

The Quirks of Confocal Imaging

Timothy J Bennett, CRA, OCT-C, FOPS



cSLO Confocal Imaging

- Focused "coherent" laser light source.
- Confocal pinhole/aperture in front of image detector.

con·fo·cal

/kən fōkəl/ ⓘ

adjective

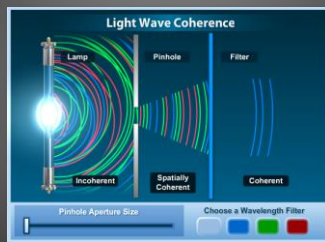
having a common focus or foci.
"confocal ellipses"

- denoting or using a microscope whose imaging system only collects light from a small spot on the specimen, giving greater resolution.



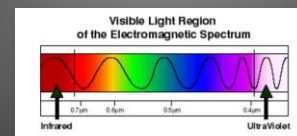
cSLO Confocal Imaging

- Scanning laser ophthalmoscopes are "coherent" light sources.



Wavelengths

- Physical distance between the crests of energy waves in the electromagnetic spectrum.
- Expressed in nanometers (nm).
- Determines color.



Clinical Confocal Imaging Devices

- Spectralis HRA
- Nidek F-10 (ring aperture)
- Eidon (slit aperture)



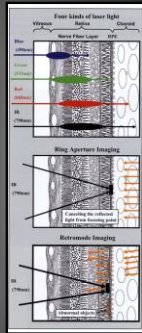
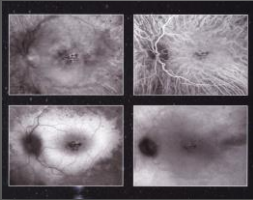
cSLO: Spectralis HRA

- 488 nm FA excitation and blue reflectance (red free)
- 790 nm ICG excitation
- 820 nm IR reflectance
- 565 nm green reflectance for MultiColor



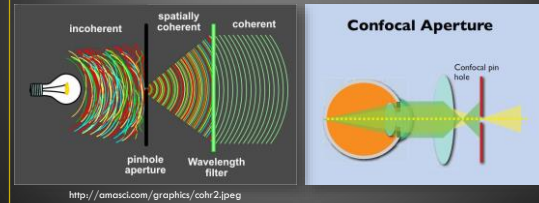
cSLO: Nidek F-10

- 490 nm
- 532 nm
- 660 nm
- 790 nm



cSLO Confocal Imaging

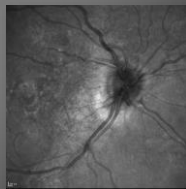
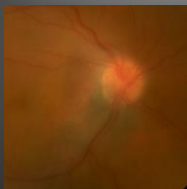
- Focused "coherent" laser light source.
- Confocal pinhole/aperture in front of image detector.
- Confocal means "having the same focus".



<http://amasci.com/graphics/cohr2.jpg>

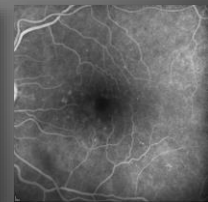
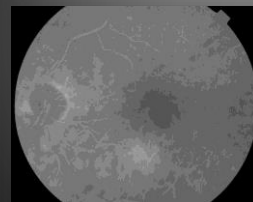
cSLO Confocal Imaging

- A confocal aperture positioned conjugate to the focal plane of the retina blocks non image-forming (out-of-focus) light from reaching the sensor to minimize scatter and improve contrast.



cSLO Confocal Imaging

- Confocal imaging reduces the effects of short wavelength scatter in the ocular media and confounding AF from the crystalline lens.



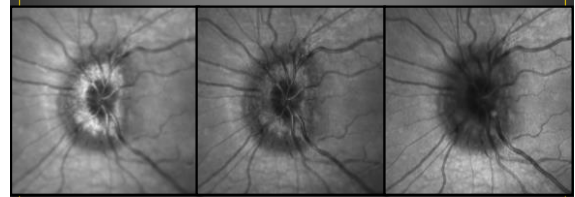
Focus and Brightness

- With a traditional fundus camera, focus and brightness are independent of one another.
- Adjusting one does not significantly affect the other.



cSLO Confocal Imaging

- cSLO is most light efficient (brightest) at the plane of focus.
- Secondary effect of the confocal pinhole is a tonal shift when focus is adjusted.

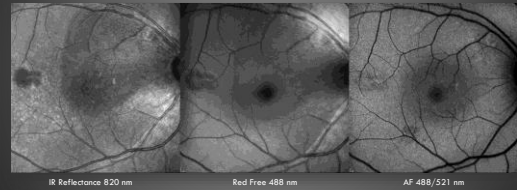


Confocal Tonal Shift



Confocal Tonal Shift

- Tonal shift is most prominent in IR reflectance.



Confocal Tonal Shift

- Tonal shift is most prominent in IR reflectance, but can also be seen in blue reflectance.



Is the Tonal Shift Artifact or Enhancement?

- The confocal tonal shift can't differentiate between vitreous blood or debris.



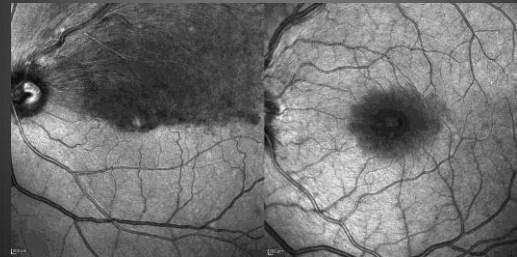
Is the Tonal Shift Artifact or Enhancement?

- Serous detachment is enhanced because of elevation and the confocal tonal shift even though serous fluid is mostly clear.



Is the Tonal Shift Artifact or Enhancement?

- The confocal tonal shift can't differentiate between blood or clear fluid edema.



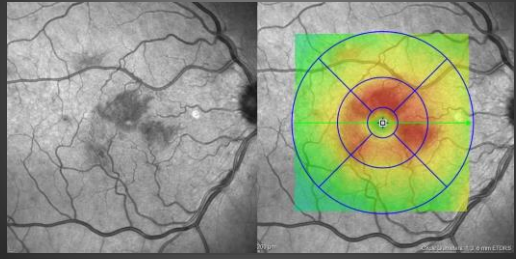
Is the Tonal Shift Artifact or Enhancement?

- NPDR – dark patches are from elevation due to DME.



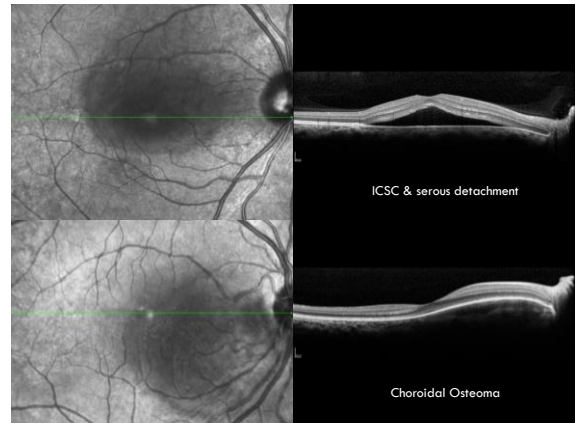
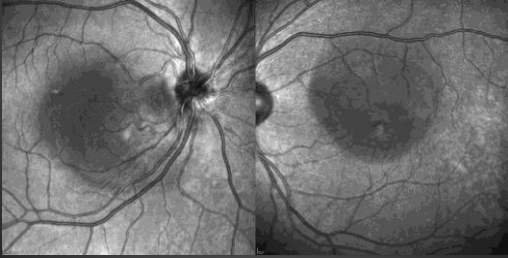
Is the Tonal Shift Artifact or Enhancement?

- NPDR – dark patches are from elevation due to DME.



Diagnostic?

- Lesions in different retinal layers can appear similar due to the confocal tonal shift.



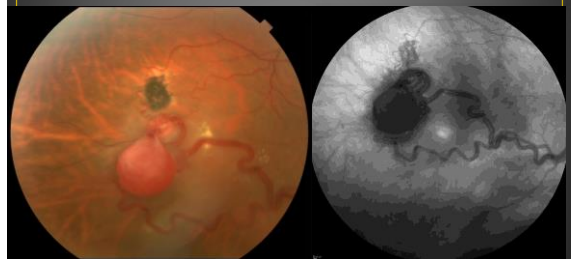
Is the Tonal Shift Artifact or Enhancement?

- Are the dark areas from absorption, blood, or elevation?



Is the Tonal Shift Artifact or Enhancement?

- Are the dark areas from absorption, blood, or elevation?



Is the Tonal Shift Artifact or Enhancement?

- Are the dark areas from absorption, blood, or elevation?



Scattered Reflection

- Disruption of normally transparent retinal tissue can appear dark. Scattered reflection will be slightly blurred and blocked by the confocal pinhole.



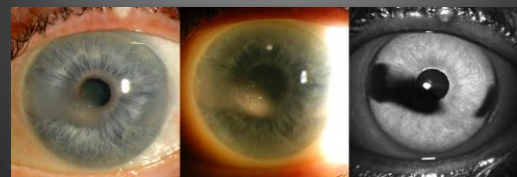
Anterior Segment Shift

- Areas of iris atrophy/thinning appear dark.
- The deep out-of-focus areas may represent the confocal tonal shift or reduced IR reflectance from thinning.



Anterior Segment Shift

- Focus is at the level of the iris with cornea being out-of-focus.
- The confocal pinhole suppresses scattered (out-of-focus) reflection from the cloudy areas of the cornea.

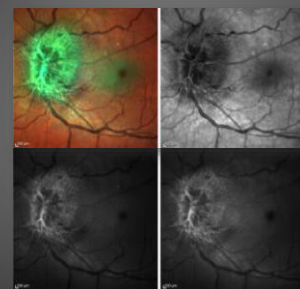


Elevation without the Tonal Shift

- Some highly reflected elevated lesions don't exhibit the tonal shift: ERM, vitelliform lesions, astrocytic hamartomas, dense fibrovascular strands.

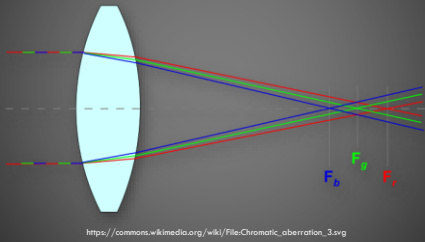


Confocal Composite MultiColor



Images courtesy of Gary Miller, CRA, OCT-C

Confocal Composite MultiColor



Focus down (retina)

Focus up (nerve)



What About Other Confocal Devices?

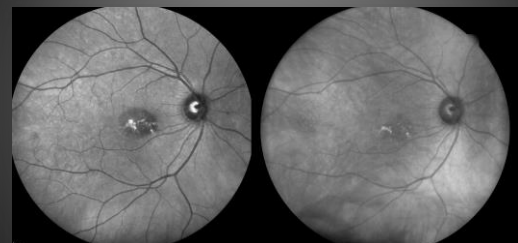
- Has anyone seen the tonal shifts with other confocal devices:
 - Nidek F-10?
 - Eidon?

Eidon

- New "confocal" retinal scanner. Slit aperture
- Hybrid device combining features of a color non-mydiatic fundus camera with confocal technology.



Eidon: No Confocal Shift?



Spectralis IR 820 nm

Eidon IR 825-870 nm

Eidon: No Confocal Shift?

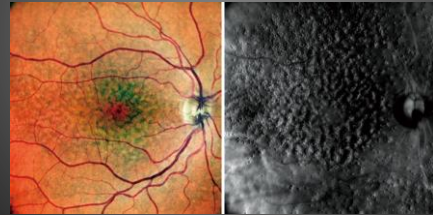


Spectralis IR 820 nm

Eidon white light 440-650 nm LED flash

Nidek F-10

- Nidek F-10 Ring aperture to produce "Retro Mode"
- Aperture deviated laterally from the confocal light path.
- Relief image of deep retinal or choroidal pathology.



Discussion:

- The literature suggests that dark areas on cSLO images are related to the absorption of IR wavelengths by blood, pigment, melanin, or turbid fluid.
- The question is whether the tonal shift is a result of reflectance and absorption as suggested by several authors, or simply confocal suppression of poorly focused areas due to elevation or scatter.

What Does the Literature Say?

- "The origin of dark lesions on examination and hyporeflectance on IR in AMN remains speculative.... there is a striking correlation between the location of interrupted OS/RPE junction (not the IS/OS junction) and the IR hyporeflective pattern. This OS/RPE junction on OCT is thought to represent the interdigitation of the tips of the photoreceptor outer segments with the apical RPE processes, where melanin granules are normally located in apical RPE."

Fawzi AA, Pappuru RR, Sarraf D, et al. Acute macular neuroretinopathy: long-term insights revealed by multimodal imaging. *Retina* 32:1500-1513, 2012.

What Does the Literature Say?

- "If the focal plane of the image is near the apex of the RPE elevation, then the lesion appears bright due to the light scattered by the pigment epithelium. However, if the image is focused deep to Bruch's membrane, a dark core caused by light absorption within the turbid sub-RPE fluid will dominate the lesion center. The edges of the RPE elevation will appear bright due to the oblique position and associated scattering of the incoming light. This summation of melanin reflectance and light scattering results in a strong NIR signal."

Theelen T, Hoyng CB, and Klevering JB. Near-infrared subretinal imaging in choroidal neovascularization. In: Holz FG and Spaide R eds. *Medical Retina, Focus on Retinal Imaging*. Heidelberg, Springer 2010:77-93.

Discussion:

- Many of the conditions that cause elevation indeed consist of blood or fluid: macular edema, retinal vein occlusion, papilledema, serous detachments, RD, etc.
- So it may seem logical that absorption of IR by blood and fluid may be the cause of the hyporeflectance.
- But we also see these dark areas in blue and green reflectance cSLO images where fluid coincides with elevation. Blood will absorb these visible wavelengths but fluid does not.

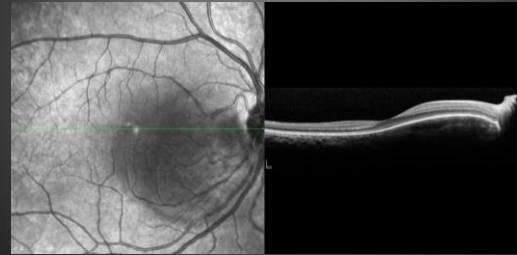
Discussion:

- We can also see hyporeflectance in elevated pathology that is not directly associated with fluid such as traction from epiretinal membranes, or fibrovascular proliferation in diabetic retinopathy.
- All this suggests that confocal rejection of focal differences may be the better explanation.



Discussion:

- Elevation/focus is the only explanation for this highly reflective choroidal lesion.



Discussion:

- I believe that what we see in confocal images is a combination of pure reflectance from the plane of focus, plus attenuated reflectance (dark areas) from out-of-focus areas.
- Abnormal elevation of retinal morphology is one cause of the confocal tonal shift.
- A secondary cause may be the confocal rejection of focal areas of tissue that scatter reflected light or IR.
- The red/green/blue color balance of Spectralis MultiColor images is also effected by focus.

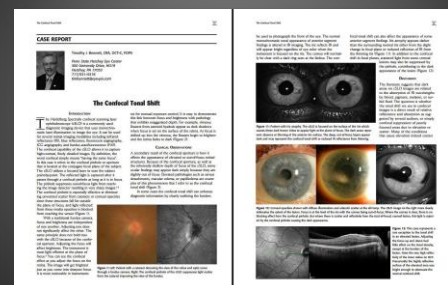
Discussion: Does it Really Matter?

- It is important to understand the confocal tonal shift when capturing or interpreting cSLO images and differentiate between structures that truly are dark in tonality, from those that are simply out-of-focus.
- In some cases the tonal shift will enhance areas of interest that may not be easily identified by other means. In others it may confound the documentation of findings that may contain blood or hemorrhage.
- A second imaging modality such as color fundus photography, OCT, or angiography is often needed to present a more complete diagnostic imaging study.

References

- Bennett TJ. The confocal tonal shift. *Journal of Ophthalmic Photography*, 38(1):17-22, Spring, 2016.
- Woot WH, Fritze RW, Chester GH, et al. The scanning laser ophthalmoscope: basic principles and applications. *J Ophthalmic Photography* 12:17-23, 1990.
- Clark TM. Scanning laser ophthalmoscopes. In: Saine PJ, Tyler ME, eds. *Ophthalmic Photography: Retinal Photography, Angiography and Electronic Imaging*. 2nd ed. Boston, Butterworth-Heinemann, 2002:306-321.
- Steffens T. Optimizing IR and OCT imaging with the Spectralis. <http://www.heldbergengineering.com/us/academy/optimizing-ir-and-oct-imaging-with-the-spectralis/>.
- Theelen T, Hoyng CB, and Klevering JB. Near-infrared subretinal imaging in choroidal neovascularization. In: Holz FG and Spaide R, eds. *Medical Retina, Focus on Retinal Imaging*, Heidelberg, Springer 2010:77-93.
- Sarraf D, Rahimy E, Fawzi AA, et al. Paracentral acute middle maculopathy: a new variant of acute macular neuroretinopathy associated with retinal capillary ischemia. *JAMA Ophthalmol* 131(10):1275-1287, 2013.
- Rahimy E and Sarraf D. Paracentral acute middle maculopathy spectral-domain feature of deep capillary ischemia. *Curr Opin Ophthalmol*. 25(3):207-12, 2014.
- Rahimy E, Sarraf D, Dollin ML, et al. Paracentral acute middle maculopathy in nonischemic central retinal vein occlusion. *Am J Ophthalmol*. 158(2):372-380, 2014.
- Fawzi AA, Pappuru RB, Sarraf D, et al. Acute macular neuroretinopathy: long-term insights revealed by multimodal imaging. *Retina* 32:1500-1513, 2012.

cSLO Confocal Tonal Shift



Journal of Ophthalmic Photography 33(1), 2016

Blog about this topic

<http://eye-pix.com/the-confocal-tonal-shift/>

