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Practical Aqueous Humor Dynamics

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Clinical Relevance

Aqueous Humor Formation

Aqueous humor is produced by the ciliary body and flows into the posterior chamber at a rate of approximately 2 to 3 microliters per minute.[1] It is believed that at least a majority of this aqueous humor production derives from active secretion of the ciliary epithelium bilayer, which is in continuity posteriorly with the adjacent retinal and, anteriorly, the iris epithelia. The outer (sclerad) pigmented ciliary epithelial cell layer lies apex-to-apex to the inner (vitread) nonpigmented ciliary epithelial cell layer. The base of the latter cells faces the posterior chamber. (Exfoliation material may occur on the base of this cell layer.)

The stroma of the ciliary body (sclerad to the pigmented ciliary epithelium) contains numerous capillaries. Potentially, both this blood supply area as well as the secreting ciliary epithelial cells themselves may be sites of drug or laser obliterative actions. Although the nonpigmented ciliary epithelium has frequently been identified as containing the enzymatic machinery involved in active aqueous humor secretion,[2-4] the actual process may require the coupling of both the nonpigmented and pigmented cell layers.[5]

It is believed that bicarbonate is actively secreted into the posterior chamber by the ciliary epithelium, carrying water with it and thus representing part of the active secretion of aqueous humor.[6] This is under the control of the enzyme, carbonic anhydrase, in the ciliary epithelium (presumably nonpigmented). Thus, carbonic anhydrase inhibitors (CAIs) can reduce aqueous humor formation (up to 40% to 50%).

Beta-adrenergic agonist activity has been believed to be involved in active secretion of aqueous humor,[1] such that beta blockade will result in a decrease in this secretion. Many investigators have thought that the site of beta-blocker activity is at the level of the ciliary epithelium, but a vascular site has not been totally ruled out. The effects of beta blockade and carbonic anhydrase inhibition are not fully additive, suggesting that there are some linkage and interrelated effects.[7]

Apraclonidine, an alpha-2 agonist, reduces aqueous humor formation[8] and is also partially additive to both CAIs and beta-blockers, but it is not certain whether the site of action is ciliary epithelial or vascular. (The vasoconstriction that the drug produces might suggest the latter.) Brimonidine is a relatively selective alpha-2 adrenergic receptor agonist. Fluorophotometric studies suggest that brimonidine tartrate has a dual mechanism of action by reducing aqueous humor production and increasing uveoscleral outflow.

The part of aqueous humor formation that is not active transport has in previous times been called *ultrafiltration*. However, whether this is a passive pressure-driven process (presumably under vascular control) or some other ciliary epithelial cell process (eg, uncatalyzed hydration of CO_2) is unclear.

Aqueous humor moves from the ciliary epithelium into the posterior chamber, and then through the pupil into the anterior chamber (AC) (Figure 3-1). Because there is usually some pupillary resistance to forward fluid flow (which is termed *relative pupillary block*), the pressure is slightly higher in the posterior chamber than the AC, resulting in forward iris convexity. In the extreme, this can cause the peripheral iris to move over the front of the trabecular meshwork (TM) and thus cause angle-closure glaucoma (usually due to pupillary block) (see Chapter 22). Iris convexity or concavity is thus a useful indicator of relative pressures in the posterior and ACs. (See later discussions of iris concavity in pigmentary glaucoma [Chapter 21] and also various iris retraction syndromes where, for example, there is posterior movement of fluid out of the eye through a retinal hole.)

Kahook MY, Schuman JS, eds.
Chandler and Grant's Glaucoma, Fifth Edition (pp 17-23).