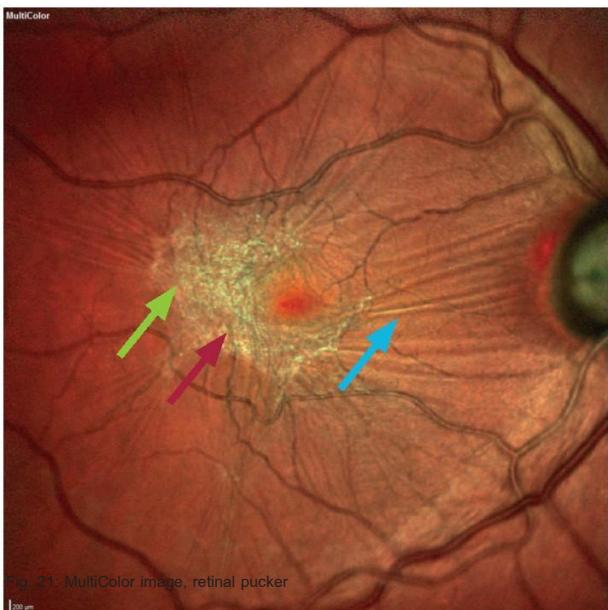


Fig. 21: MultiColor image, retinal pucker

Fovea:

Foveal architecture appears disrupted with evidence of **retinal striae** becoming visible in the blue and green reflectance image.

ONH/RNFL:

The reflectivity of the retinal nerve fiber layer appears normal.

Retinal blood vessels:

The **blood vessels** in the macular area are **stretched** by the retinal pucker.

Pattern of changes:

The **retinal pucker** shows a star pattern with its center close to the fovea.



Selective Information Shown in Individual Reflectance Images

The **TWBR** image and the **GR** image clearly show the traction lines radiating out in a star pattern from the center of the retinal pucker.

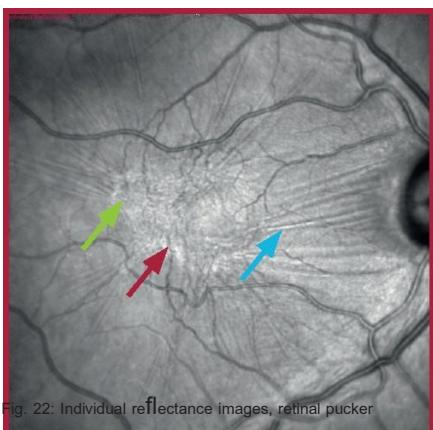


Fig. 22: Individual reflectance images, retinal pucker

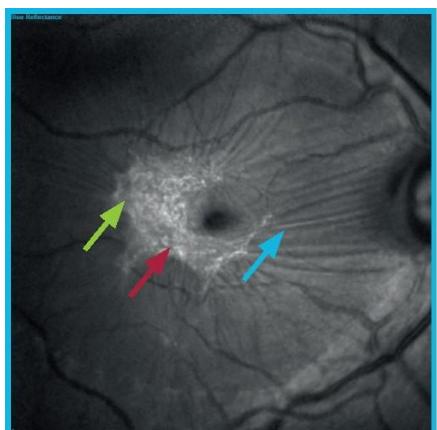


Image Enhancement



To enhance the contrast of the retinal pucker, change the color balance setting to <>Green-Blue-Enhanced>>.

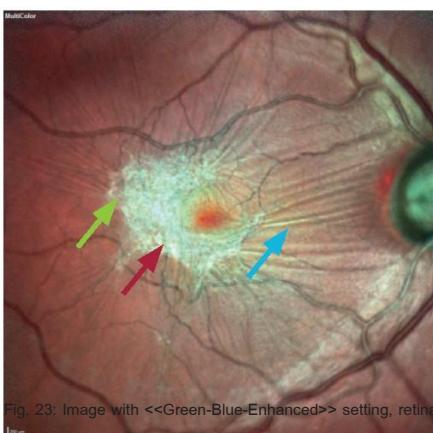


Fig. 23: Image with <>Green-Blue-Enhanced>> setting, retinal pucker



MultiColor Image Interpretation

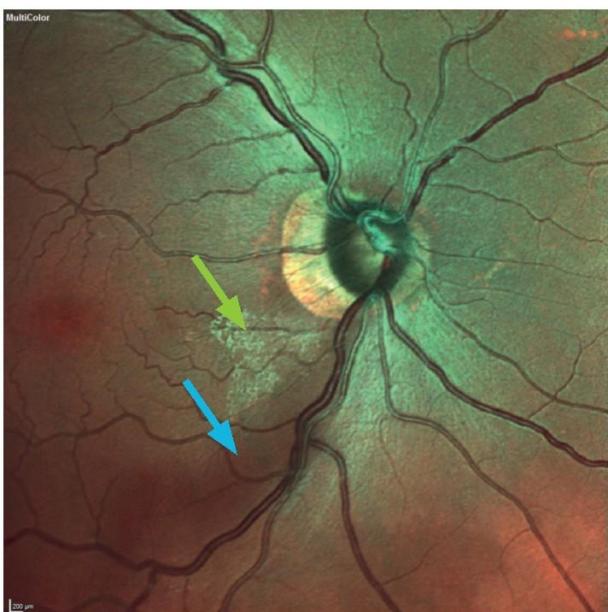


Fig. 24: MultiColor image, RNFL defect temporal-inferior

Fovea:

No obvious changes visible.

ONH/RNFL:

The reflectivity of the retinal nerve fiber layer temporal-inferior is reduced due to a loss of retinal nerve fibers.

Retinal blood vessels:

No obvious changes visible.

Pattern of changes:

An area with epiretinal glial cells is visible temporal-inferior, above the nerve fiber bundle defect.



Selective Information Shown in Individual Reflectance Images

Since retinal nerve fibers have a high reflectivity in shorter wavelengths, the loss of RNFL is best visible as hyporeflective areas in the GR and BR image.

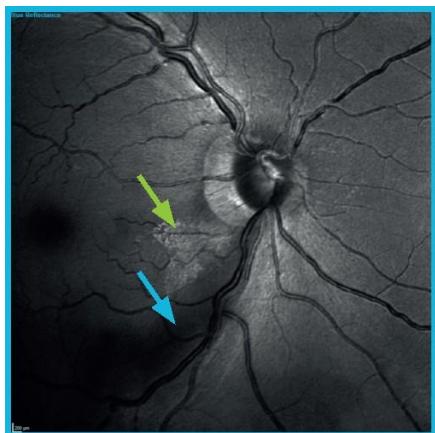
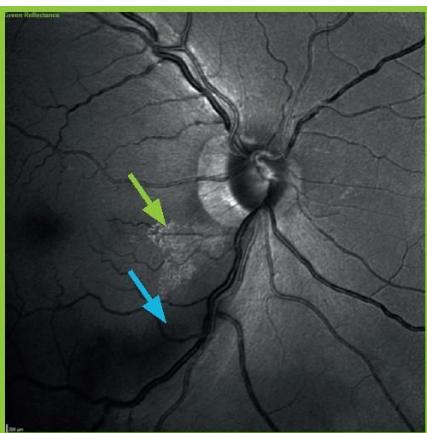
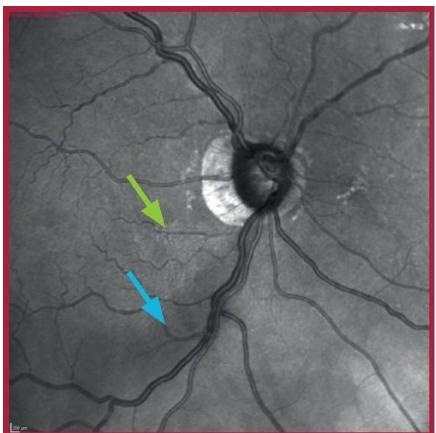
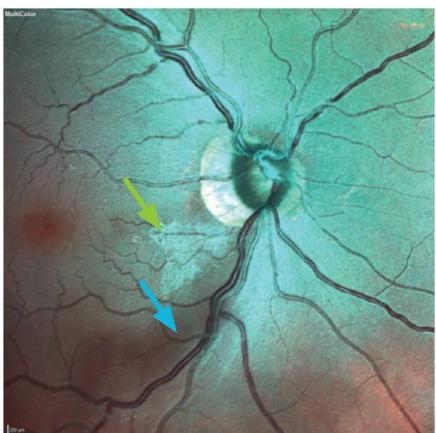


Fig. 25: Individual reflectance images, RNFL defect temporal-inferior



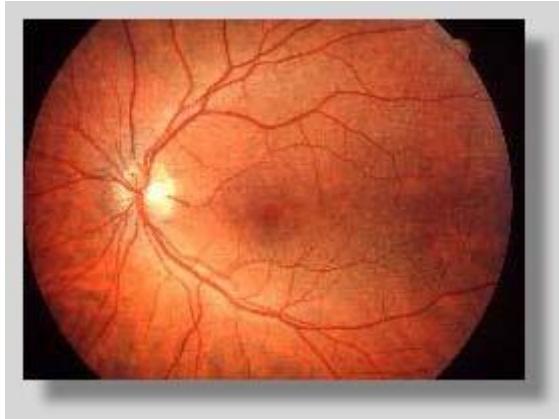
Image Enhancement



To enhance the contrast of the retinal nerve fiber bundle defect, change the color balance setting to <<Green-Blue-Enhanced>>.

Fig. 26: Image with <<Green-Blue-Enhanced>> setting, RNFL defect temporal-inferior

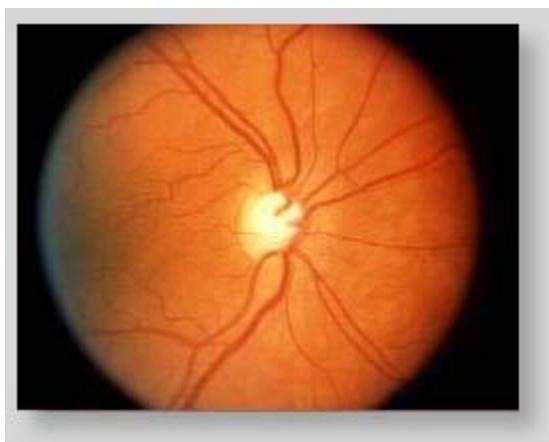
Retinal Fundus Photographs



Normal Fundus Photograph

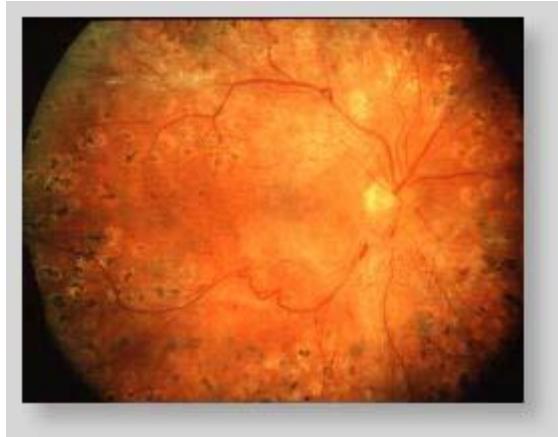
Fundus photographs are visual records which document the current ophthalmoscopic appearance of a patient's retina. One picture is worth, in this instance, a thousand words in the physician's notes. They allow the physician to further study a patient's retina, to identify retinal changes on follow-up, or to review a patient's retinal findings with a colleague.

Fundus photographs are routinely ordered in a wide variety of ophthalmic conditions. For example, glaucoma (increased pressure in the eye) can damage the optic nerve over time. Using serial photographs, the physician studies subtle changes in the optic nerve and then recommends the appropriate therapy. (Ref: Armaly, MF. Optic cup in normal and glaucomatous eyes. Invest. Ophth. 9(6):425-429)



Glaucoma

Fundus photography is also used to document the characteristics of diabetic retinopathy (damage to the retina from diabetes) such as macular edema and microaneurysms. This is because retinal details may be easier to visualize in stereoscopic fundus photographs as opposed to with direct examination. (Ref: Kinyoun, JL, et al, 1992. Ophthalmoscopy versus fundus photographs for detecting and grading diabetic retinopathy. Invest. Ophthalmol. & Vis. Science. 33:888-93.)



Diabetic Retinopathy

Fundus photography is also used to help interpret fluorescein angiography because certain retinal landmarks visible in fundus photography are not visible on a fluorescein angiogram.

How to tell right from left eye in a fundus photo?

The optic nerve and macula are your key identifiers when distinguishing between the left and right eye in an image. In ophthalmology, "temporal" is used instead of "lateral," and "nasal" replaces "medial." Picture yourself looking directly into the eye. The optic nerve always lies on the nasal side, while the macula is always on the temporal side. Therefore, if you see the optic nerve on the right half of the image, you're looking at a right eye. Conversely, if the optic nerve appears on the left half of the image, it's the left eye.

Anatomical Structures

Fundus photos are routinely divided into four quadrants to pinpoint abnormalities. Two ways of describing locations are suggested: 1- Cardinal Directions: superior, inferior, nasal, and temporal. 2- Combined Directions: superior temporal, superior nasal, inferior temporal, and inferior nasal. We'll review each anatomical structure with their normal and pathologic findings.

Optic Disc



Left optic disc of a patient with POAG. Note the increased vertical cup:disc ratio and thinning of the superior neuro-retinal rim.

The optic nerve head or disc is located nasally and visible when observed through the pupil from an angle approximately 15 degrees temporal to the optical axis (when the patient is asked to “look straight ahead”). The optic disc appears yellow-orange to pink in color, with sharp margins, particularly pronounced temporally and somewhat less so nasally. The disc is vertically oval and features a central, paler more horizontally oval pit known as the optic cup. The cup edge is best seen by the bend in small and medium-sized blood vessels as they leave or descend into the cup^[2]. Size of the cup varies with the size of the disc (larger disc, larger cup), with a normal cup-to-disc ratio typically less than 0.5.

To accurately describe optic disc and cup size changes, especially in glaucomatous conditions, correct identification of scleral ring and neuroretinal rim is important. Scleral ring surrounds the outer border of the scleral ring. It is formed by the termination of the sclera as it meets the point where the optic nerve fibers enter the eye. It appears as a distinct boundary between the optic disc and the surrounding retinal tissue. Neuroretinal rim: The tissue between the border of the cup and the disc is the neuroretinal rim. This tissue consists mainly of nerve fibers with some glial cells and is usually pink. It tends to be symmetric at the superior and inferior margins of each disc. The **ISNT** rule is a mnemonic used to describe the normal distribution of neuroretinal rim thickness in the optic disc. In most healthy cases, the rim thickness follows this pattern: Inferior (thickest), Superior, Nasal, and Temporal (thinnest).

Optic Disc Color Changes

When light hits the fundus, it undergoes total internal reflection through the axonal fibers and reflects off the capillaries on the disc surface, creating the characteristic yellow-pink color of a healthy optic disc. Variations in the optic disc shape or color can be observed in both normal and pathologic conditions. Correct diagnosis should be made based on clinical history and eye examination.

White or pale optic disc

Typically, a white or pale color in gross pathological presentations indicates a loss of blood vessels and possible ischemia, or fibrosis and scar formation, or myelination and reactive gliosis in the nervous system.

1. Ischemic (vascular) optic neuropathies: The optic disc pallor may be diffuse or segmental (sectoral). Segmental pallor occurs if part of the blood supply to the optic nerve is occluded. [Anterior ischemic optic neuropathy \(AION\)](#), specifically giant cell arteritis is a relatively common cause.
2. [Optic nerve atrophy](#): It is a pathological term referring to the death of the retinal ganglion cell axons that comprise the optic nerve, resulting in a pale optic nerve appearance on fundoscopy. The white appearance results from a combination of capillary loss over the optic nerve, reactive gliosis, and fibrosis^[3]. Optic nerve atrophy is not a disease itself but rather a condition that can result from various underlying causes.
3. [Optic nerve hypoplasia \(ONH\)](#): ONH is characterized by a small and gray-white optic nerve head. This can be due to conditions such as septo-optic dysplasia.
4. Normal variant: Non-pathologic causes of a pale disc include, but are not limited to, pseudophakic eyes, a large physiologic cup in axial myopia, and pseudo-brightness caused by bright light during examinations.

Hyperemic optic disc

1. Optic disc hyperemia: Optic disc hyperemia results from optic disc edema or inflammation, which can stem from various chronic and acute conditions. Optic disc edema refers to swelling of the nerve fiber layer at the optic nerve head due to an optic neuropathy of any etiology (inflammatory, infiltrative, compressive, etc.) whereas the term papilledema refers to optic disc edema caused by raised intracranial pressure.
2. Optic Disc Neovascularization: Abnormal, fragile blood vessels can grow on the surface of the optic disc, distinct from the normal vasculature. This can occur due to diabetes, retinal vein occlusions, and other conditions. More mature appearing collateral vessels on the optic nerve can sometimes be confused for the fine neovascular vessels.

Pigmented optic disc

1. [Optic Disc Melanocytoma](#): They appear as black lesions of varying sizes and shapes on the optic disc, typically situated eccentrically.
2. Optic Disc Melanoma: Uveal melanoma can invade the optic nerve, presenting as a pigmented lesion overlying or abutting the optic disc.

Optic Disc Shape Abnormalities

Optic disc edema

Optic disc edema is the swelling of the optic nerve head, typically characterized by blurred optic disc margins and hyperemic optic disc. [Papilledema](#) refers specifically to optic disc edema caused by increased intracranial pressure. It is crucial to distinguish papilledema from [pseudopapilledema](#), where the optic nerve head appears elevated without swelling of the nerve fiber layer. Frisén scale ^[4] is a widely recognized grading system to grade papilledema.

Peripapillary Atrophy (PPA)

Peripapillary atrophy involves the disruption of the retinal pigment epithelium (RPE) and chorioretinal thinning. Complete loss of RPE results in the absence of normal fundus hue and reveals large choroidal vessels underneath. In cases of incomplete RPE loss, there may be hyper- or hypopigmentation at the edges of RPE irregularities. PPA displays two distinct zones: the alpha zone, marked by irregular hyperpigmentation and hypopigmentation at the periphery of the parapapillary atrophy, and the beta zone, characterized by visible sclera and large choroidal vessels, located between the peripapillary scleral ring and the alpha zone [\[5\]](#). PPA is non-specific findings and can occur in both benign and pathologic conditions such as high myopia and glaucomatous changes [\[6\]](#).

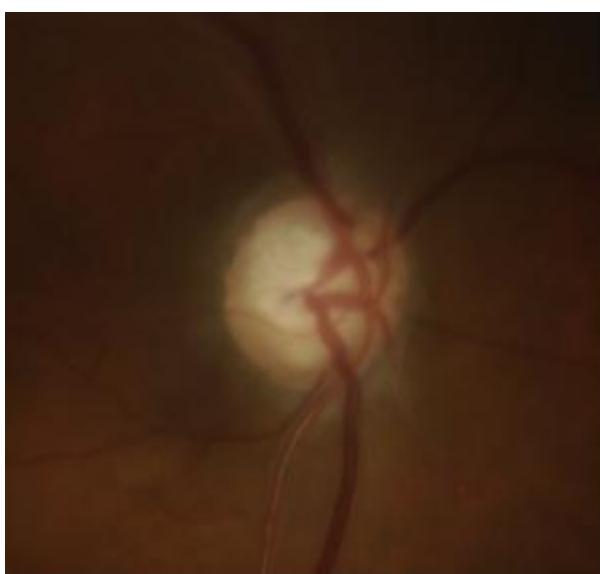
Physiologic Grey Crescent

It appears as a slate-gray crescent within the peripheral portion of the neuroretinal rim. These crescents are typically bilateral and found along the temporal or inferotemporal disc margin [\[7\]](#). This pigmented crescent can hinder accurate assessment of the neuroretinal rim and lead to falsely high cup-to-disc ratio measurements [\[8\]](#). It is commonly seen in patients of African descent with glaucoma [\[9\]](#).

Myopic Crescent

With progressive myopia, the disc becomes tilted, inserting into the eye at an angle. This tilted insertion along with the absence of choroid in this area and RPE thinning, the peripapillary scleral expansion appears as a whitish hypopigmented, sharply demarcated crescent on the temporal side of the optic disc. This feature is usually bilateral and is generally associated with PPA and high myopia.

Optic disc notching



Right optic disc notching

Optic disc notching occurs when there is a localized loss of the Retinal Nerve Fiber Layer (RNFL), resulting in a focal notching or thinning of the optic disc contour. These changes are associated with glaucomatous alterations of the optic disc.

Myelinated Retinal Nerve Fiber Layer (MRNFL)

MRNFL are retinal nerve fibers located anterior to the lamina cribrosa that possess a myelin sheath, unlike typical retinal nerve fibers. They appear as white-grey, sharply demarcated patches with frayed or feathered borders, obscuring the underlying retinal vessels [\[10\]](#).

Optic Nerve Pit

An optic nerve head pit is a rare congenital anomaly and appears as a grey-white round or oval depression on the inferotemporal optic nerve, often with adjacent peripapillary atrophy or retinal pigment changes.

Optic disc drusen

Optic disc drusen are calcified, round, white-yellow deposits found on the nerve's surface or buried beneath it. The optic disc often appears elevated, with lumpy-bumpy irregular margins [\[9\]](#).

Vasculation

The central retinal artery and vein emerge from the optic disc, dividing into four branches superotemporal, inferotemporal, superonasal, and inferonasal branches. In approximately one-third of the population, a cilioretinal artery, derived from the ciliary circulation, supplies the area around the macula, between the superotemporal and inferotemporal regions of the inner retina. As they extend beyond one disc diameter, they are called arterioles and venules. Arteries appear narrower and lighter in color compared to veins.

Exudate

Exudate is fluid that leaks from blood vessels into surrounding tissues due to altered endothelial permeability. Exudates can be classified as hard exudates or soft exudates. Hard exudates appear as bright yellow, sharply demarcated lesions typically within or immediately beneath the retina and can be seen in any conditions with chronic vascular leakage. Soft exudates are yellow-white or grayish-white fluffy lesions with indistinct borders that result from retinal nerve fiber layer (RNFL) infarcts. Exudations may look like drusen to an inexperienced eye.

Exudative lesions in the eye can be categorized based on their vascular source: retinal exudations originating from the superficial retinal vasculature or deeper retinal and choroidal vasculature or both.

Exudates originating from retinal capillary plexus:

- [Hypertensive retinopathy](#)
- [Neuroretinitis](#)

- Retinovascular occlusion (BRVO, CRVO)
- Coat's disease

Exudates originating from choroid:

- Choroidal neovascularization (CNV) such as CNV seen in age-related macular degeneration (AMD)
- Peripheral Exudative Hemorrhagic Chorioretinopathy
- Myopic CNV
- Traumatic CNV related to choroidal rupture



A case of malignant hypertensive retinopathy - Note the lipid exudates (left arrow), flame-shaped hemorrhages, and the arteriolar sclerotic vascular changes (right arrows)

Patterns of exudate in certain retinal conditions can provide clues to the underlying pathology and aid in differential diagnosis. For example, macular star pattern, defined as a stellate pattern of hard exudates in the macula are commonly associated with hypertensive retinopathy, and neuroretinitis. Additionally, presence of exudate with drusen and sometimes hemorrhage is highly suggestive of neovascular AMD. Moreover, exudate deposition in a circinate pattern around a large vascular out pouch is suggestive of retinal macroaneurysm and lastly, in macular telangiectasia, exudates are commonly found on the macula's temporal side.

Vascular related abnormalities

Arterio-venous nicking

It is characterized as indentation or focal attenuation (nicking) of retinal veins by adjacent stiff (arteriosclerotic) retinal arteries. The most common cause is chronic hypertension.



A case of hypertensive retinopathy - Note the areas of copper-wiring and silver wiring (lower arrows) and nicking of the vein at the second arteriovenous crossing (upper arrows).

Microaneurysm

Microaneurysms are small local widening of retinal capillary walls which manifest as small round dots in a fundus image. They are often seen in diabetic retinopathy but can be seen in any pathologies affecting retinal microvasculature.

Intraluminal plaques

Intraluminal plaques can appear as a result of cholesterol (Hollenhorst plaque), talc, or calcium deposition at the vessels bifurcation.

Discontinuity in vessels

Vascular discontinuity in a fundus photo can occur in two main ways:

- Vessel interaction with abnormal structures: This occurs when vessels enter or exit a retinal mass or abnormal structure. Examples include vessels penetrating subretinal or intraretinal tumors such as retinoblastoma or capillary hemangioma.
- Non-perfusion conditions: In these cases, normal vessel flow is disrupted. This can be observed in conditions like branch retinal artery occlusion (BRAO) and cavernous hemangioma.

Hemorrhage

Hemorrhages can occur in different layers of the retina. A two-dimensional fundus photo often provides clues that help determine the depth of retinal lesions. Retinal hemorrhages serve as an excellent practical example for identifying lesion depth, and these principles can be helpful to determine the depth of other retinal lesions as well.



Subretinal and preretinal hemorrhage

- **Vitreous hemorrhage (VH):** VH occurs when blood leaks into and around the vitreous humor. Since vitreous lies anterior to the retina, VH blocks the underlying retinal structures. Due to the lack of boundaries, the hemorrhage can spread throughout the vitreous humor or conform to its anatomy. Over time, chronic VH may settle inferiorly due to gravity. Initially, fresh VH appears bright red. As the hemorrhage ages, it changes to yellow, or white due to the dehemoglobinization of red blood cells.
- **Pre-retinal hemorrhage:** It can be categorized into two types: sub-hyaloid and sub-internal limiting membrane (ILM) hemorrhage. Sub-hyaloid hemorrhage occurs between the vitreous base and the ILM, while sub-ILM hemorrhage is located between the ILM and the retinal nerve fiber layer (RNFL). These hemorrhages often have distinctive shapes like round or scaphoid (boat-shaped), with clear boundaries. Both types can obscure underlying retinal features, posing a challenge for clinical differentiation. One distinguishing feature is their mobility: sub-hyaloid hemorrhages tend to move inferiorly with changes in head position, whereas sub-ILM hemorrhages remain stationary [11].
- **Intra-retinal Hemorrhage:** These hemorrhages occur within the retinal layers, and the depth and specific layer of the hemorrhage can be distinguished by their unique structural appearance.
- **Retinal Nerve Fiber Layer Hemorrhage:** Several types of hemorrhage can be seen at the level of RNFL.
 - **Flame shaped:** These hemorrhages, uncommon in peripheral retina, occur due to bleeding within the superficial retina and capillary plexus and peripapillary capillary beds and they do not obscure the superficial retinal vasculature [12]. They have a thin or elongated shape (flame-shaped) due to the parallel arrangement of ganglion cell axons and the distribution of RNFL bundles in the retina. Their borders are indistinct and can appear feathered, splintered, or brush-stroke-like.



Note the white centered hemorrhages (Roth spots)

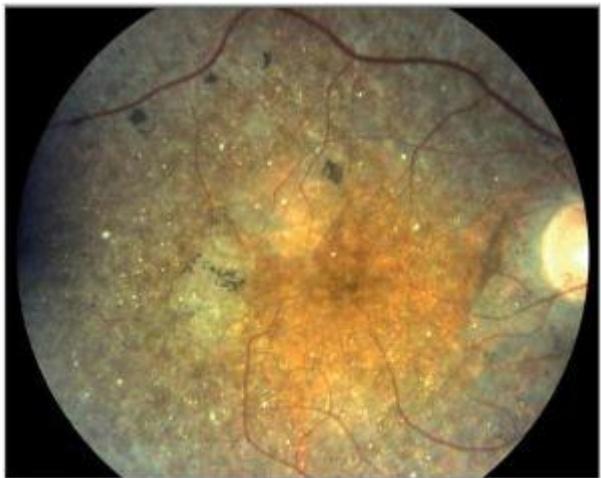
Dot or blot (Intraretinal) Hemorrhage: Dot or blot hemorrhages are located within the inner nuclear or outer plexiform layers of the retina. They occur due to bleeding from the pre-venular deep capillary layer, resulting in their dark red coloration compared to the hemorrhages mentioned above. These hemorrhages have well-defined borders, and the compressive forces exerted by surrounding layers result in their characteristic dot or blot shapes.

- **Roth spot:** A Roth spot is a round or flame shaped hemorrhage with a white-pale center. Roth spots are the result of retinal capillary rupture and subsequent platelet-fibrin plug formation [\[13\]](#).
- **Disc (Drance) hemorrhage:** These splinter-shaped hemorrhages typically taper towards the disc and have a feathery appearance away from it, oriented perpendicular to the optic disc [\[14\]](#). They are commonly found within one disc diameter, often seen in the inferotemporal and superotemporal regions, and are associated with an optic disc notch [\[15\]\[16\]](#).
- **Sub-retinal Hemorrhage:** Sub-retinal hemorrhages occur above the RPE but below the photoreceptor layer of the retina, originating from either choroidal or retinal circulation. These hemorrhages appear deep red in color, with an amorphous shape and indistinct margins. Overlying retinal vessels are still seen traversing over subretinal hemorrhages.
- **SubRPE Hemorrhage:** Located between the RPE and Bruch's membrane, these hemorrhages appear dark red with defined and confined borders (in contrast to subretinal hemorrhages). [See more in choroid hemorrhage below]

Neurosensory Retina, Macula, and Fovea

The macula is an avascular and dusky area measuring approximately 5.5 mm in diameter located two-disc diameters temporal and inferior to the optic disc. Macula generally looks darker to the surrounding retina due to taller RPE cells with higher density of pigments. Also, the choroid layer underneath macula is thicker at the center, getting thinner going to periphery. The fovea, which lies in the center of the macula, measures 1.5 mm in diameter and has the greatest density of cone photoreceptors. A small area of oxygenated carotenoids, particularly lutein and zeaxanthin, accumulate within the central fovea and contribute to its yellow color.

Crystalline Retinopathy



An example of crystalline retinopathy in a case with Bietti Crystalline Dystrophy

Crystalline deposits manifest as multiple small yellow accumulations that can occur due to a variety of etiologies and can be found in any layer of the retina. Depending on the cause, these deposits may form characteristic patterns that provide clues to the underlying pathology. Common causes include talc retinopathy, Bietti disease, Cystinosis, Tamoxifen retinopathy.

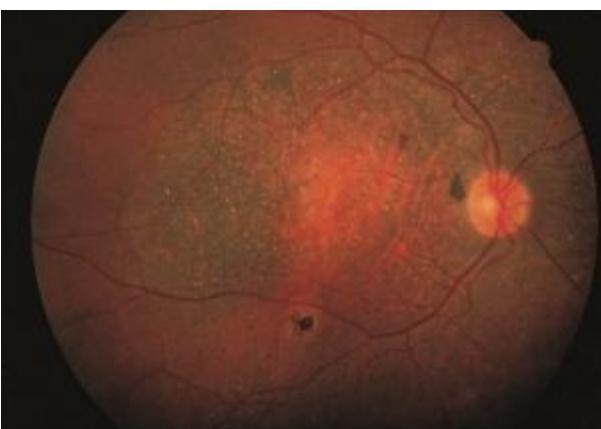
Epiretinal membrane (ERM)

ERM, also known as macular pucker, appears as clear, white, or yellow fibrovascular membrane overlying the macular area causing a loss of normal convex foveal contour and wrinkling on the retinal surface from the membrane contracture.

Retinal Pigment Epithelium (RPE)

In a fundus photograph, the RPE layer is visible at the back of the retina, situated between the retina and the choroid. Changes in the RPE can be age-related or result from pathological processes. Key structural changes include the loss of melanin granules, increased density of residual bodies, accumulation of lipofuscin, buildup of basal deposits on or within Bruch's membrane, drusen formation, thickening of Bruch's membrane, and microvilli atrophy [\[17\]](#).

RPE Atrophy



Note the atrophic-like changes of RPE and patchy atrophic change of choriocapillaris vessels and crystalline-like lesions in a patient with Bietti crystalline dystrophy.

RPE atrophy, which can progress to complete RPE loss, appears as sharply demarcated edges in an oval, circular, or patchy pattern. This manifests as a loss of the normal fundus hue and increased visibility of the underlying large choroidal vessels and choroidal pigmentation. Typically, at the edge of RPE loss, areas of hyperpigmentation indicate hyperproliferation of the RPE. RPE atrophy can be observed in various conditions. In age-related macular degeneration (AMD), RPE atrophy is central to the macula, whereas in conditions like gyrate atrophy or cobblestone degeneration, it is more peripheral.

Pattern dystrophy

Pattern dystrophies are a group of disorders characterized by abnormal development and deposition of RPE pigment in the macula. Correctly identifying the patterns of each dystrophy in a fundus photo aids in accurate diagnosis. Examples include butterfly dystrophy, and adult-onset vitelliform macular dystrophy.

RPE Hyperpigmentation

RPE cells contain two different pigments, lipofuscin and melanin. RPE hyperpigmentation manifests as dark green, or black lesions compared to normal RPE cells. A classic example of RPE hypertrophy with hyperpigmentation can be seen in [congenital hypertrophy of the retinal pigment epithelium \(CHRPE\)](#). Another classic RPE hyperplasia associated with hyperpigmentation is Forster-Fuchs spot which is a raised, pigmented, circular scar commonly seen in pathologic myopia.

RPE Hypopigmentation

Generalized RPE hypopigmentation can be seen in individuals with lighter skin tones, which sometimes is referred to as blonde fundus. Albinoid fundus is another example and is observed in oculocutaneous albinism. Tessellated or tigroid fundus is another example of RPE depigmentation in which low pigment level in the RPE with deep pigment in choroid make the choroid vasculature more visible, and is associated with pathologic myopia.

RPE Depigmentation

RPE depigmentation can classically be seen in the chronic stage of [Vogt-Koyanagi-Harada disease](#), leading to a pale optic nerve surrounded with peripapillary choroidal depigmentation known as a “sunset-glow fundus”.

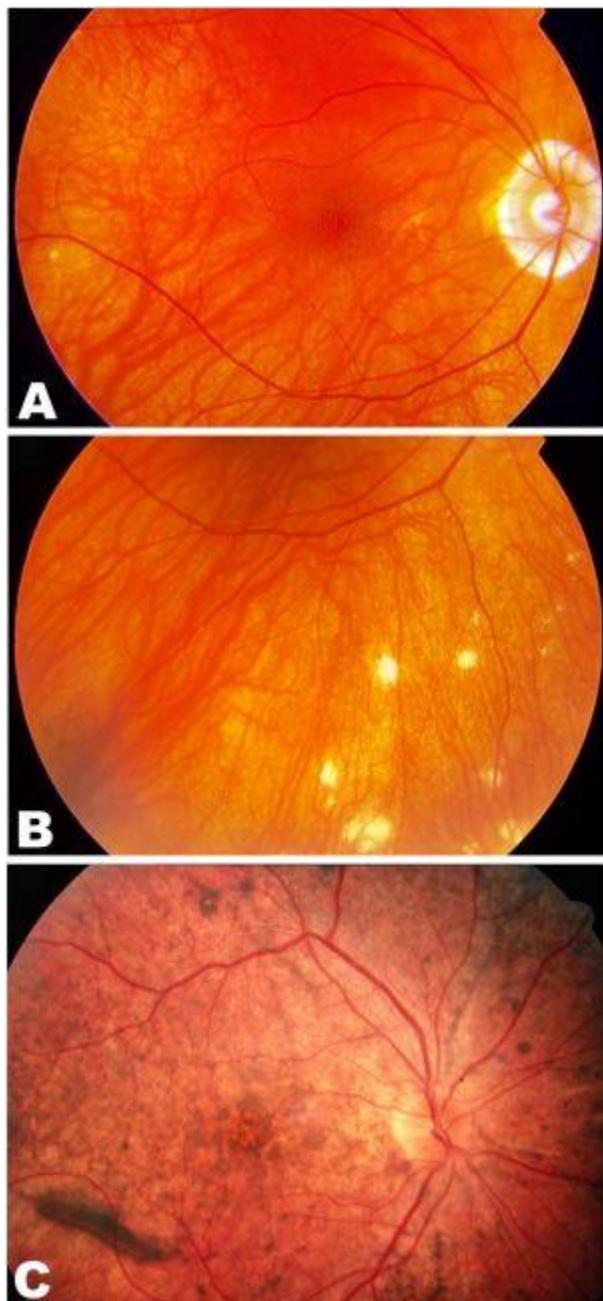
Drusen

Drusen are round yellow lesions located between the RPE and Bruch's membrane and mostly found in the post equatorial retina. Drusen are categorized as hard (discrete with clear border), soft (amorphous and poorly demarcated), and confluent (contiguous drusen without clear boundaries).

Uvea

The color of the background retina is influenced by retinal pigmentation and the visibility of the choroidal vessels beneath it. The degree of retinal pigmentation correlates with the individual's skin and hair pigmentation. Choroidal vessels are visible beneath the RPE in a normal eye, giving the fundus photo a dark hue more easily visible in most eyes in the periphery

Choroidal related abnormalities



Nummular chorioretinal scars (B)

Chorioretinal scar

It appears as white fibrotic tissue located anywhere on the retina, depending on the underlying cause.

[Choroidal folds](#)

Choroidal folds can sometimes be seen as parallel transparent elevated lines in a fundus photo. These may indicate hypotony, posterior scleral and choroidal compression from extraocular masses, or from other causes.

Choroidal inflammation

In general, choroidal inflammation presents as yellow-white choroiditis spots with blurred margins due to surrounding edema. In Multiple Evanescent White Dot Syndrome (MEWDS) choroidal inflammation appear as multiple flat, small, white dots outside the fovea. A highly suggestive finding in MEWDS is transient foveal granularity. In birdshot chorioretinopathy, as the name implies, multiple yellow-white choroiditis spots are often initially observed inferior to the optic nerve head, displaying the characteristic "birdshot" appearance and distribution [18].

Choroidal hemangioma

Choroidal hemangiomas can present in either diffuse or circumscribed forms. A circumscribed hemangioma appears as a dome-shaped hamartoma within the choroidal vessels and can be challenging to differentiate from the surrounding normal retina. However, if the overlying RPE has degenerated or atrophied, the bright red color beneath it becomes more apparent. In diffuse hemangiomas, a homogeneous red hue beneath the retina is observed. For unilateral diffuse hemangiomas, comparing with the other eye can be helpful in diagnosis.

Choroidal nevus and melanoma



Choroidal melanoma

A choroidal nevus manifests as a flat or minimally elevated melanocytic lesion, typically dark gray or black. It is usually round with well-defined borders but can also appear irregular or feathery, and sometimes associated with overlying drusen. It may or may not have overlying RPE atrophy. Uveal nevus can transform to uveal melanoma, which classically presents as a unilateral, elevated, dome-shaped melanocytic lesion with irregular borders. Less commonly, melanoma can be amelanotic.

Suprachoroidal calcification

Multiple discrete white-yellow placoid lesions without a clear border, usually seen in superotemporal arcade.

Choroidal osteoma

Single yellow-white distinct lesions with overlying pigment clumps, usually seen juxtapapillary or peripapillary.

Choroidal metastases

Yellow-white and less commonly orange lesions appearing singular or multiple, unilateral or bilateral yellow lesions with plateau configuration.

Retinoblastoma

In general, retinoblastoma presents as a solitary or multifocal, well-circumscribed intraretinal mass with a white or cream-colored appearance. As the disease progresses, increased vascularization within the tumor can cause it to appear pink.

Vitreous

Normal vitreous should appear as clear, transparent media. If there's a vitreous opacity, from causes like [vitreous hemorrhage](#), [asteroid hyalosis](#), or [primary vitreoretinal lymphoma](#) the vitreous can obscure the underlying structures.

Abnormal structures in the retina categorized by their color

White lesions

- Scar or fibrosis
- Necrosis
- Inflammation
- Soft exudates or Cotton wool spots
- Chorioretinal atrophy
- Myelinated nerve fiber layer
- Calcification (calcium deposits or due to tumors with calcifications)
- Intraluminal calcium or talc plaques

Yellow Lesions

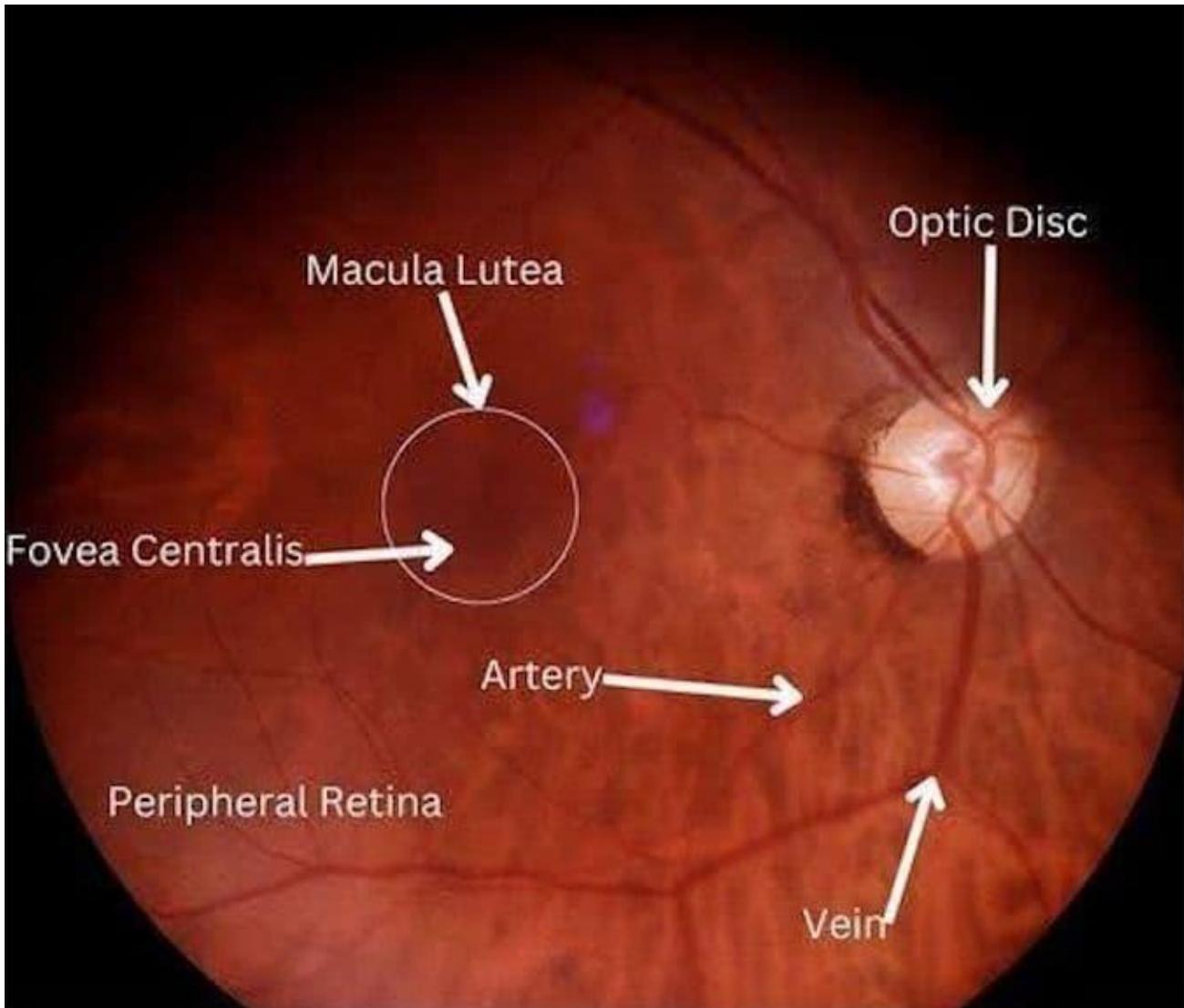
- Necrosis
- Inflammation
- Hard Exudates
- Drusen
- Crystalline deposits
- Intraluminal Cholesterol plaque
- Early necrosis following pan retinal photocoagulation therapy (PRP)

Pigmented Lesions

- RPE hyperpigmentation
- Late-stage scar of PRP
- Hemorrhage
- Choroidal nevus
- Choroidal Melanoma
- Bone spicules in retinitis pigmentosa
- Table 1: Key landmarks found in a normal fundus exam of a healthy retina.

Structure	Typical Findings	Common Pathologies
Optic Disc	Round or slightly oval, neuroretinal rim respecting the ISNT rule, symmetric cup-to-disc ratio in both eyes	Glaucoma: Optic disc cupping, asymmetry in cup-to-disc ratio, breaking ISNT rule
Macula (Macula lutea + fovea centralis)	Small, dark, circular area in the central retina, free of lesions, hemorrhages, or abnormalities; central depression reflects light, flat and free of pigment, blood, or lesions, foveal reflex present in younger patients	Macular degeneration: Drusen, geographic atrophy, macular edema; Macular edema: Thickening, cystoid spaces
Retinal vasculature	Arteries lighter than veins, A/V ratio 2:3, vessels uniformly small with no arteriolar narrowing or vascular nicking	Diabetic retinopathy: Microaneurysms, hemorrhages, cotton wool spots, neovascularization; Hypertensive retinopathy: Widening of arteriolar light reflex, copper-wiring of arterioles, hemorrhaging, cotton wool spots, hard exudates, retinal edema
Retinal background / posterior pole	Smooth, even coloration; absence of hemorrhages, exudates, or pigmentary changes in the macular region and periphery	Diabetic retinopathy: Hard exudates, hemorrhages; Hypertensive retinopathy: Flame-shaped hemorrhages, cotton wool spots, arterial narrowing
Retinal periphery	Tapered vessels with less density, vitreous base meets ora serrata, visible dentate processes at retinal periphery	Retinal detachment: Retinal tears, peripheral ischemia, subretinal fluid

- Figure 1: Labeled fundus photograph of key landmarks outlined in Table 1.



Diabetic retinopathy (DR)

Diabetic retinopathy is the **most common cause of vision loss in working-age adults in the US**, and is characterized by vascular damage leading to ischemia, swelling, and eventually vasoproliferation in the retina.⁵ Early stages often do not exhibit symptoms, while pathologic changes are visible on fundus photography.^{6,7}

As DR progresses from non-proliferative to proliferative, and as **diabetic macular edema (DME)** may ensue, fundus photography can be instrumental in noticing subtle changes as well as confirming the stage and making proper referral decisions.

In addition, DR is a particularly poignant example of when to use fundus photos to assist in **patient education**. Visualizing retinal bleeding can often have a meaningful impact on patients who have not yet fully recognized their risk of vision loss with continued medication or diet noncompliance, for example.

Table 2: Breakdown of DR stages with corresponding descriptions of clinical characteristics on fundus imaging.^{8,9}

DR Stage	Fundus Appearance	Description
Mild non-proliferative diabetic retinopathy (NPDR)	Retinal microaneurysms	Tiny, round, red spots appearing on the retina, often seen in the peripheral retina
	Retinal hemorrhages	Dot or blot-shaped hemorrhages, typically in the outer plexiform and inner nuclear layers, visible as small red dots
	Exudates	Yellowish, well-defined deposits in the retina, often around the macula, indicating lipid and protein accumulation
Moderate NPDR	Cotton wool spots	White, fluffy patches in the retina, usually near the optic disc or in the posterior pole, signifying nerve fiber layer infarctions
	Venous beading	Bead-like dilations and tortuosity of retinal veins, seen as irregular, dilated veins in the mid-peripheral retina
Severe NPDR	Intraretinal microvascular abnormalities (IRMAs)	Abnormal, dilated, tortuous vessels in the retina, often visible as abnormal, branching blood vessels in the mid-peripheral retina, indicating ischemia
Proliferative diabetic retinopathy (PDR)	Vitreous hemorrhage	Presence of blood in the vitreous cavity, visible as hazy or clouded areas obscuring the retinal view
	Retinal neovascularization	New, abnormal blood vessels, often seen at the optic disc or on the retinal surface, appear as fine, fragile, irregular vessels that may be in the process of growing or bleeding
Diabetic macular edema (DME)	DME	Swelling of the macula, often accompanied by lipid exudates, is visible as thickening in the macular region, which may cause loss of the normal foveal reflex

Fundus photography pearls for DR:

- Using an image swap or overlay feature in photography software can assist in identifying subtle changes. Early detection is crucial for preventing progression to severe stages.
- Using a **red-free filter** on most fundus cameras (emitting green light at **570nm**) assists in viewing blood vessels and aids in evaluating their caliber, crossing changes, or the presence of pathology.¹⁰
- Patients with mobility issues, for whom sitting through dilated fundus exams can be challenging, may benefit from **photography-guided dilated fundus exams**.
 - This type of exam relies on both a fundus photo in addition to a dilated fundus exam to closely evaluate retinal health and screen for diabetic changes.

- Widefield photography offers increased visibility for evaluating retinal changes pertaining to diabetic retinopathy outside of the posterior pole, which may not be as easily visualized during a dilated fundus exam alone
- Widefield swept-source OCT angiography provides a non-invasive, high-resolution alternative to [fluorescein angiography](#) and ultra-widefield fundus photography for detecting diabetic retinopathy lesions, bleeding, and edema.¹¹
- Photography allows for time-consuming comparison and analysis that fundus examination often does not.
 - Simple zoom features, as well as enhancement filters or tools, can be used to inspect high-risk areas for early neovascularization. For example, cotton-wool spots will often predict the future location of IRMA and retinal neovascularization.
- Photography can be used in addition to OCT in the close monitoring of mild center-involving (CI)-DME when acuity is 20/30 or better, as seen in Figure 2 below.

Figure 2: Fundus photograph of moderate NPDR with center-involving macular edema.



A leading cause of central vision loss in the elderly, AMD occurs as either [dry \(nonexudative\)](#) or [wet \(exudative or neovascular\)](#). Dry AMD is most common, occurring in **90%** of affected individuals, while **10%** progress to wet AMD.^{8,9}

Table 3: Breakdown of AMD stages with corresponding descriptions of clinical characteristics on fundus imaging.^{8,9}

AMD Stage	Fundus Appearance	Description
Dry AMD (nonexudative)	Drusen	Small, yellowish deposits under the retina, often clustered near the macula; drusen are a hallmark of early dry AMD
	Geographic atrophy	Well-defined areas of retinal thinning and atrophy, particularly in the macular region, leading to visible tissue loss
Wet AMD (exudative / neovascular)	Pigment epithelial detachments (PEDs)	Elevated areas of the retina, often with a “tear-drop” shape, caused by fluid accumulation beneath the RPE
	Subretinal hemorrhages	Red or dark patches on the retina, often around the macula, indicating bleeding from abnormal blood vessels
	Choroidal neovascular membrane (CNVM)	Irregular, abnormal blood vessels beneath the retina, often seen in the macula with red / green / brown hue, which may leak fluid or blood, causing retinal distortion

Fundus photography pearls for AMD:

- Use the **green-free filter** to enhance the visibility of drusen. This filter increases contrast between the yellowish drusen deposits and the surrounding retina, making them stand out, especially in the early stages of dry AMD.¹⁰
- Fundus photography is essential for detecting early signs of AMD, such as drusen and pigment epithelial detachments. Early identification allows for monitoring progression, especially in dry AMD, before it progresses to the wet form.
- Regular fundus photography is key for [monitoring geographic atrophy](#), a late-stage manifestation of dry AMD. It helps clinicians observe the extent of retinal tissue loss and plan for intervention if needed.
 - The leading edge of progressing geographic atrophy often shows hyperfluorescence on FAF. This hyperfluorescence indicates metabolic activity at the outer retina, and its appearance is useful for assessing disease progression.²
 - This can help identify areas of active degeneration and predict the potential expansion of atrophic regions.
- Widefield imaging provides a broader view of the retina, which is useful for detecting AMD-related changes, particularly in areas that might not be visible with a standard fundus exam. This is especially helpful for detecting peripheral lesions or early-stage changes.

- Fundus photography can help identify [CNVMs](#), abnormal blood vessels that form under the retina in wet AMD. Detecting CNVM early is crucial for preventing further vision loss and guiding treatment options.
- Fundus photography is an effective tool for educating patients about the progression of AMD. Visualizing changes such as drusen, geographic atrophy, or hemorrhages can help patients understand the severity of the condition and the importance of adhering to treatment and follow-up visits.

Figures 3 and 4: Fundus images of intermediate AMD with large drusen and advanced dry AMD (i.e., geographic atrophy), respectively.

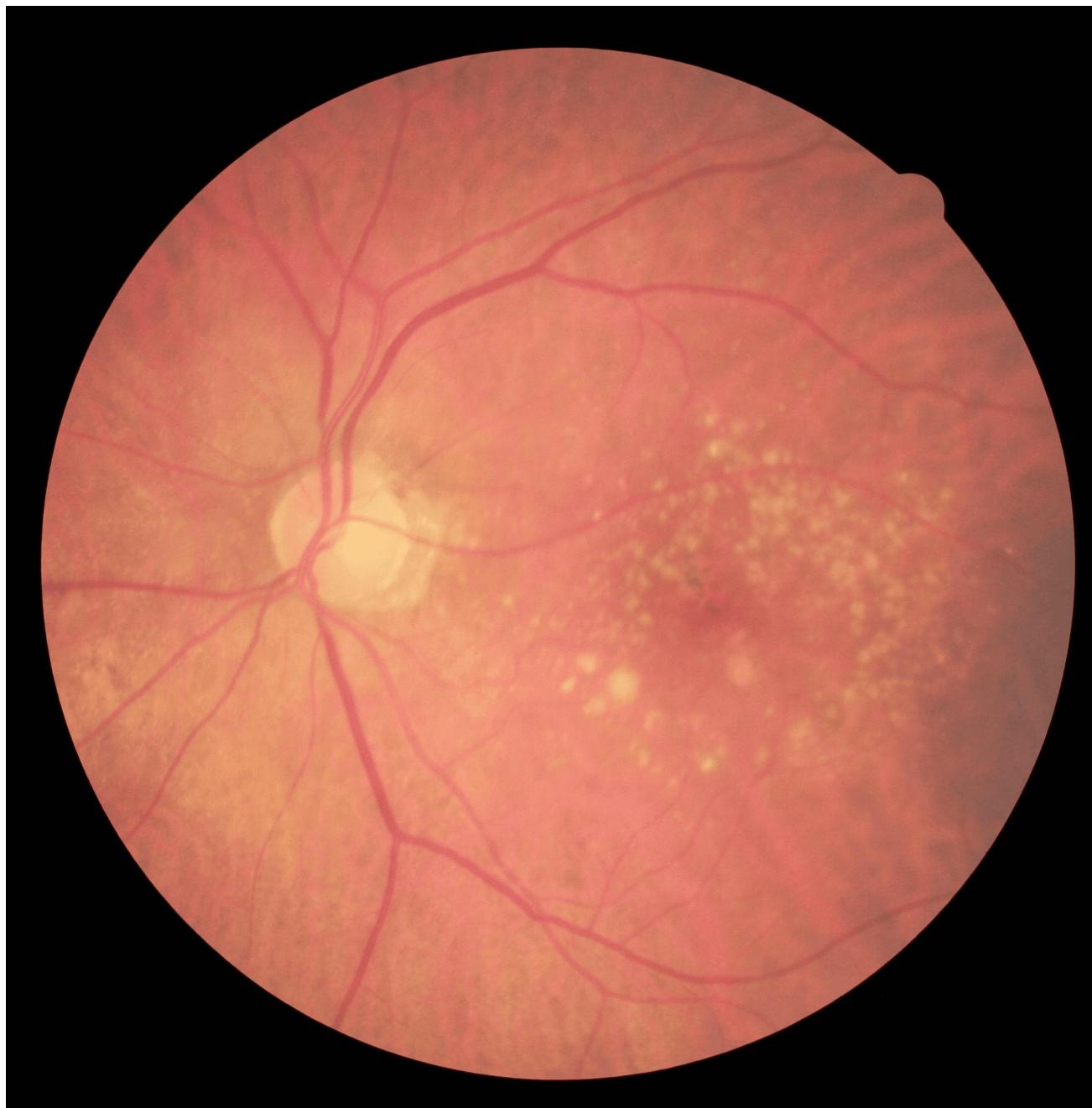
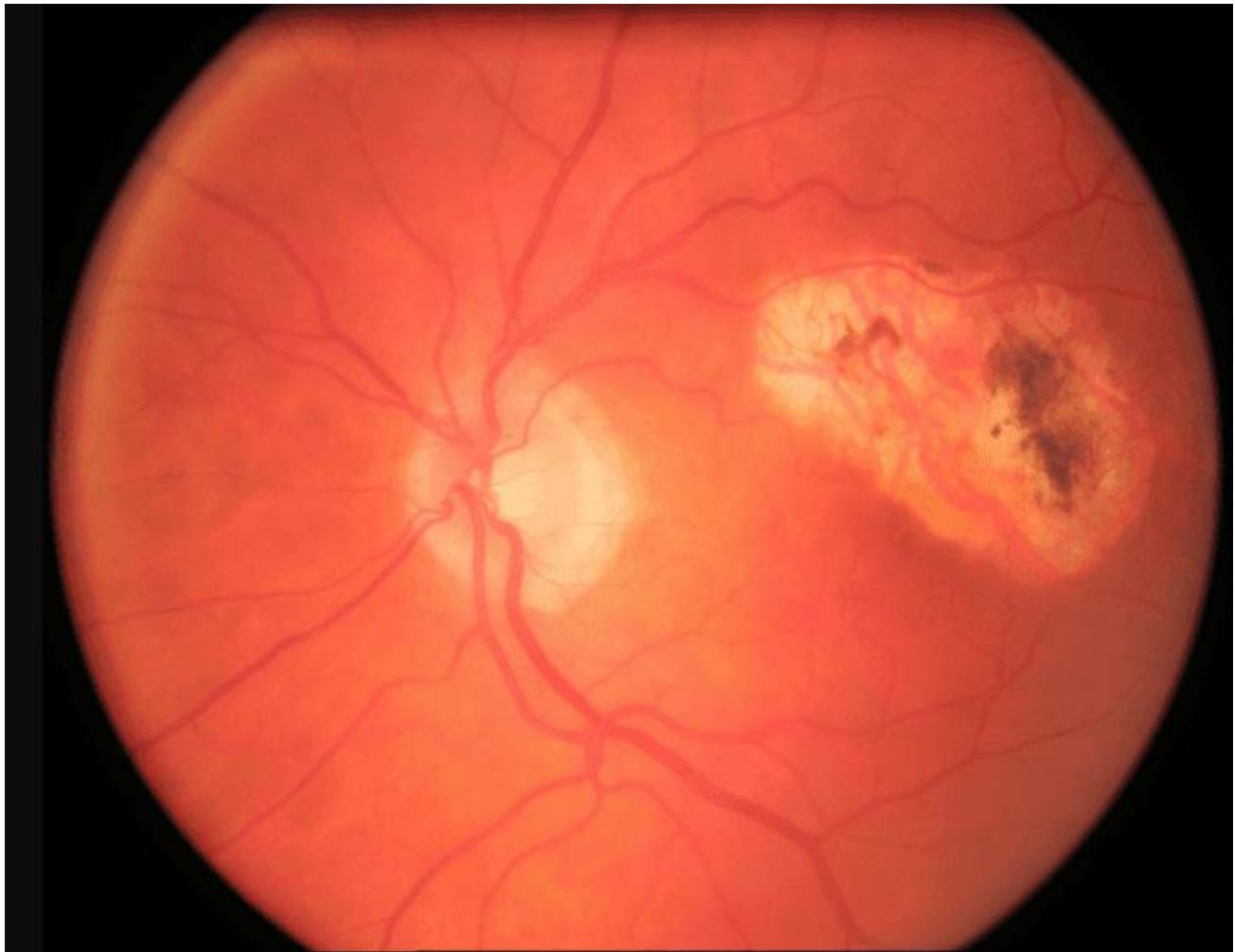


Figure 3: Courtesy of Julie Rodman, OD, MSc, FAAO.



Retinitis pigmentosa

Retinitis pigmentosa (RP) is a hereditary condition that leads to progressive retinal degeneration, initially affecting night vision and peripheral vision, followed by central vision loss.^{8,9} Patients often present with **night blindness** and **reduced peripheral vision**.

Table 4: List of clinical characteristics of retinitis pigmentosa that can be identified on fundus imaging.^{8,9}

Clinical Findings	Description
Bone spicule-like pigment	Scattered pigment deposits in the peripheral retina
Attenuated retinal vessels	Narrowing of the retinal vessels
Optic nerve pallor	Seen in advanced stages of retinitis pigmentosa

Fundus photography pearls for RP:

- FAF can assist with early diagnosis, which is key for genetic counseling. Active areas of progression will demonstrate hyperfluorescence due to lipofuscin deposits, while atrophy will be hypofluorescent

Figure 5: Fundus images of bone spicules in the periphery, attenuated blood vessels, and waxy pallor of the optic disc due to retinitis pigmentosa.

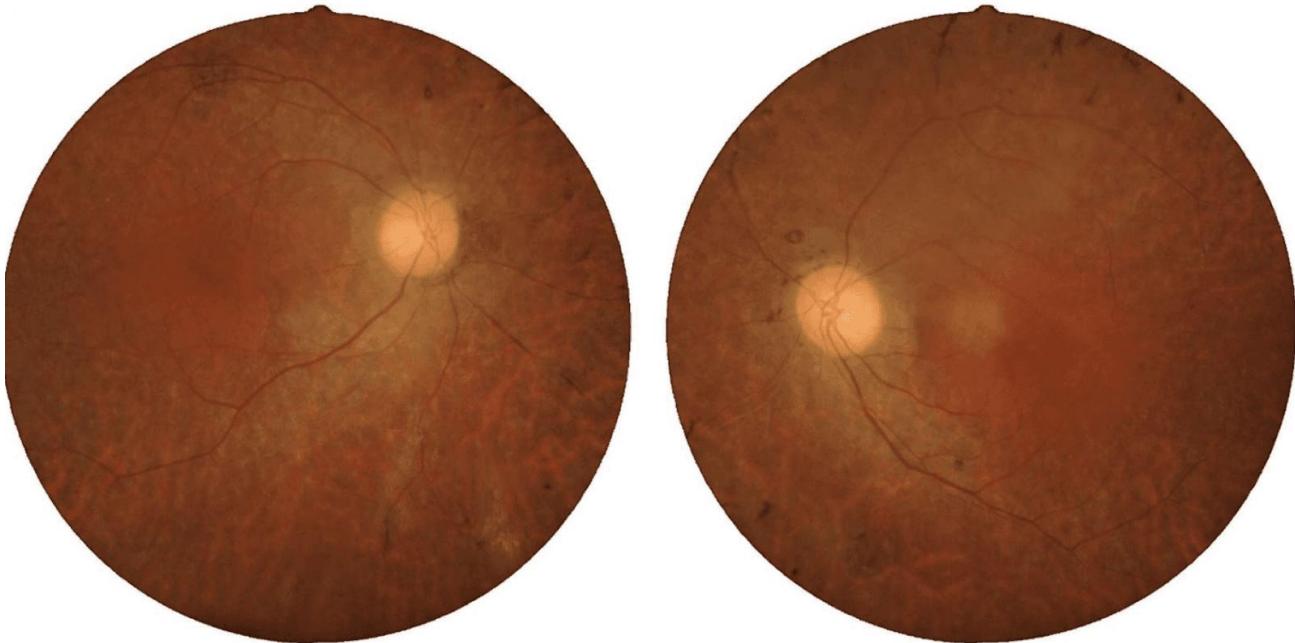


Figure 5: Courtesy of Inrava Khasnabish, OD, FAAO.

Retinopathy of prematurity (ROP)

Advancements in retinal imaging for **pediatric and premature populations** have led to the development of specialized tools such as handheld fundus imaging systems.¹² These technologies enable clinicians to perform effective retinal screenings in infants and young children who may be unable to cooperate with traditional imaging methods.

In particular, early detection of **retinopathy of prematurity (ROP)**, a leading cause of childhood blindness, has been greatly improved with these innovations, allowing for more timely interventions. ROP affects premature infants, characterized by abnormal retinal blood vessel growth. If untreated, it can lead to retinal detachment and blindness.^{8,9}

Table 5: Breakdown of ROP stages with corresponding descriptions of clinical characteristics on fundus imaging.^{8,9}

ROP Stage	Fundus Appearance	Description
Stage 1	Line of demarcation	A white line that separates the vascularized retina from the avascular retina, indicating the boundary of retinal development
Stage 2	Ridge formation	A raised, white ridge at the junction of vascular and avascular retina, signifying more advanced retinal neovascular activity
	Extraretinal neovascularization	Fine, frond-like vessels growing outward from the retina, marking the onset of neovascular changes
Stage 3	Exuberant neovascularization	Prominent, fragile blood vessels extend into the vitreous, leading to

ROP Stage	Fundus Appearance	Description
		increased risk of hemorrhage and traction
	Plus disease	Dilated and tortuous blood vessels, typically seen in the posterior retina, indicating worsening vascular pathology
	Retinal edema	Swelling of the retina, often causing blurred margins of the optic disc, indicative of worsening retinal pathology
Stage 4	Retinal folds	Wrinkling of the retina caused by fibrous tissue traction, leading to deformation of the retinal structure
	Vitreous hemorrhage	Presence of blood in the vitreous cavity, often resulting from ruptured neovascular vessels
Stage 5	Complete retinal detachment	Presence of blood in the vitreous cavity, often resulting from ruptured neovascular vessels
	Severe vitreous hemorrhage	Complete obscuration of the retina due to massive blood accumulation in the vitreous, hindering vision

Fundus photography pearls for ROP:

- Retinopathy of prematurity is a leading cause of blindness in premature infants.
- Regular screening in preterm infants is essential for early intervention.
- Capturing fundus photography on the pediatric population can be challenging, external fixation (sometimes with toys) assist tremendously with capturing fundus photos

Figures 6 and 7: Fundus images of stage 1 and stage 3 ROP, respectively.

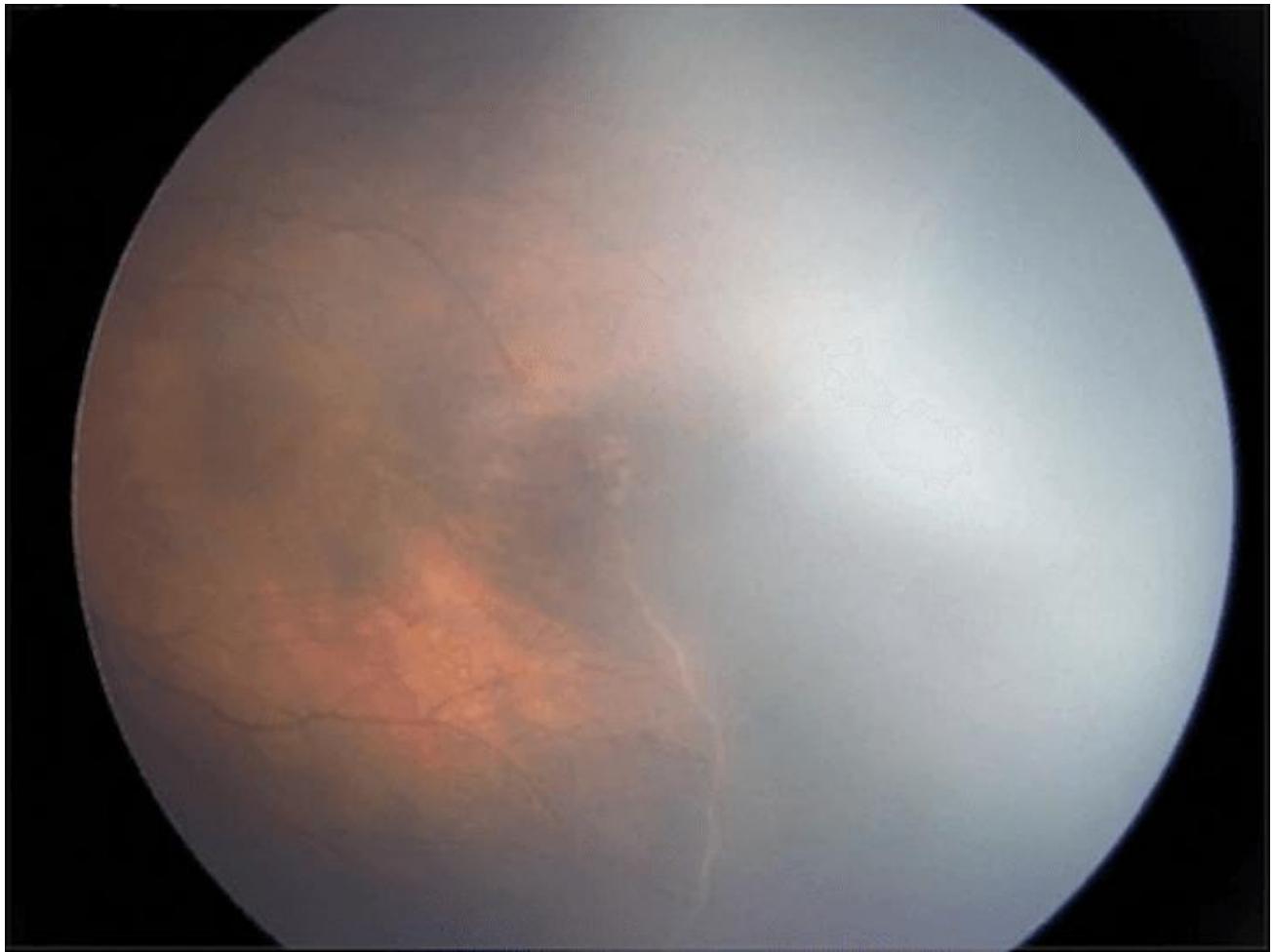


Figure 6: [ROP fundus images](#) © Xinyu Zhao, et al. Image cropped and used under [CC BY 4.0](#).

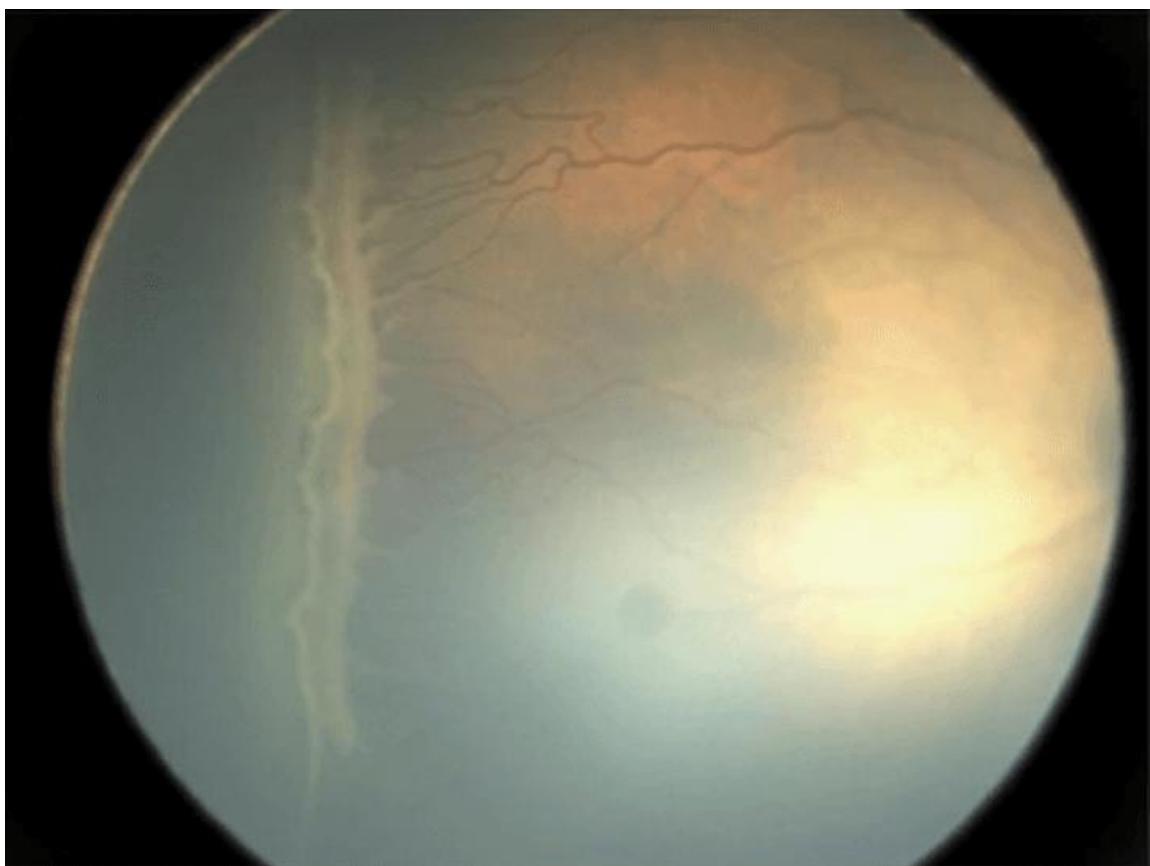


Figure 3:

