SOARING Rx

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Optical Age Spots

[Without] apparent effort, the human visual system recovers the 3-dimensional form of the visible environment from inherently ambiguous 2-dimensional retinal images.
– Peter U. Tse

Read this column only if you need to see small details accurately – such as another aircraft at a distance, or small type. Otherwise, it's irrelevant.

The lucky among us are aging – and the thing we notice about skin is that little brown spots show up and seem to reproduce when we're not looking. More than one woman has said to me, "Get rid of them! I don't like them!" For most of us, these just keep on showing up.

There are actually many reasons for those little brown spots, and the longer we stick around, the more show up. The most important factor is light exposure.

Our eyes develop something similar. Here, the spots are called "drusen." And, yes, nearly everyone gets them, but light exposure is a factor only in making them more bothersome.

Drusen are the main observable abnormality in macular degeneration, the leading cause of blindness in the Western world.

Because nearly all of us develop drusen, and because something can be done to mitigate macular degeneration, this is important generally. Because drusen distort our perception of detail, it's relevant to pilots' need to "see-and-avoid" and to correctly read instruments and charts and to perceive our environment accurately.

The bottom line is: don't use tobacco, wear good sunglasses (see the May, 2012, Soaring Rx, "the best article on sunglasses," http://tinyurl.com/kzefltt), and eat, every other day, dark green leafy vegetables (spinach, kale, beet greens) or take zeaxanthin and lutein made from all-natural sources.

What is Happening in the Eye?

Anatomy: As you can see, the eye is a white globe of tough fiber. Front center is an optically clear spot (cornea, pupil, lens) rimmed with an attractively colored variable aperture (iris). The insides are propped up by a glob of clear jelly (vitreous humor).

It's lined by the retina, which is covered with optically-clear nerve fibers and nerve cells in about five thin layers. Beneath these are the light-sensitive rods and cones.

The rods and cones have high metabolic rates (require a lot of oxygen, fuel, and precursors for synthesis). Between these and the rich network of blood vessels (choroid) is a layer of nutrient cells (retinal pigment epithelium) that actively transport specific substances to and from the rods and cones, and keep in balance the fluids of the retina.

The retinal pigment epithelium (RPE, in the lingo) is crucial to visual function, and macular degeneration is actually loss of retinal pigment epithelial cells – with loss of their supporting function causing visual loss. The *drusen* of macular degeneration are basically scars where the RPE cells have croaked.

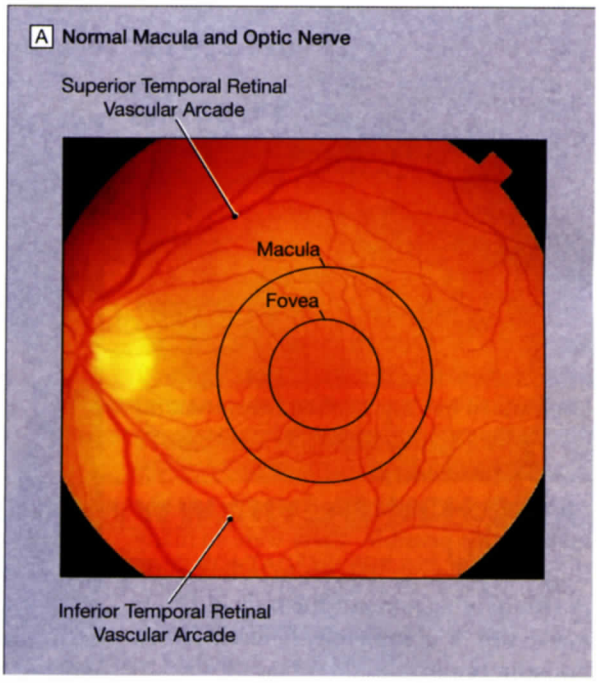
This lost supporting function causes tiny blind spots where cone cells can't work. But the retina doesn't merely detect light; it processes information in *ganglion* nerve cells. These also require a healthy environment, maintained by the RPE cells that sit astride retinal blood vessels.

The cones and rods are photon detectors – rods can detect single photons, cones by the score. But the optic nerve does not pass signals from rods and cones to the brain. There is considerable preprocessing in the retinal ganglion cells (of which there are several types). Edge detection, orientation, motion, regional brightness, and color analysis occur in the optically clear nerve layer of the retina. So with macular degeneration, there's also some degree of *distortion*.

Compare this with a digital camera. The cones of the fovea and daytime retina are a 7-megapixel camera; the rods of the nocturnal retina are a 120-megapixel camera! But the optic nerve contains fibers from only about 1 million retinal ganglion cells. Thus, considerable information analysis must occur in the retina.

The information from the retina emphasizes contour, texture, fill color, and motion. Higher brain levels reconstruct from this a 3-dimensional representation, and match this to image memory to accomplish recognition.

The anatomy of visual perception is highly organized, complex, and interesting. You can read about it by searching academic sites. Our focus here is simply to point out that where the RPE has deteriorated, it is inevitable that signal processing by retinal ganglion cells in the



area must be impaired – and this must lead to *distorted* form perception.

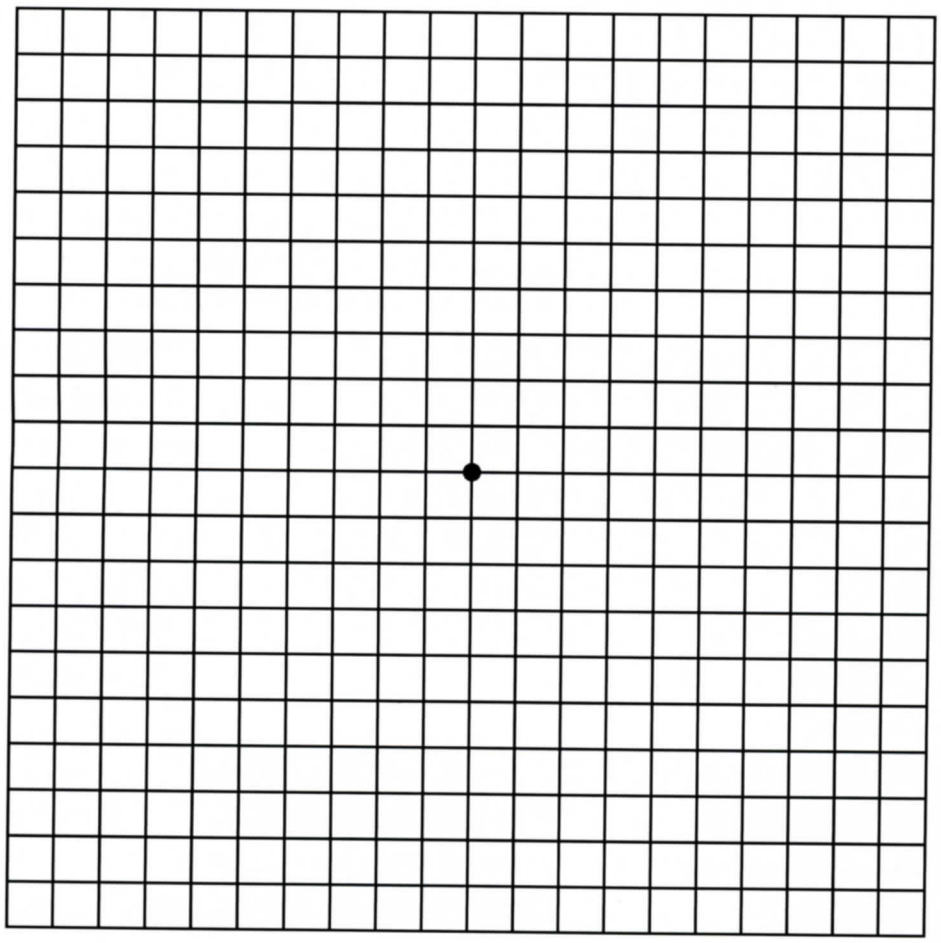
I learned how distressing this can be when a patient phoned me in the middle of an afternoon – a writer, he abruptly had to put his nose four inches from the computer screen to see his text because the letters were distorted. He promptly saw an ophthalmologist, who confirmed that there was only macular degeneration. The next morning, he awoke with normal vision, a great relief.

Here's the deal. Where drusen are located, the nutrient and regulatory RPE cells are kaput, and so are the cones and ganglion cells dependent on them. But there are no fences in the retina – cones *near* these drusen, and those dependent on damaged RPE cells will falter when asked to do more work than usual, such as looking at bright light for a long time, which requires that visual pigments be continually refreshed at a high rate, for hours at a time. After a night's sleep, a better equilibrium has been restored.

The Amsler Grid

In 1945, Swiss ophthalmologist Marc Amsler used the fact that defective RPE function produces distorted form perception to devise a simple grid, to test for macular degeneration. To use this grid, hold it at normal reading distance, cover one eye, focus on the center spot, and observe for wrinkles in the lines.

A downloadable, printable grid can be obtained on the Internet, such as from allaboutvision.com, at http://tinyurl.com/n8makz3.



Obvious implications

You have now figured out that macular degeneration may cause tiny details, like that glider silhouetted against a cloud three miles away, to be invisible or distorted. This is much more likely in bright sunlight, under which we normally fly. This is relevant to flying safety.

What to Do

Basically, there are two influences you can't change, and two that you can.

You can't change your parents or your age. Most people over 40 have drusen without detectable vision impairment, and the number and impairment risk increases with age. Heredity is important: the identical twin of someone with macular degeneration has a 20-fold increased risk. Caucasians have the same numbers of drusen as blacks, but more vision impairment.

Choices you make when young are important. Smoking almost triples the risk of macular degeneration, and female former-smokers still have a doubled risk for at least 15 years after quitting. People who culturally eat about a half-cup of chard or spinach at least three times a week have half the risk of developing macular degeneration, and people who begin eating this, or take lutein with zeaxanthin daily, have a 25% reduction in progressive severity versus those who do not.

While bright light stresses the retina metabolically, it has not been shown to cause or worsen the damage of macular degeneration.

I'm an old guy, and have watched a fair amount of water spill over the medical dam. In 1994, a study was published in the AMA Journal that showed that a diet rich in dark, green leafy vegetables, specifically high in the carotenoids, lutein and zeaxanthin, especially spinach and collards, had a 43% lower risk of developing macular degeneration.

Two things surprised me afterward.

One was that ophthalmologists seemed to ignore this, and kept prescribing their favorite brand of eye vitamins for which there never was any evidence of therapeutic benefit, nor were those vitamins reformulated to include lutein or zeaxanthin for many years. Since only God has a patent on plants, nobody can get a profitable monopoly on their sale, and thus we see no production or advertising about the benefits.

Even today, patients are not advised to eat the leaves – they're sold pills of mixed pedigree. On the other hand, collard greens, kale, and spinach are somewhat culture-specific, and certainly not a mainstay of the diets of the upper Midwest, where I live.

The other surprise was that my patients with macular degeneration often explicitly preferred to chance blindness rather than eat green vegetables they weren't used to, didn't know how to prepare, and

didn't like. "Isn't there a pill?" was the plaintive bleat.

Well, yes, there is a pill. Natural foods producers package desiccated marigolds, a rich source of lutein and zeaxanthin. You can find it online. Good luck on the dose. What's the marigold equivalent of a fourth-cup of collard greens a day? Glad you asked: About 2.5 mg (2500 micrograms).

There is a list of lutein and zeaxanthin contents of vegetables online. One source of this list is https://www.macular.org/lutein.

Official Pills

For those of you who'd like to stay out of the garden and prefer manufactured drugs, there's the AREDS vitamins (Age Related Eye Diseases Study).

This is part of the long American tradition of taking the somewhat vague results of dietary research (do *you* remember what you had for lunch last Friday?), doing Deep Thinking about what might be the most important elements of the foods correlated with better health outcome, then synthesizing those chemicals. We put these in a nice red capsule (red works better), apply for a grant or sweet-talk a venture capitalist, and then do a Study. (Or *not* do a study, if we're in the neutraceuticals arena.)

In general, the results of various such adventures over the last 40 years in what could be called Synthetic

Functions of the retinal pigment epithelium

Light absorption.

Light is absorbed by the pigment of the RPE, preventing back-scatter, which would cause blur. Photographic film has a pigmented back-layer for the same reason. The RPE contains several pigments that are specialized to absorb different damaging wavelengths of light, as well as melanin, which absorbs all wavelengths.

Additional light is absorbed in rods and cones by the pigment's lutein and zeaxanthin, which absorb blue light before it gets to the RPE cells. Blue light is dangerous for RPE cells because it creates cell-toxic substances. Perhaps this is why people who eat dark-green leafy vegetables such as kale and spinach (a half-cup 3x/week) have only about half the risk of getting macular degeneration.

Nocturnal animals have a non-pigmented retinal area, so that unabsorbed photons have a second chance at activating the rods after being reflected. This improves night vision at the cost of some blur. This area, the *tapetum lucidum*, is the reason that such animals, including cats and dogs, have "eyeshine" when looking at a flashlight at night.

Nutritional transport

Water, electrolytes, glucose (needed by all retinal cells) and vitamin A (retinol – needed by rods and cones) are actively moved to and from the retina as needed. Nothing is there accidentally.

Visual pigment recycling

Retinol is transformed in the RPE to 11-*cis*-retinal, needed by rods and cones to create the visual pigment, rhodopsin. Photons cause this to change to opsin plus 11-*trans*-retinal, which RPE restores to *cis* form, permitting pigment regeneration. Without this recycling, we'd lose vision in seconds.

Cell regeneration

Photosensitive rods and cones break down and are renewed. RPE cells absorb fragments of degenerated rods and cones (phagocytosis) and reprocess the ingredients for excretion or reuse.

Metabolic regulation

RPE cells produce proteins such as vascular endothelial growth factor that regulate the activity and responsiveness of supported cells.

Cross-section of the eye and retina

It's important to know that the "choroid" is the layer of blood vessels that nourish the eye.

Diagram 'B', right, shows that the nerve-cell layer is "on top of" the light-sensitive rods and cones, which are "on top of" the nurturant "retinal pigment epithelium" which lies against the blood vessels ("choroid"). Light passes through all the nerve cells on the way to the rods and cones.

Drawing 'C,' lower right, shows that the location of drusen blocks the nutrient action of RPE cells.. They're between the blood vessels (choroid) and the cones/rods. This diagram shows degenerated photoreceptors, but it's important to realize that there are more "distressed" photoreceptors than "degenerated" ones.

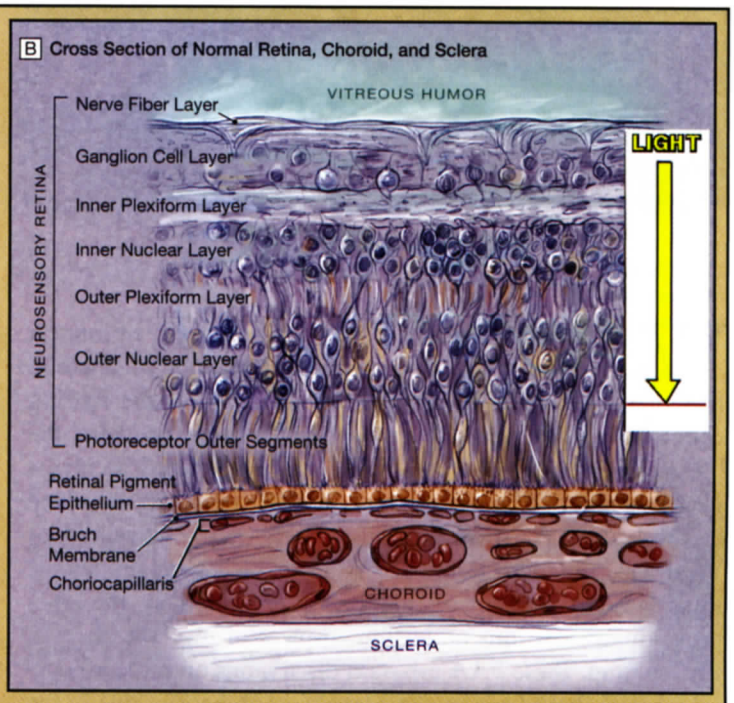
In "dry" macular degeneration, some of the pigment-epithelial cells that lie between the retinal blood vessels and the cones fail (form plaques called "drusen"), and instead of actively passing nutrients on to their associated cones, become an obstacle. This decreases the rate of pigment regeneration.

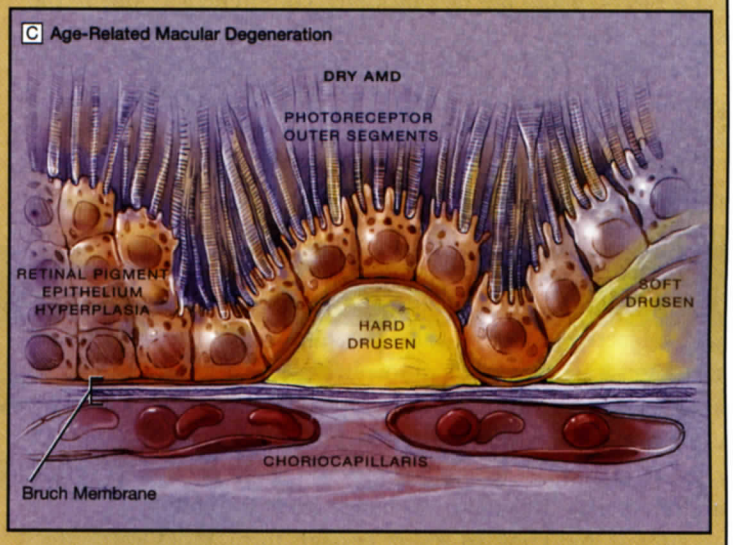
In "wet" macular degeneration, new blood vessels begin to form in drusen. This causes additional damage through inflammation.

Precis: The cones of the retina, essential for sharp vision, are highly active metabolically – they require a steady supply of oxygen and glucose in order to continually regenerate the pigments used to detect light. Failure of pigment regeneration = failure to "see" properly.

The more light-processing that cones are required to do, the greater is the pigment regeneration that's needed.

Conclusion: keeping the light as dim as is comfortable will decrease the workload and the energy needs (glucose, oxygen) of the cones, preserving clear vision. This means sunglasses outdoors, and turning down the screen brightness on your computer – and avoiding bright lights in general.





Eating have been neutral to harmful. The AREDS vitamin studies are a case in point. But at least we have pretty good data that:

- supplemental lutein and zeaxanthin improve macular degeneration risk in the 25% of people who don't eat vegetables.
- Beta-carotene (vitamin A) isn't helpful, and increases the risk of lung cancer in smokers (one more reason not to smoke).
- Omega-3 fatty acids are not helpful (but are not harmful, so can be used for their benefit in cardiovascular disease).
- The original AREDS vitamins reduce the risk of progression of macular degeneration by about 25%. These do not contain lutein or zeaxanthin and do contain zinc, copper (to prevent the zinc from causing anemia), and vitamins C, E, and A.

(Based on the AREDS-2 study, and the fact that synthetic vitamins A and E have been shown to be harmful, I suspect that it's the vitamin C and zinc that are important here.)

If you do have any defective or distorted vision, see an optometrist or ophthalmologist promptly. Don't assume it's macular degeneration and that buttercup extract will be the ticket.

If you do have macular degeneration, check your vision against an Amsler grid regularly, of a morning. If you notice any new distortion, take your eyes promptly to your ophthalmologist, because sometimes the garden-variety "dry" macular degeneration changes to the rather worse "wet" macular degeneration. This carries a greater risk of blindness but is also treatable with eye injections.

Until then, Happy Flying!

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