SOARING Rx

BY DR. DANIEL L. JOHNSON

The Lens of the Eye: When Fog Rolls In

(All prior columns are at: tinyurl.com/drdanscolumns)

Joe tugged the brim of his cap a little lower, to bring the flight computer into better focus. The sun wasn't really in his eyes, but the sky was bright, and somehow that made the screen font hard to make out. He could dimly remember, decades ago, that this sort of thing didn't bother him. But it couldn't be his eyes! The world had changed, not him! Back then, there weren't any flight computers, the letters and numbers on the instruments were big and clear. No tiny letters on a dim computer screen!

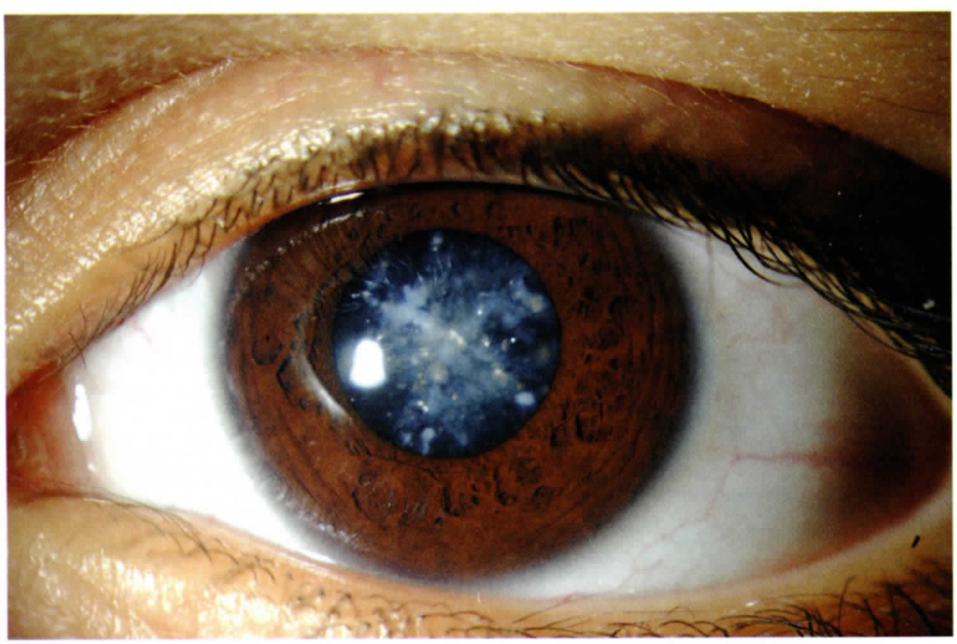
Last week, he'd driven to visit his cousin, the Country Mouse. He was used to the brightly lit city, and while driving back home on a dark two-lane road he was grateful for the fog line at the right edge of the pavement. Every time he met a car, that line faded, and he had to pay close attention, looking down and to the right to make sure he caught each bend in the line that would reveal the next curve.

His cousin, a professional photographer, had taken him to a show of his landscape work. Joe remembered being thrilled, years ago, by the exquisite detail in his big prints. This time, they looked clear enough, yet when he drew close, he just didn't see the delightful snap there used to be. "Are you using a different camera?" he asked. Well, of course he was – the whole world has gone digital. That must be it!

The Normal Ocular Lens

The lens of the eye, in our youth, is a thing of crystalline clarity. It's always a delight to examine a young eye. The magical clarity, for the examiner, dissipates years before the eye's owner notices a change.

Eventually, as the years pass, and we get beyond our fifth decade, the lens may acquire motes of crystal, or lumped protein, and become as frustrating as a windshield full of bug splats. This, a cataract, is the commonest cause of vision impairment worldwide. When advanced, the lens looks like a tiny waterfall behind the pupil.



Cataracts are the most common cause of vision impairment.

Fixing the Foggy Lens

You know about cataract surgery. The clouded lens is removed and replaced with a fine, unclouded artificial lens. The world suddenly becomes clear, colors bright, and fine print legible. The joy of vision is back, usually at the cost of daily eye drops. Rarely, some catastrophe may happen to the eye.

There is no known prevention for cataracts and no effective medication. Surgery is the only resort.

Well, that's that. The lens gets cloudy with age; this hinders vision and makes perceptual errors more likely. The clouded lens can be replaced, and visual life is typically good again. You may stop reading here, unless ....

Care for More Detail?

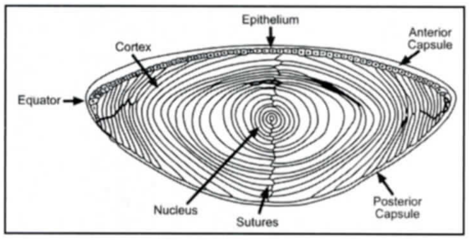
Since you're curious and like to know how things work, let's first review in a simple way how the lens is formed and how it functions.

The embryonic eye forms, in just the right location due to developing regional and local protein expression, as a small pit. If the pit is removed, the eye does not develop, and if the pre-eye tissue beneath the pit is removed, the lens does not form. These, like nearly all structures in the fetal body, are, for proper development, interdependent on neighboring tissue expressing relevant proteins.

The Lens

The developing lens area is nourished from the vessels of the developing brain by an extension of the ophthalmic artery, the *hyaloid artery*, for about 10 weeks in humans. Afterwards and forever, the lens is nourished by transport of substrates through the humors of the eye.

The mature eye is a compound optical device with four refracting surfaces: the outer and inner surfaces of the cornea and the outer and inner surfaces of the lens. The lens is a living transparent tissue that grows throughout life, whose cells are configured to remain fully transparent for decades.



Human eye lens cross section. (Copyright Dr. Joan E. Roberts, with permission.)

The lens has a central nucleus and a cortex lamellated like an onion. These lamellations join at "sutures" that look like a fine branching Y. The long, thin cells of the lens attach at one end to a suture. These cells are linked to each other by proteins that pass nutrients along and that permit movement for accommodation.

The lens is attached at the equator to a muscle, the *ciliary body,* with microscopic cables, the *zonular fibers.* The lens, during the first half of life, is flexible and is thinned to see distant objects and fattened to see near ones. This flexibility is enormous in early childhood, then rapidly decreases and the lens becomes uselessly stiff sometime between 40 and 60.

In addition, the lens itself has a variable refractive index uniquely suited to focus light coherently on the hemispherical retina beyond. The highest refractive index is at the lens nucleus, and decreases exponentially toward the edges. If you carefully formed a single lens from optical glass the size and shape of the natural lens and with the same mean refractive index, this would be optically poor because of chromatic and spherical aberration.

The lens is encapsulated by a tough, thick membrane over a single layer of epithelial cells that are relatively thick, cuboid in cross-section, and hexagonal in the floor plan. These epithelial cells actively transport molecules to and from the cells of the lens to maintain nutritional homeostasis.

The lens grows from the epithelial cells at the equator of the lens. Epithelial cells are formed throughout life. They elongate to create the crystalline lens, lengthening until they are up to 1,000 times as long as their very slender width. When one end attaches to a suture and the cell is full length, it actively disgorges its nucleus and organelles. Remaining in these long, hairlike cells are crystalline proteins that create structure and maintain function. New cells are added slowly to the front part of the lens in adulthood.

The cells of the lens persist through life without turnover and are metabolically dynamic. About half the surface area of these threadlike cells is occupied by channels that bind the cells tightly and flexibly to one another and allow transport of precursors and nutrients throughout the lens.

Any disturbance of lens development or of the cellular mechanisms that support tissue homeostasis erodes transparency and progresses toward opacification (a cataract). For example, surgical removal of the vitreous disrupts lens nutrition and accelerates development of cataracts.

The fiber cells of the lens are packed systematically, and their membranes interlocked, in ways that preserve transparency and integrity during the flexing involved in accommodation. There are complex interlocking proteins that maintain the shape of the entire structure of the lens during the mechanical disturbance of fast accommodation.

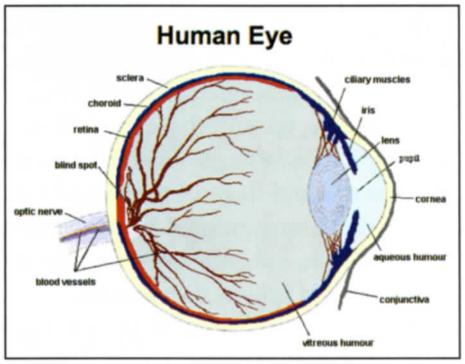
Within the lens-fiber cells, the proteins aren't renewed and damage accumulates through life. UV radiation shorter than 295 nm is absorbed by the cornea and the lens absorbs UV 295-320 nm in childhood, 295-400 nm in adulthood, and 295-500 nm when elderly (removing deep blue). Thus the cornea and lens protect the retina from UV light.

Lens proteins are damaged by excess glucose, UV light, and the phototoxic chemicals in smoke and fumes. Young lenses are crystal clear, and become gradually yellowed after middle age, usually becoming somewhat cloudy (cataractous). Antioxidants like vitamins C and E, lutein, and glutathione delay this progression. Eating green and yellow vegetables and fruit is important because they contain these antioxidants.

Nearly everyone over 55 has some clouding of the lens that's visible to the examiner. Eventually, many people notice this progression and seek cataract surgery in order to mitigate the loss and restore better acuity.

Cataract Surgery

At worst, a cataract is a white opacity where there should be a black pupil. It's easy to imagine poking a miniature harpoon into it and simply hoisting it out of the eye. This would have two drawbacks: first, opening the eye allows infection. Second, the lens is not loose, and yanking it out would damage the anterior structure of the eye.



Human eye cross section. (Copyright Dr. Joan E. Roberts, with permission.)

Thus, the skill and technology of cataract removal entails opening the eye without permitting infection, closing it without distorting the optics of the cornea, and removing the opacified lens without damaging the iris or letting the vitreous leak into the anterior chamber.

That's only the getting-it-out challenge. There have been great advances in equipment and technique through the decades to make this seem routine.

What about the lens? We lose a lot of optical power when that comes out, and we have no useful vision unless it is somehow replaced.

Readers as old as I will remember the thick coke-bottle lenses of yore. They were heavy, round glass, whose weight might make the bridge of the nose sore. They were in front of the eye, so the image on the retina was sized differently than with the native lens – a big problem for binocular vision if the native lens remained in the other eye.

In the middle of the 1970s, the *anterior chamber* intra-ocular lens was developed, with technology to anchor it centrally in front of the iris and techniques to insert it safely. Gone were the thick lenses. This was a wonderful advance. I remember vividly an elderly woman at church who sought out one of the first surgeons in Minnesota to have this new lens, and how thrilled she was with the good result.

Yet these were not perfect. First, they were still anterior to the position of the natural lens, so there was still an image-size discrepancy between eyes. Second, nearly everyone needed eye drops: this position and the extensions necessary to hold it in place tended to hinder fluid circulation in the eye, so increased pressures and glaucoma were frequent. And the presence of this plastic foreign body tended to cause inflammation and irritation; some people's eyes were chronically uncomfortable.

Further advance in materials, technology, and technique led, in the late 1980s, to the development of the *posterior chamber* lens, which rests in the location of the native lens. Optically, this is just what the doctor ordered. The artificial lens does not have the internal refractive-index gradient of the normal lens and can't accommodate, but is wonderful to the person who's been living with a cataract.

Accommodating Intraocular Lenses

A great deal of work is being done to provide IOLs that reduce the need for bifocals. There is a variety of lenses using various materials and optical approaches, each bringing some improvement in the distance range of best vision, but each bringing some cost in terms of needing to be located within the eye with unusual precision, sometimes needing to be supplemented by LASIK because of astigmatism, that somewhat decrease best acuity in the range of best vision, and bring distracting subtle distortions.

My own sense is that before choosing such a lens, study its engineering and limitations, and speak to others who have had the lens implanted, as well as asking the ophthalmologist to review the pros and cons. Fussy people like ourselves may be surprised and disappointed by some of the optical and perceptual compromises unless we take time to understand them.

Basically, these lenses give useful accommodation, but not enough to completely avoid cheaters for reading.

Opportunities for Disappointment with IOLs

Placement of intraocular lenses is remarkably safe. Visually disabling complications are unusual. But even if the surgery goes well technically, the patient may be disappointingly surprised by one nuance or another in the outcome.

This may be a need for eye drops, "minor" distortions of vision (*dysphotopsias),* or recurrence of foggy vision, due to "posterior capsular opacification."

Because the native lens is surrounded

by a tough basement membrane, and because it's undesirable for the vitreous to leak into the anterior chamber of the eye, surgeons shell out the old lens with the posterior membrane intact, and leave this in place protectively.

This membrane generally clouds up during the following year or two. This clouding, *posterior capsular opacification*, is due to epithelial cells that remain at the equator of the lens capsule periphery migrating to its south pole. When this degrades vision, a laser is used to ablate its central part to restore clear vision. This is a better time than when the eye is open and lens replacement is taking place.

An intraocular lens with square posterior edges hinders this migration, but the hard edges reflect and refract light, leading sometimes to bothersome flare and false images. Intraocular lenses, in general, are prone to what are called *dysphotopsias*: shadows, central flashes, dark curves, or bright rings. These are found to be very common when patients with IOLs are asked.

Lens replacement has a very low risk of adverse, unintended sequelae, so has become almost routine. Yet not every operation has the result desired by the patient. This can sometimes lead to cognitive dissonance with the surgeon, as only the patient can know what is the post-operative visual experience, and the surgeon knows all too well the limitations and risks, and tends to feel satisfied when the operation has gone as well as it could under the circumstances.

Should Joe Have His Cataracts Replaced?

And this is the dilemma for the patient: we patients notice and feel the frustration and dysfunction of blurred and foggy vision, but haven't experienced placement of an intra-ocular lens, and so don't know just what to expect afterward. The surgeon knows very well what to expect technically, yet can never (medical telepathy being poor) know just what is the patient's experience or hopes.

Ultimately, Joe has to decide whether he's functional and safe with his degraded vision. Then he can only describe this accurately to the ophthalmologist and ask which annoyances can be expected to vanish after surgery.

Typically, ophthalmologists are not fully aware of their patients' visual experiences after surgery: they are generally satisfied with a clear eye, well-positioned lens, the absence of visually disabling complications, and corrected best vision of 20/20. There are perceptual nuances, some related to the individual, others to the technique.

This makes it important to talk to other people about their experiences – but that has its own disappointments: few people are able to be articulate about their experience, and disappointment may be expressed in emotional, objectively unhelpful language, and their personal needs and eye anatomy may be different from your own.

In the end, all we can do is to try to understand clearly what things about our aging eye are contributing to decreasing visual function and how each contributes, the planned procedure and what it will and will not do, and what the major and nuanced risks are.

Pilots do not have the same standards as the average recliner-driver with a remote, so we are a little harder to please. This makes self-education important, which permits us to bring intelligent questions to the ophthalmologist (yes, do write them down).

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