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ARGON LASER TREATMENT OF OPEN ANGLE GLAUCOMA

I

Photocoagulation of the anterior chamber angle as a new treatment for open angle glaucoma has recently been described by Dr. James B. Wise and Dr. Stanton L. Witter, writing in the February 1979 issue of the Archives of Ophthalmology, (Vol. 97, page 319). They report that following therapy with the argon laser, they observed pressure reduction in forty of 41 phakic eyes. Their work has been repeated, with comparable results, by other ophthalmologists, and it seems possible that their technique will prove to be an important adjunct in the treatment of the disease.

Initial efforts to improve drainage of aqueous from the glaucomatous eye by means of photocoagulation of the angle structures were directed at fashioning, by means of heat-induced necrosis, new pores or passages in the trabecular meshwork. In retrospect, it is not surprising that the results of such efforts were disappointing, since one might anticipate that whatever tissue was destroyed by the laser would quickly be replaced by equally impermeable scars. The method of Wise and Witter, on the other hand, differs from earlier work in that it does not attempt to create new channels for aqueous drainage but to enhance the function of existing ones by subjecting them to mechanical forces similar to those by which miotics are thought to improve the facility of outflow.

Resistance to the outflow of aqueous may occur both within the trabecular meshwork and within the canal of Schlemm, and the resistance of either of these structures may increase or decrease by its being compressed or distended as the case might be. The evidence as to which site of resistance, meshwork or canal of Schlemm, predominates in the control of aqueous humor dynamics is as yet inconclusive. Laser photocoagulation of the inner wall of the trabecular meshwork can potentially affect them both.

Consider the trabecular meshwork as a filter having the shape of a ring. In order to escape from the eye, fluid must pass from the inner surface to the outer surface of the ring. The inner surface of the ring faces the anterior chamber. If the ring is compact, so that the distance from its inner to its outer surface is small, its pores will be compressed, and fluid will have a difficult time getting through. If, on the other hand, the ring is spongy, so that the distance from its inner to its outer wall is increased, then it stands to reason that the fluid channels within the meshwork will be large and will present much less resistance to the flow of fluid. The outer surface of the ring is the canal of Schlemm. If the canal of Schlemm is collapsed, or nearly so, its flow resistance will be high. If, on the other hand, the canal is distended, its resistance, obviously, will be very low.

It has long been assumed that pilocarpine lowers the intraocular pressure either by opening the canal of Schlemm or by distending the trabecular meshwork, or both. When pilocarpine causes the ciliary muscle to contract, it is thought that the scleral spur is drawn posterior and inward by a small amount, the trabecular meshwork is distended, its pores are enlarged, and the resistance that it offers to the drainage of aqueous is correspondingly decreased. Since the canal of Schlemm is formed in part by the outer wall of the meshwork, distention of the meshwork from its inner aspect, if sufficient in magnitude, will also tend to open the canal. Because of the rigidity of the scleral tissue, the effect of pharmacologic stimulation of the ciliary muscle is limited. It can accomplish only so much, and unfortunately, there are many patients with open angle glaucoma for whom what miotics can accomplish is not enough. It is easy to understand how the effectiveness of pilocarpine, or for that matter, of the tissue forces in the unmedicated eye might be enhanced, if the inner wall of the meshwork were somehow tightened, were made more taut. This, precisely, is what photocoagulation of the meshwork is designed to achieve. The discussion which follows reflects the best current hypotheses. In time they will be confirmed or refuted.

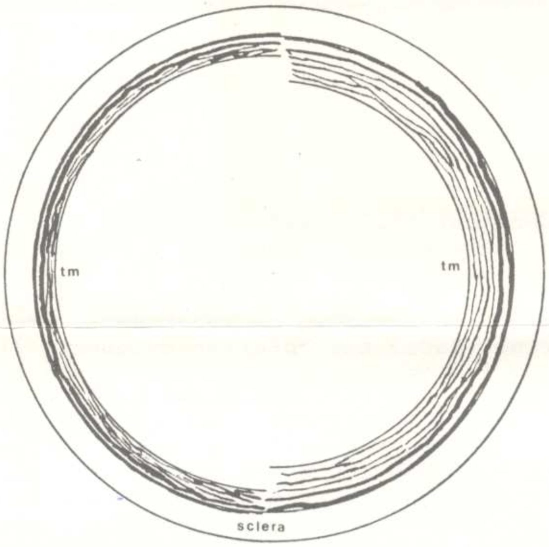

FIGURE 1 - Diagram of section in equatorial plane at level of trabecular meshwork, on the left, before, and on the right, after photocoagulation. Notice that on the left, the trabecular meshwork (tm) is compact, and the canal of Schlemm is narrow, while on the right, where photocoagulation has decreased both the circumference of the inner wall of the meshwork and its radius of curvature, the meshwork is distended and the canal widened. It is not known whether the enhanced facility occurs primarily in the meshwork or in the canal.

The punctate burns produced by the laser beam on the meshwork cause its inner wall to shrink. Immediate contraction occurs from the denaturing of collagen. Delayed contraction follows as collagen is replaced by new fibrous tissue. The effect of the laser-induced burns, therefore, is to diminish the circumference of the inner wall of the trabecular meshwork. The decrease of the circumference entails a decrease also of the radius of the inner wall, and a corresponding centripetal tension within the meshwork. Depending on the respective elastic properties of the meshwork itself and of the wall of the canal of Schlemm, this centripetal tension may open either the interspaces of the meshwork or the lumen of the canal of Schlemm or both. When the amount of energy delivered is small, the deeper layers of the meshwork are unaffected, and on account of its contraction the inner wall is pulled away from the outer wall, thereby enlarging the intra-trabecular channels. As the energy of the laser beam is increased, the scarring may extend through the depth of the meshwork, causing the deep layers to shrink as much as the superficial ones. Under these circumstances, no distention of the meshwork will be brought about, but contraction of the circumference of the meshwork may still serve to open the canal of Schlemm. Finally, if photocoagulation is so strong as to cause necrosis of the canal as well, the outflow mechanism will be effectively destroyed, and severe tension elevation may be expected to supervene. It is likely that when the energy delivered exceeds a certain critical but as yet undefined threshold, the procedure is bound to fail.

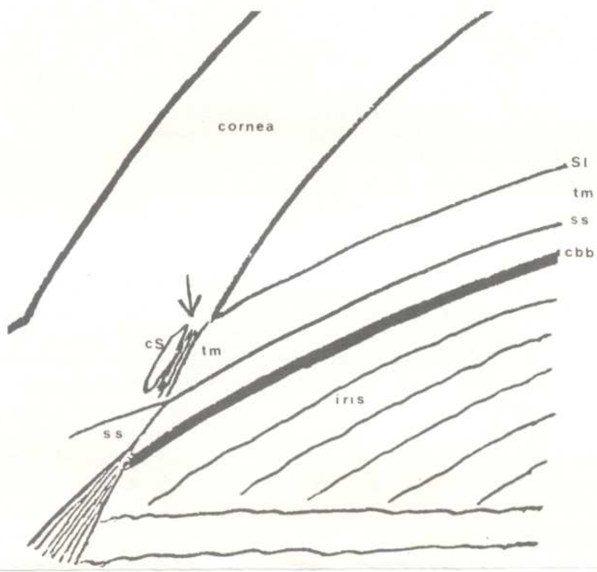

FIGURE 2 - Diagram of anterior chamber angle before photocoagulation. cS, canal of Schlemm; tm, trabecular meshwork; ss, scleral spur; cbb, ciliary body band; Compare Figure 3.

In choosing the parameters of treatment, one must keep in mind that in the area where it is struck by the beam of the laser the function of the trabecular meshwork is destroyed. Wise and Witter emphasize that the time of the laser photocoagulation is critical and should not be greater than 0.1 second, but parameters other than the duration of the laser burst are also of importance, specifically the number, size, intensity and distribution of the spots. Excessive treatment is as likely a cause of failure as too little. Wise and Witter calculate, and it is easy to confirm their arithmetic, that the exposure they advocate cauterizes 14% of the meshwork. It is because the function of the remaining 86% is substantially enhanced that the overall outflow facility increases and the pressure declines. Thus one may construct a curve representing the facility of outflow as a function of the total area of meshwork surface cauterized. As one increases the area of meshwork cauterized, one would expect the facility of outflow likewise to increase, up to a point. But beyond that point, increasing the area further will bring about a diminution in outflow facility, as the increase in facility produced by the distention of the meshwork or of the canal of Schlemm, as the case may be, is more than offset by the decrease of facility brought about by the loss of surface area, until, if the entire meshwork were destroyed, the facility would approach zero. As information about the effect of varying the parameters of treatment is obtained, the shape of the curve will become apparent.

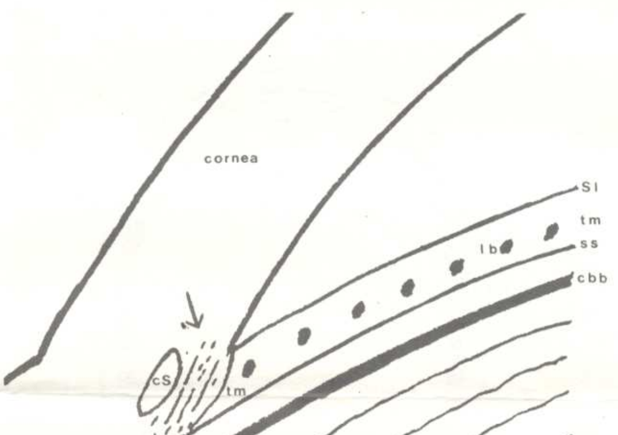

FIGURE 3 - Diagram of anterior chamber angle after photocoagulation, with laser burns (lb) on the meshwork. Compare with Figure 2, and notice the wide-open canal of Schlemm (cS) and the distended trabecular meshwork.

When the entire meshwork is treated at one sitting, one may sometimes observe, a day or two after treatment, marked elevation of the intraocular pressure. In some patients this elevation has proved so severe that it has led to immediate filtering surgery and at least one patient is reported to have been subjected to peripheral iridectomy in the belief, almost certainly mistaken, that angle closure had supervened. The patient is placed on miotics, epinephrine, timolol and carbonic anhydrase inhibitors, if he is not receiving them already. If the tension does not decrease promptly, osmotic agents may be necessary. The tension elevation seems to subside in a week to ten days, provided the glaucoma has not been made permanently worse by too extensive treatment. A substantial proportion of patients who have such transient tension elevation seem to get good results from laser treatment in the end. An occasional patient, however, may need prompt filtering surgery. In any event, since most eyes subjected to laser photocoagulation of the meshwork have discs that are badly damaged, it is imperative that they be spared this further insult, transient though it be. Fortunately this potentially hazardous complication can probably be entirely avoided if the treatment is fractionated, i.e. if only one third, or at most one half of the meshwork is treated at a given session, and each treatment is separated by at least two weeks from its predecessor.

In the aphakic eye, laser photocoagulation for open angle glaucoma is relatively less effective. If photocoagulation is done prior to cataract extraction, the technique is generally successful, and its benefits appear to last beyond the cataract operation. If, however, an eye with open angle glaucoma is first subjected to cataract extraction, subsequent photocoagulation of the meshwork seems not to work so well. No explanation for this phenomenon has been offered in the literature, but if one reflects on the mechanical effects of cataract extraction on the structural mechanics of the anterior segment, a likely reason immediately becomes apparent. In the phakic eye, in addition to its other functions, the lens and its associated zonules serve to stabilize the sclera and to maintain the sphericity of the anterior segment. The tension of the zonules which acts to cause accommodation for distance also serves to maintain the circular shape of the ciliary body. After cataract extraction, these forces are absent, and external forces, perhaps those exerted by the lateral recti muscles, tend to deform the anterior segment, creating the well-known astigmatic refractive errors of the aphakic eye. As a result of this distortion, the cross-section of the sclera overlying the trabecular meshwork

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ceases to be circular and becomes oval or elliptical. The trabecular meshwork may, in this context, be viewed as an elastic band attached to the inner surface of the sclera. When, following lens extraction, the cross-section of the sclera becomes elliptical, the trabecular meshwork is also deformed, as follows: Where the meshwork is oriented parallel to the major axis of the ellipse, the inner wall of the meshwork is stretched and the body of the meshwork is compressed. Where the meshwork is oriented parallel to the minor axis of the ellipse, the inner wall of the meshwork is made flaccid and the body of the meshwork is distended. That is why photocoagulation of the distorted meshwork in the aphakic eye is less likely to bring about a significant enhancement in the facility of outflow.

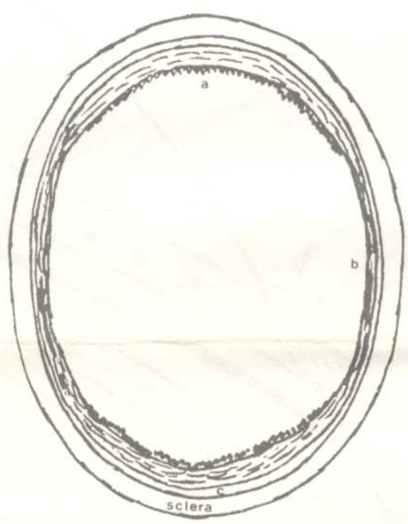

FIGURE 4 - Diagram of section of aphakic eye in equatorial plane at level of trabecular meshwork. Neither photocoagulation of the flaccid inner wall at 12 or 6 o'clock, nor photocoagulation over the compressed meshwork at 9 or 3 o'clock would have much effect on distending the meshwork or opening Schlemm's canal. Compare Figure 1.

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