

Iris Structure, Aqueous Flow, and Glaucoma Risk

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Modeling of the biomechanical structure of the iris and the flow of aqueous humor has revealed new insights and risk factors for glaucoma.

We have constructed a computer model of the iris embedded in a model of the eye that includes the cornea, sclera, lens, anterior chamber, posterior chamber, and aqueous fluid. We used principles of elasticity to evaluate pressure-induced stresses in the iris and Navier–Stokes equations of fluid dynamics to describe aqueous flow.

The iris is the colored part of the eye, situated between the cornea and lens, and its central aperture forms the pupil (Fig. 1). As an optical element in the visual system, the iris is a variable diaphragm that allows the pupil to dilate and constrict in response to changes in ambient light.

The iris forms a boundary separating the aqueous-filled anterior and posterior chambers of the eye. The aqueous fluid is constantly in motion, passing from the posterior chamber through a channel formed between the iris and lens into the pupil area of the anterior chamber and then through the anterior chamber angle between the iris and cornea before exiting the eye (Fig. 2).

The flow of aqueous through the iris–lens channel is driven by a pressure differential between the posterior and anterior chambers, with the pressure in the posterior higher than that in the anterior. The pressure differential is controlled by the iris–lens channel height, which is a measure of the proximity of the iris to the anterior surface of the lens. From our calculations, we predicted that channel heights $>5\ \mu\text{m}$ would not produce

pressure differentials of clinical interest. However, channel heights $<5\ \mu\text{m}$ would lead to pressure elevations in the posterior chamber that would be a glaucoma risk.¹

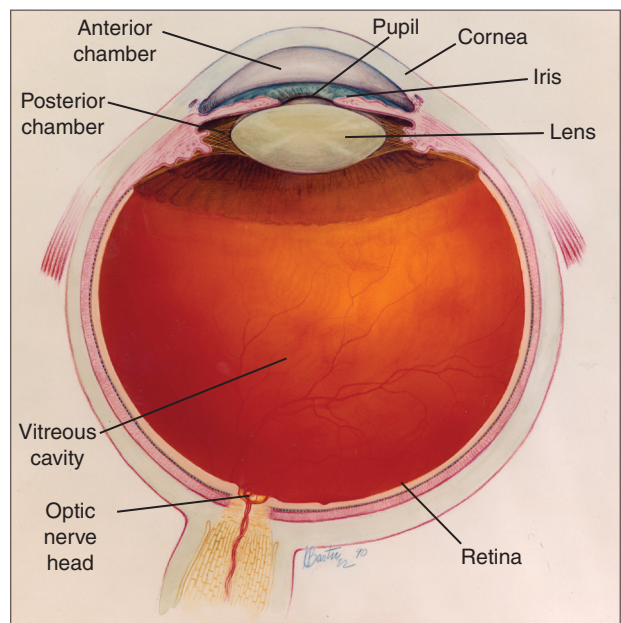


Figure 1. Components of the eye. (Image courtesy of the National Eye Institute, National Institutes of Health.)

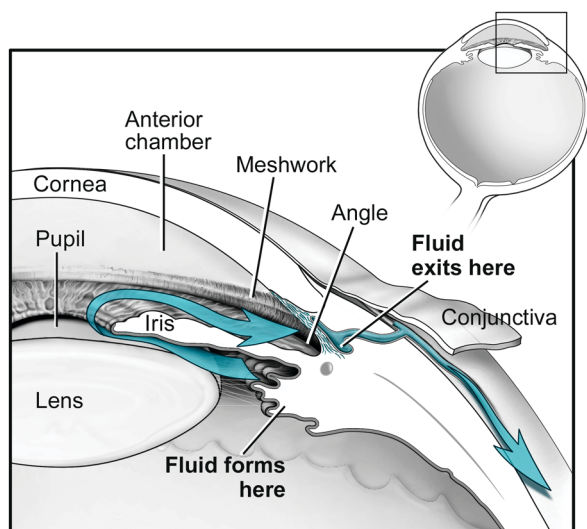


Figure 2. Blue arrows indicate the flow of aqueous fluid. (Image courtesy of the National Eye Institute, National Institutes of Health.)

We note that tonometry, the standard measurement of intraocular pressure, measures the anterior chamber pressure but does not estimate the true pressure in the posterior chamber and vitreous cavity. Hence, the operative pressure at the site of glaucoma interest, the retina and optic nerve head, may be incorrectly estimated in some eyes with narrow channel heights, thereby obscuring a risk factor.

Our iris model predicts that changes in pupil size affect the geometry of the iris–lens channel and the

anterior chamber angle. For instance, if the volume of the iris is conserved upon dilation, the iris can be expected to increase up to 50% in thickness, causing the iris to block the anterior chamber angle. Blocking the angle would impede aqueous flow and lead to higher intraocular pressure. Therefore, the iris must act like a sponge and ultimately lose volume upon dilation to maintain healthy aqueous flow.

We used ultrasound biomicroscopy to image the eye in conditions of bright light (Fig. 3) and darkness (Fig. 4). Upon dilation in darkness, we found immediate iris thickening with anterior chamber narrowing, as predicted. In further work, we used anterior segment ocular coherence tomography and found that, for normal healthy eyes, the iris loses volume within ~10 s after dilation by releasing fluid, thereby returning the iris to a thinner conformation and opening the exit angle. However, we found that eyes with angle-closure glaucoma do this much more slowly.² It turns out that those with acute attacks of angle-closure glaucoma lose no iris volume upon pupil dilation.

Our research collaboration has uncovered an important new concept for the field of angle-closure glaucoma. Pupil dilation is accompanied by iris thickening and angle closure, giving rise to constraints on aqueous flow and changes in intraocular pressure. For healthy aqueous flow, the iris needs to lose volume upon pupil dilation. This discovery translates into an additional new risk factor in angle-closure glaucoma damage and, in the future, may lead to a predictive, noninvasive test.

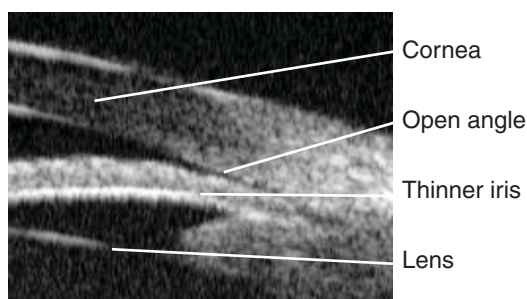


Figure 3. Bright light causes pupil constriction, accompanied by a thinner iris and an open angle.

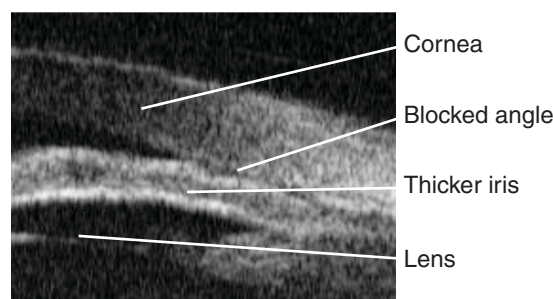


Figure 4. Darkness causes pupil dilation, accompanied by a thicker iris and a blocked angle.

For further information on the work reported here, see the references below or contact david.m.silver@jhuapl.edu.

¹Silver, D. M., and Quigley, H. A., “Aqueous Flow Through the Iris-Lens Channel: Estimates of Differential Pressure Between the Anterior and Posterior Chambers,” *J. Glaucoma* 13, 100–107 (2004).

²Quigley, H. A., Silver, D. M., Friedman, D. S., He, M., Plyler, R. J., Eberhart, C. G., Jampel, H. D., and Ramulu, P., “Iris Cross-Sectional Area Decreases with Pupil Dilation and Its Dynamic Behavior Is a Risk Factor in Angle Closure,” *J. Glaucoma* 18, 173–179 (2009).