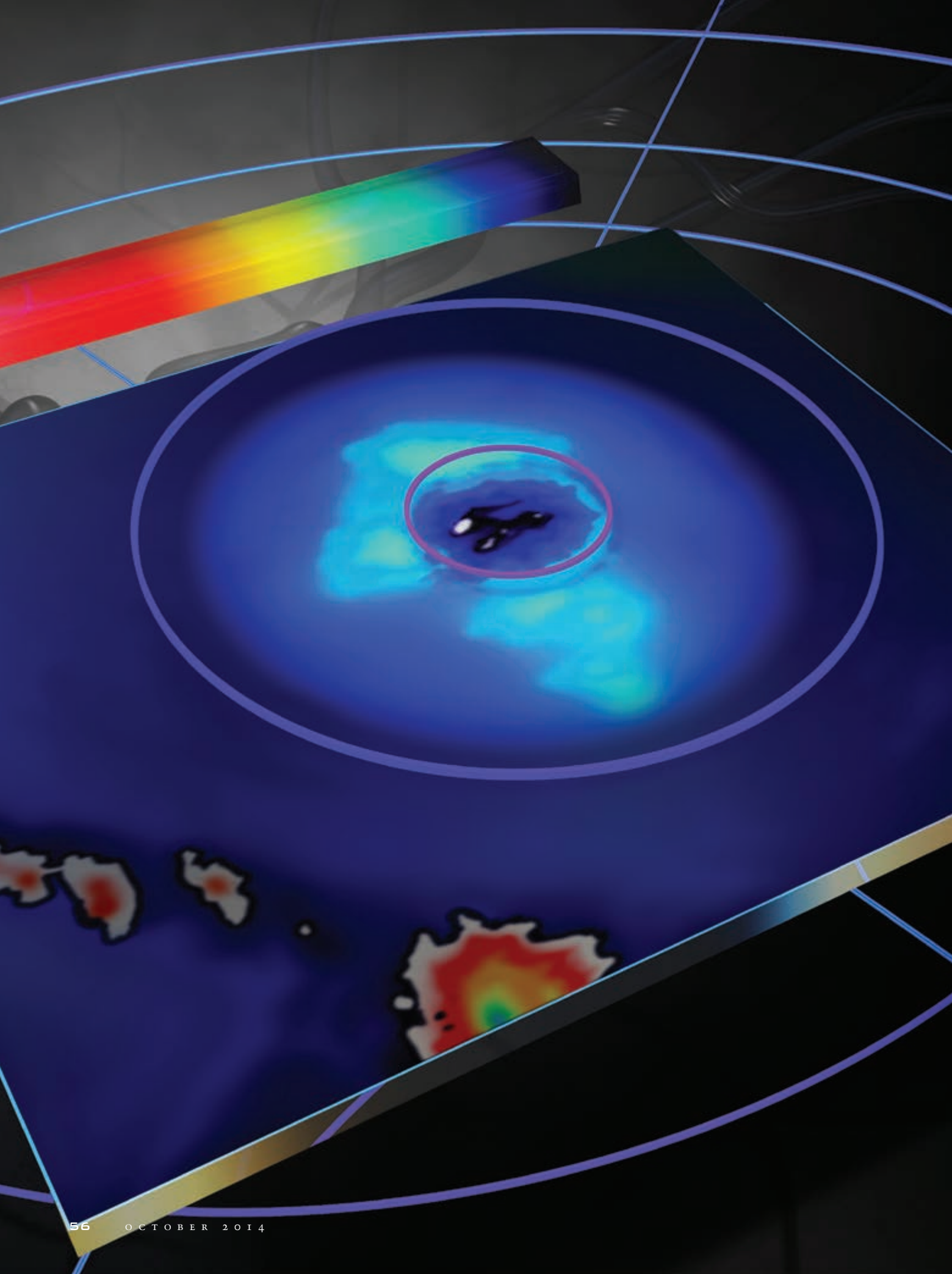


EXTRA
CONTENT AVAILABLE

What's Wrong With This Picture?

Better resolution. Higher scanning speeds. Eye-tracking capability.

Despite major improvements in OCT technology, artifacts can still lead you—and your patients—down the wrong path.

LEARN TRICKS FOR AVOIDING THE TRAPS.

Even as technology advances, familiar problems may remain. Take, for instance, optical coherence tomography (OCT). Sequentially measuring reflections of laser light from the tissue of interest, time-domain OCT (TD-OCT) was limited by the speed of image acquisition and the number of images that could be obtained in the time a patient could sit still, said Sanjay G. Asrani, MD, glaucoma specialist at Duke Eye Center of Cary, N.C.

"Many of these challenges have been obviated by the advent of spectral-domain (SD) OCT," he said, "which can produce significantly more detail in each image and allows detection of subtler changes in pathology at earlier stages."

Faster acquisition speed of SD-OCT has minimized motion artifacts. And eye-tracking features—available with many commercially available devices—also make it possible to follow the eye if it moves or blinks. Nevertheless, your evaluation of glaucoma or retinal diseases can be seriously compromised by motion artifacts, artifacts from operator or software error, or the presence of confounding pathology.

In fact, the overall artifact rate with SD-OCT is not very different from that of TD-OCT, said Glenn J. Jaffe, MD, retina specialist at Duke Eye Center in Durham, N.C.

Because artifacts haven't gone away, and because they can interfere with interpretation of OCT images, it's important to understand the problems that artifacts can pose, be familiar with the various types of artifacts and how to spot them, and know when to rescan the patient's eye.

BY ANNIE STUART, CONTRIBUTING WRITER

The Problem With Artifacts

"Interpreting OCT scans involves a combination of knowing whether the morphology is abnormal or normal, and whether the resolution is sufficient to identify problems," said Dr. Jaffe. It's also necessary to watch for artifacts for several important reasons.

They can compromise areas of interest. Artifacts become clinically significant when they can cloud clinical judgment due to incorrect interpretation, said Dr. Asrani. For example, said Dr. Jaffe, about 30 percent of the time, artifacts affect the center subfield—a circular region with a diameter of 1 mm centered on the fovea. This area is crucial for evaluating retinal diseases such as age-related macular degeneration (AMD) and diabetic macular edema.[1]

They can cause quantitative interference. Although artifacts may hinder qualitative comparisons of OCT images, they're more likely to trip up the clinician's quantitative analysis, said Jay S. Duker, MD, director of the New England Eye Center in Boston.

Misidentification of the retinal nerve fiber layer (RNFL) by the SD-OCT software, for example, can lead to either a mistaken diagnosis of significant glaucoma, subjecting a patient to unnecessary testing or treatment, or a missed diagnosis, added Dr. Asrani.

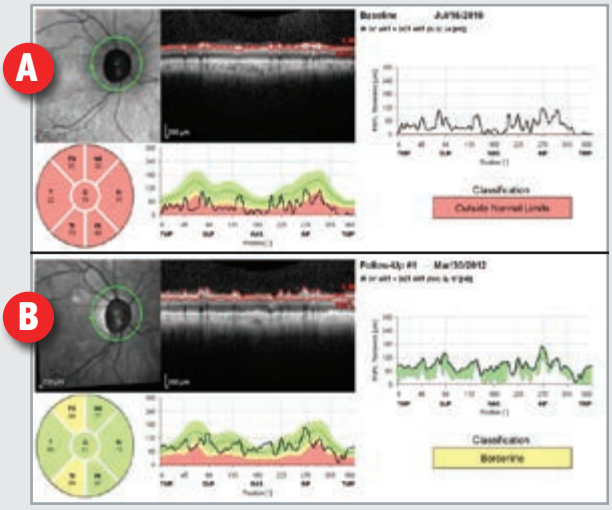
They can act as confounders. A good example of a potentially confounding situation is that of uveitic glaucoma with inflammation-associated swelling in the RNFL: Is the thickness seen in the image due to edema or the tissue structure itself?[2]

"Swollen nerve fiber can fool a clinician into thinking there is no damage," said Dr. Asrani. "Conversely, with uveitis control, a thinner RNFL than previously imaged may appear to be a sign of glaucoma progression. In addition, many glaucoma interventions involve procedures that result in subtle RNFL swelling, which can look deceptively like nerve preservation."

They can mislead the unwary practitioner. Artifacts may interfere most when clinicians and researchers are assessing disease progression and treatment response, said Kaweh Mansouri, MD, MPH, glaucoma consultant, Geneva University Hospitals in Switzerland.

"Unless we are aware of how artifacts can mislead us, we can be led significantly astray," said Dr. Asrani.

Uveitic Glaucoma With RNFL Swelling



A. Baseline. This shows a severely depressed RNFL close to or below the floor effect in a patient with end-stage glaucoma.

B. Follow-up. "Here we see a 'reestablishment of the RNFL,' which isn't physiologically possible in a glaucoma patient," said Dr. Mansouri. "In the en face images, the scans are both centered, and there are no motion or other types of artifacts visible. With major peripapillary changes as seen here, you would expect concomitant changes in the optic nerve head, which are not present."

Instead, this change is likely due to uveitis-related edema in the RNFL; this swelling could be erroneously interpreted as an increase in RNFL tissue thickness, he said.

■ **Here, change in the RNFL thickness is clearly unrelated to glaucoma. Conversely, if the edema had decreased, it could be misinterpreted as worsening of glaucoma.**

SANJAY G. ASRANI, MD

Types of Artifacts

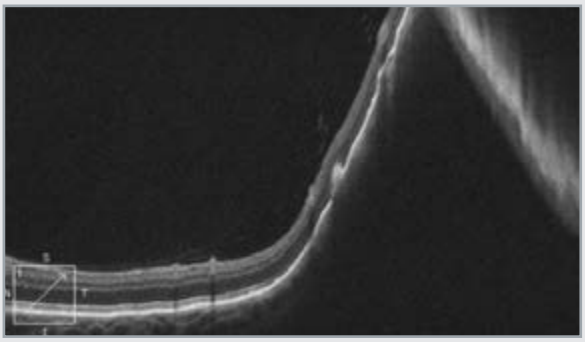
There is currently no agreed-upon classification system for artifacts, said Dr. Mansouri. But for simplicity's sake, he divides artifacts into categories of operator error and pathology.

Operator-related artifacts. "These play a big role but are largely ignored, simply because clinicians may not take the time or have the knowledge to look beyond the final printout, where not all artifacts are apparent," said Dr. Mansouri. "Many operator errors can be corrected," he said. "For example, you can manually readjust inaccurate segmentation lines or exclude B-scans with cut-edge artifacts."

Common examples of operator-related artifacts include:

- **Segmentation.** With segmentation artifacts, the software doesn't identify structures correctly and generates inaccurate numbers. This is the number-one artifact when evaluating retinal diseases, according to Dr. Duker, who said it occurs for reasons as diverse as dry eye, pathology, or motion during imaging. "Where operator error comes into play is when the interpreter doesn't recognize the software failure and relies on the wrong information to make clinical decisions," he said.
- **Centration.** The image is not centered in the grid used to calculate thickness of tissue. This is particularly

Mirror Artifact



JAY S. DUKER, MD

You wouldn't normally see the triangular shape on the right side of the screen; it's a mirror image of the scan. And, said Dr. Duker, "if spectral-domain technology is new to you, you might think this image is due to a defect with the machine. But once you know what a mirror artifact is, it's easy to identify. Fortunately, mirror artifacts also occur less often in the macula, an area affecting clinical judgment."

■ **It is not always possible to prevent mirror artifacts, but you may be able to minimize their occurrence by properly positioning the retina to avoid crossing the zero-delay line (the OCT's "focal point").**

important when monitoring thickness over time in response to therapy, said Dr. Jaffe.

- **Motion.** These types of artifacts are still a problem with SD-OCTs, especially with those that don't include an eye-tracking system, said Dr. Duker. "Even though you acquire each individual scan more quickly with SD-OCT than with TD-OCT, you're still taking three seconds to do a macular scan, in which case a motion artifact can still occur."
- **Blink.** When the patient blinks during scanning, blank areas are displayed by default in the en face images, and B-scans lose retinal data, said Dr. Mansouri.
- **Cut edge.** An edge of the image is cut off. These tend to be less problematic, said Dr. Jaffe, because, typically, they do not affect the central retinal thickness measurements and can often be eliminated by rescanning the eye. But they need to be recognized by the technician while the patient is still seated at the OCT machine. The technician can then promptly repeat the scan, which will usually solve the problem.
- **Shadow.** A variety of factors such as floaters can cast a shadow and result in a low signal, said Dr. Asrani.
- **Mirror.** The OCT generates two images, one a mirror image of the other. "Depending upon the placement of the scan, you may never see the mirror image," said Dr. Jaffe. "But if the scan is not placed properly within the box, or if the person being scanned is very myopic (and the retina is very curved), you'll see that mirror artifact."[3]

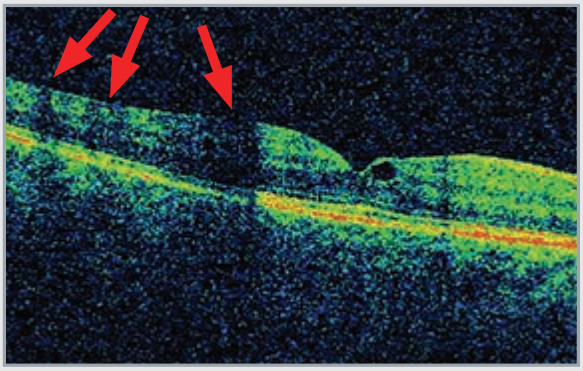
Disease-state artifacts. With glaucoma, the most common artifact is coexisting pathology, said Dr. Asrani. For example, epiretinal membrane and vitreous traction can cause significant thinning or thickening of the RNFL and commonly affect glaucoma interpretation. However, the better resolution afforded by SD-OCT makes it possible to detect many of these artifacts more easily than in the past.[4]

Interpreting images based upon the classification in the OCT's database can also lead to errors, said Dr. Asrani. These devices make calculations based upon a normative database of healthy subjects. "They usually don't include conditions such as uveitis, AMD, high myopia, or diabetes," added Dr. Mansouri. "Therefore these deviations can be erroneously flagged as glaucomatous."

Red flags. It's important, said Dr. Mansouri, to "have a heightened index of suspicion for artifacts whenever there's a change or absence of change that's contradictory to the rest of the ophthalmic examination."

For example, be more skeptical about an OCT image that shows increased thinning if the IOP is well controlled, the optic nerve looks good, and visual fields are normal. "Don't hesitate to go back to the technician and request to look at individual captured images," he said.

Shadowing



JAY S. DUKER, MD

"Although you can't see what it is, something is casting a shadow [arrows] on the left side of the fovea," said Dr. Jaffe. "Because that area is not well resolved, the computer might have trouble identifying the inner and outer retinal lines, which could throw off measurements."

Poor resolution from the shadow artifact also makes it more difficult to evaluate the retina's morphology, he said. "Just to the right of the fovea is a cyst. There may also be more than one cyst in the area of the shadow; but, due to the shadow artifact, it is difficult to assess how many."

■ **Areas of shadowing may affect both qualitative and quantitative interpretation.**

Identifying Artifacts
GLAUCOMA

Dr. Asrani and Dr. Mansouri recommend taking several steps to identify any artifacts in SD-OCT images when evaluating glaucoma.

1. Note whether signal strength is symmetrical between the two eyes, said Dr. Mansouri. To ensure quality resolution, make sure signal strength is at least 6 or greater in both eyes. Poor signal strength can be a major source of artifacts. For example, defocusing an image by at least 2 diopters can result in as much as a 10 µm thinning of the RNFL.[5]

2. Look at the qualitative information in the images.

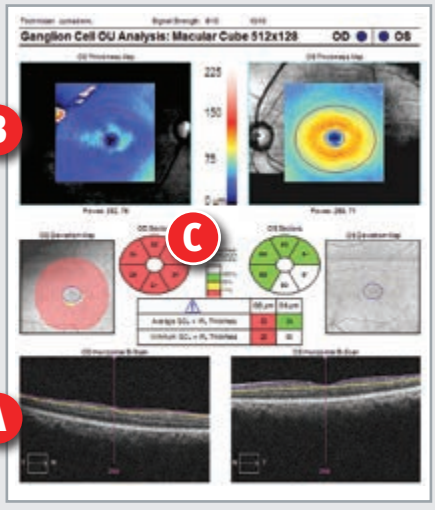
- Check lines demarcating the boundaries of the RNFL to see whether the software correctly identified the RNFL.
- Check for lines or blacked-out areas; these are signs of a blink artifact.
- Check for irregular anatomic patterns such as a break in blood vessels, a sign of a motion artifact.

3. If you haven't spotted any artifacts, you can review and rely upon quantitative data concerning the RNFL, optic nerve head, and ganglion cell loss. Parameters are represented as green, yellow, or red (from thickest to thinnest) or white for values outside of limits. "If artifacts are present, you will likely notice asymmetry or extreme values here," said Dr. Mansouri. "In glaucoma, for example, the RNFL cannot logically be less than 40 microns because the glial cells themselves have a thickness of about 30 to 40 microns."

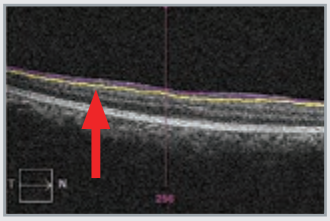
Also, he said, "check to see how the OD and OS lines flow from temporal side to temporal side. Are they separate from each other in any location? Are they dipping into the red region in any one focal area?"

Ganglion Cell Analysis, Both Eyes

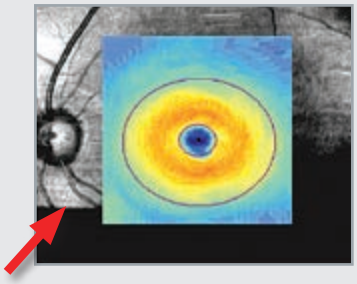
"The machine tried to segment out the ganglion cell layer," said Dr. Asrani, "and unfortunately it was not successful."



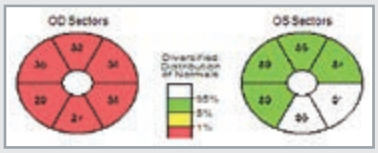
A. Horizontal B-scan. In the right eye, the yellow line is placed incorrectly because the device has misidentified the boundaries of the ganglion cell layer. In the left eye, the yellow line correctly indicates the lower end of the ganglion cell layer, and the purple line correctly identifies the upper end of the ganglion cell layer.



B. Thickness map. "In the right eye, the software identifies the ganglion cell layer as wiped out," said Dr. Asrani, contrasting this completely dark blue circle with the yellow circle of the left eye. "The eyelid or a small pupil may be covering this area in the right eye, contributing to lower image quality and segmentation failure," said Dr. Mansouri. The ganglion cell layer in the left eye has an even thickness, but there is a blink artifact, said Dr. Mansouri, blacking out the area at the bottom of the background image (arrow).



"Although the segmentation lines on the B-scan look fine, in individual B-scans you might find that the segmentation lines measure some noise erroneously in this blackened-out area," said Dr. Mansouri. "However, as this is outside the measurement area, it should not have an effect on overall GCL [ganglion cell layer] and IPL [inner plexiform layer] thickness."

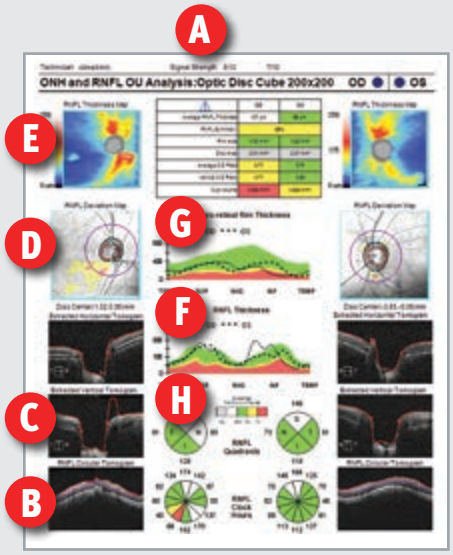


C. Sectors. The right eye sectors are completely off. In the left eye, measurements in the green sectors are within normal limits, but the blink artifact may be responsible for the two whitened sectors (above normal) seen here, said Dr. Mansouri. The only way to be sure is to look at the individual B-scans.

■ **If the artifact in the right eye were not identified, the patient might be subjected unnecessarily to multiple tests and treatment for what appears to be severe glaucoma.**

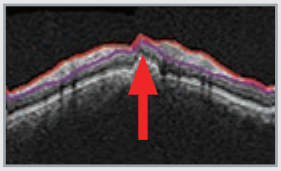
SANJAY G. ASRANI, MD

Optic Nerve Head and RNFL Analysis, Both Eyes

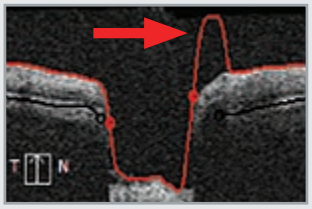


A. Signal strength. The signal strength is more than adequate: 8/10 for the right eye and 7/10 for the left eye.

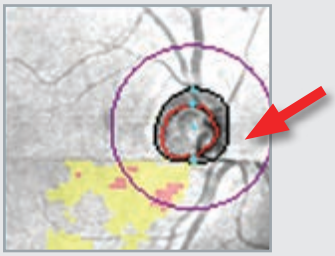
B. RNFL circular tomogram. In the right eye, the software has incorrectly identified the inner (purple line) and outer (red line) boundaries of the nerve fiber layer. The two lines meet in the middle (arrow), and the nerve fiber layer measurement goes down to zero. "That is a red flag," said Dr. Asrani, "because even in the most extreme cases of optic atrophy, there is some thickness left. When it drops down to zero, you know it's an artifact."



C. Extracted vertical tomogram. In the optic cup of the right eye, the software has incorrectly identified a surface, where the red line jumps up and down (arrow). "That peak is a major artifact," said Dr. Asrani, "because there is no tissue there."



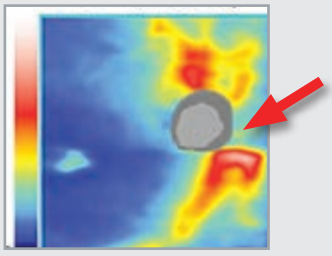
"On the en face image, a shift of major retinal vessels is visible **(D)**, indicating an incongruent superior and inferior half of the image," said Dr. Mansouri. "This may be why the segmentation line erroneously picked up a false inner retinal interface. Another cause of a similar segmentation failure can be a prominent hyaloid interface, mimicking the inner RNFL boundary."

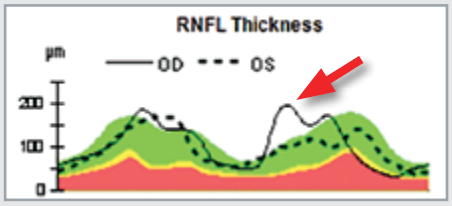


With the segmentation failure seen here, he said, you obtain values that are far outside of the statistical distribution, so the software creates whitened quadrants superiorly and nasally.

D. RNFL deviation map. In the image of the right eye's optic nerve, blood vessels are displaced, and a horizontal line is present (arrow). This is a blink artifact.

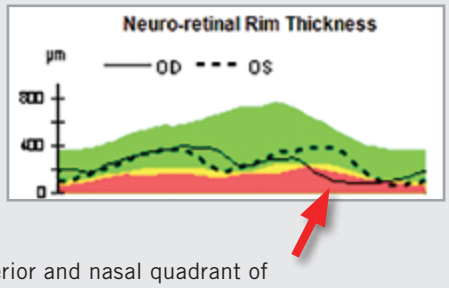
E. RNFL thickness map. With this artifact, the red flame-like distributions of the RNFL are correct superiorly but inferiorly are displaced toward one edge of the blue square.

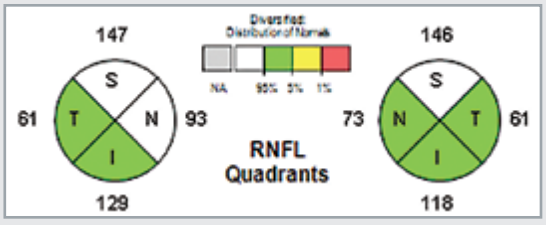




F. RNFL thickness. The separation between the lines in the right and left eye indicates asymmetry.

G. Neuroretinal rim thickness. The line of the right eye dips into the red. Although the signal is strong in both right and left eyes, said Dr. Asrani, the measurements are unreliable in the right eye.





H. RNFL quadrants. "The superior and nasal quadrant of the right eye measures white, but the extracted images don't explain exactly why this is the case," said Dr. Mansouri. "Here, you would have to go back to the B-scan to confirm."

■ **The left eye is free of artifacts, but the right eye must be rescanned because of multiple artifacts.**

SANJAY G. ASRANI, MD

Identifying Artifacts
RETINA

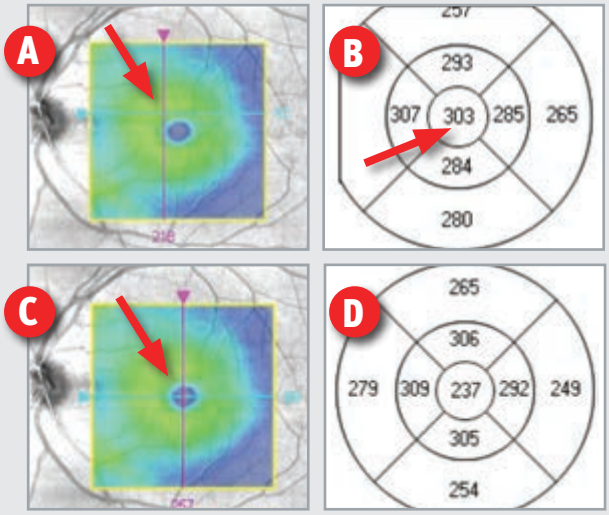
Dr. Jaffe and Dr. Duker recommend taking these three steps to identify artifacts in SD-OCT images when evaluating retinal diseases.

1. Look first at the color-coded macular map. The fovea should be centered. Check for areas of sudden change in the topography of the macula that can't be explained by normal anatomy or pathology. For example, if you see triangular or square areas of blue (suggesting retinal thinning) within areas of white (extra thickness), you know that the software has failed. "It's not physiologically possible to move from a thickened area of retina to a tiny area that's really thin and back to a really thick area again," said Dr. Duker.

2. To confirm the presence of an artifact, review the cross-sectional B-scans, which show where the software actually measured the thicknesses. Make sure the lines that the software drew correspond to what they should.

3. Know when the data are trustworthy. If artifacts are not present, you can review and rely upon the quantitative data.

Centration Error



"Also known as a misaligned fovea, a misplaced grid is common in patients with eccentric fixation," said Dr. Duker. He added that you can often prevent this artifact by having the patient fixate on a light with his or her "good eye."

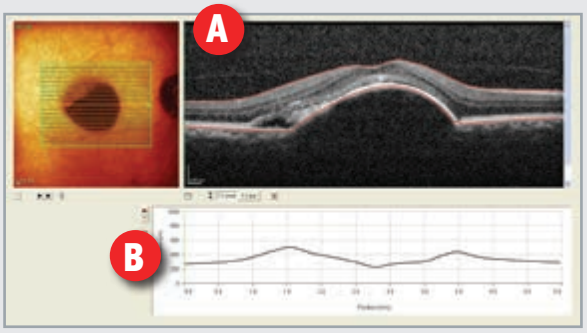
A. Misplaced ETDRS grid. In this image of a relatively normal retina, the crosshairs are not centered properly on the fovea (arrow). Therefore, the computer has generated inaccurate average thickness values in each quadrant of the Early Treatment Diabetic Retinopathy Study (ETDRS) grid **(B)**, said Dr. Jaffe, including that of the center subfield, the central 1-mm circular zone of the fovea (arrow).

C. Corrected position and map. After realignment, the crosshairs are centered over the thinnest (blue) area (arrow), and the grid **(D)** fits within the square with nothing cut off. The number in the center subfield has changed by roughly a quarter.

■ **If you recognize a centration artifact, you can manually realign at the time of scanning, which takes only a few seconds.**

GLENN J. JAFFE, MD

Outer Retinal Misidentification



"Outer retinal misidentification tends to be more common with AMD because there is often pathology in this area," said Dr. Jaffe. "The computer has a hard time figuring out whether it is looking at a normal or an abnormal structure."

A. 2-D cross section. The computer adds inner and outer segmentation lines to the image (red lines on figure), and the distance between these two lines gives a retinal thickness measurement **(B)**. However, the computer's software erroneously placed part of the outer segmentation line on a detached retinal pigment epithelium (RPE; the bright white line), instead of on Bruch's membrane.

B. The thickness map. The thickness values calculated by measuring the distance between the two segmentation lines are inaccurate.

■ **Incorrect identification of the inner retina produces inaccurate thickness measurements.**

GLENN J. JAFFE, MD

EXTRA **MORE ONLINE** For comments on three more OCTs and tips from Mr. Kelly for optimal screening, see the Web Extras that accompany this article at www.eyenet.org.

Scanning Protocols to CORRECT ARTIFACTS

Michael P. Kelly, ophthalmic photographer and director of Duke Eye Imaging Labs at Duke Eye Center in Durham, N.C., noted several specific types of artifacts and recommended the following solutions.

Misidentification of the inner retina often occurs due to vitreomacular adhesion, vitreomacular traction, and vitreopapillary traction. Rescan using enhanced depth imaging, which reduces or eliminates the detail of the posterior vitreous.[6] Or manually adjust the segmentation line after scanning.

Misidentification of the outer retina is often seen in patients with AMD, cystoid macular edema, and central serous retinopathy. Manually adjust the segmentation line after capture.

Eccentric fixation can affect the accuracy of macular thickness maps. Move the thickness map grid to the proper location after scanning. Or rescan using the external fixation device, centering the fovea. For patients who can't see either the internal or external fixation devices, put a Post-it with a big X on the wall for gross fixation, then swing/tilt the imaging head to center the fovea more accurately.

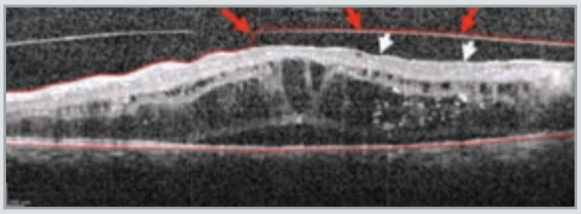
Mirror artifact may be encountered while scanning high myopes or elevated lesions such as tumors or retinal detachment, especially in the periphery. Try oblique or vertical scanning to eliminate or reduce the mirror artifact.

Iris vignetting can occur due to lack of dilation. Dilate the pupil, or turn off room lights and dim the monitor to allow for natural dilation.

Shadow artifact can be induced by factors such as a gas bubble, large floaters, or vitreous hemorrhage. Try to avoid the shadow by rescanning with oblique or vertical scan lines.

If a vitreous hemorrhage or large floater is obscuring the posterior pole, have the patient look away for a few seconds and then quickly back to the fixation point. This allows a small window of time for scan capture by temporarily shifting the hemorrhage and revealing the posterior pole. ■

Inner Retinal Misidentification



"Inner retinal misidentification may be more common with diseases such as diabetes, uveitis, and vitreoretinal interface disease such as vitreomacular traction," said Dr. Jaffe.

2-D cross section. The outer segmentation line is in the correct location. But because the vitreous (posterior hyaloid) is partially detached, the computer erroneously identified the posterior hyaloid—a bright line—as the inner retina. The inner segmentation line (red line) jumps away from the inner retina (white arrows) to the vitreous (red arrows) in this area.

1 Han I et al. *Ophthalmology.* 2010;117(6):1177-1189.
2 Asrani S et al. *JAMA Ophthalmol.* 2014;132(7):877-880.
3 Ho J et al. *Invest Ophthalmol Vis Sci.* 2010;51(7):3714-3720.
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5 Balasubramanian M et al. *Opt Express.* 2009;17(5):4019-4036.
6 Mansouri K et al. *Am J Ophthalmol.* 2014;157(5):1022-1032.

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