CRYOSURGERY OF THE CILIARY BODY*

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DURING THE PAST YEAR the cryosurgical laboratory at New York Hospital Cornell Medical Center has been investigating the effects of freezing the ciliary body with a view to developing an operation suitable for the treatment of glaucoma. This approach to glaucoma was first made by Bietti in 1950. Bietti applied solid carbon dioxide cylinders over the ciliary body of rabbits and humans. In his paper of that year[1] he remarked that he obtained atrophy of the ciliary body and a temporary reduction in ocular pressure. He felt the procedure a safer and milder operation than cyclodiathermy, but less effective for the control of glaucoma. In December, 1963, Polack and de Roetth reported on their re-evaluation of Bietti's work.[2] They too froze the ciliary body of rabbits and, later of patients, with a carbon dioxide applicator. From their histologic sections they concluded that freezing results in an eventual hyperplasia of ciliary epithelium. Like Bietti they observed that the ocular pressure in animals was temporarily reduced by freezing and tends to return to normal. However, it was their feeling that the restoration of ocular pressure to normal levels was the result of a homeostatic mechanism and that in fact aqueous production was permanently reduced. It was therefore concluded that the operation might succeed in the glaucomatous eye where presumably the homeostatic mechanism would be less effective.

In our laboratories the investigation of a cyclocryothermy operation had been planned as one part of our work on cryosurgery. A report on the first part of our work, concerning the treatment of retinal detachment, has already been presented.[3] In the course of the retinal work we had developed a liquid nitrogen probe with versatile performance, and so were not limited to the temperature of carbon

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dioxide. We had observed that conjunctiva and sclera tolerated freezing with little permanent damage. Most compelling, however, was the observation that neuroepithelium was very sensitive to freezing. Both the pars optica and the pars pigmentosa underwent involution after freezing. The choriocapillaris also atrophied, but the larger vessels of choroid and retina continued to function. We thought, therefore, that it might be possible to destroy ciliary epithelium and thus the secretory activity of the ciliary body, without damaging the vascular integrity of the eye. Further, we felt that as conjunctiva and sclera tolerated freezing so well, an extensive operation would not compromise the outer coats of the eye.

MATERIALS

The liquid nitrogen apparatus, developed for retinal surgery, in collaboration with the Linde Division of the Union Carbide Company adapted easily to freezing the ciliary body (Figure 1). The apparatus stores liquid nitrogen in its handle and delivers it to the tip at a controlled rate. The temperature at the end of the probe is monitored by a thermocouple and can be lowered or raised by increasing or decreasing the rate of flow. The apparatus is engineered so that one can dial the desired temperature on the recorded controller and obtain it at the end of the probe with only a few seconds' delay. The device is capable of a range of temperature from +37°C. to −120°C., with a rate of change of 10°C. per second. With this probe we were able to search over a wide range for the ideal combination of temperature and time.

Ninety-three animal eyes were studied. Of these 70 were rabbit eyes and 23 were cat eyes. In 23 experiments the second eye was studied as a control. Seven patients with absolute or advanced glaucoma were treated with cryosurgery.

METHOD

The ciliary body of the subject eye was frozen by applying the cryosurgical probe over the limbal conjunctiva. Lesions were made ranging from −20°C. to −120°C. The time of application varied from 10 to 60 seconds and the number of applications in any one eye varied from 3 to 18.

The animal eyes were observed for clinical effect for periods of

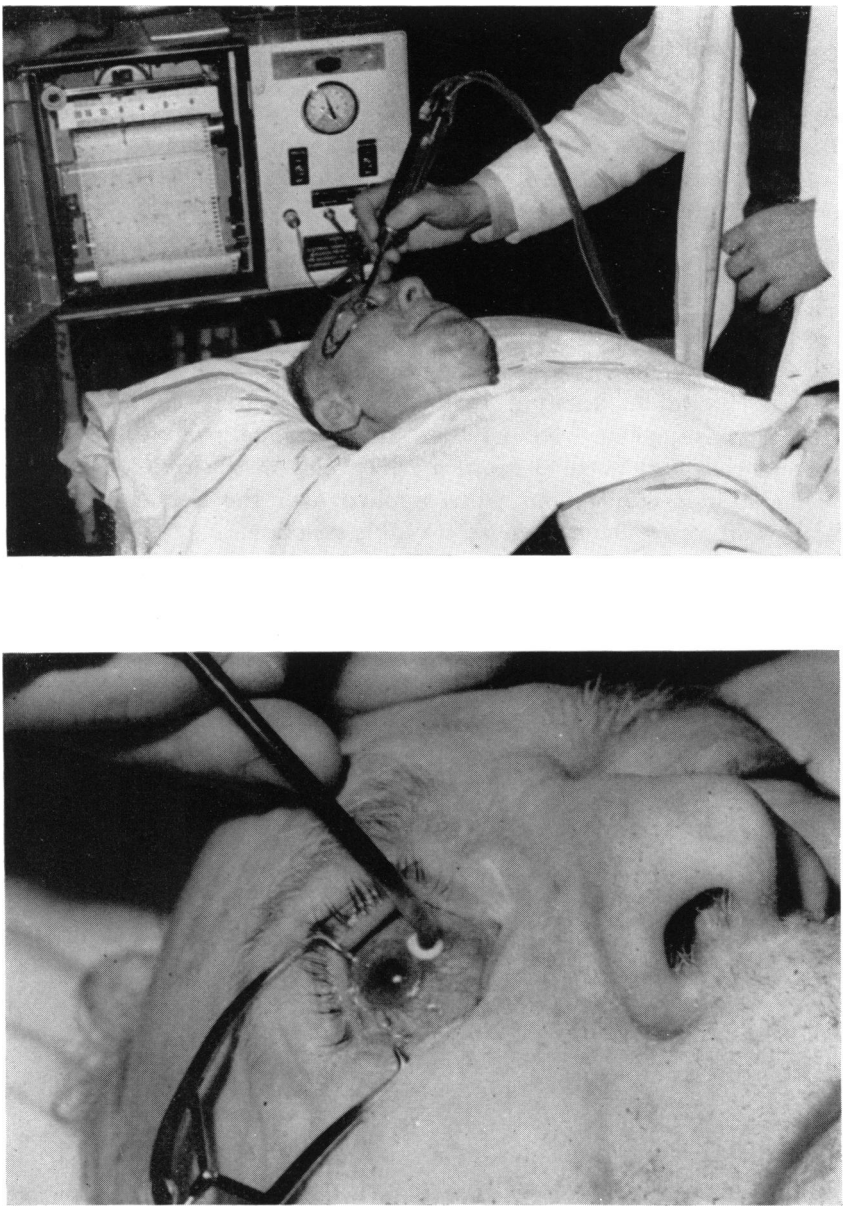


FIGURE 1

Top, probe being applied to patient's ciliary body under local anesthesia. *Bottom,* close-up of freezing lesion at −80° C. for 20 seconds.

up to three months. A comparison of the Schiøtz pressure in the operated and unoperated eye was made at frequent intervals, usually every other day. Ocular pressure was taken with the use of topical anesthesia. The procedure was standardized as much as possible so that comparative values would be meaningful. Aqueous production was studied by tonography and perfusion techniques. Finally the animals were sacrificed at periods ranging from 1 to 90 days, and gross and microscopic examination of the internal structures was made.

RESULTS OF ANIMAL EXPERIMENTS

In the retinal detachment project therapeutic lesions were produced with a probe temberature that ranged from −20°C. to −40°C. Applications in these temperature ranges, when observed ophthalmoscopically, are seen to cause a white puff in the retina in a few seconds. Such applications when applied over the depressed ciliary body were insufficient to cause a visible reaction.

HISTOLOGIC STUDIES

1. Experiments were made with the probe cooled to −20°C., −25°C., −30°C., and −40°C. for 10 to 60 seconds. One minute is

FIGURE 2

Detachment of ciliary epithelium 24 hours after freezing at −80° C.

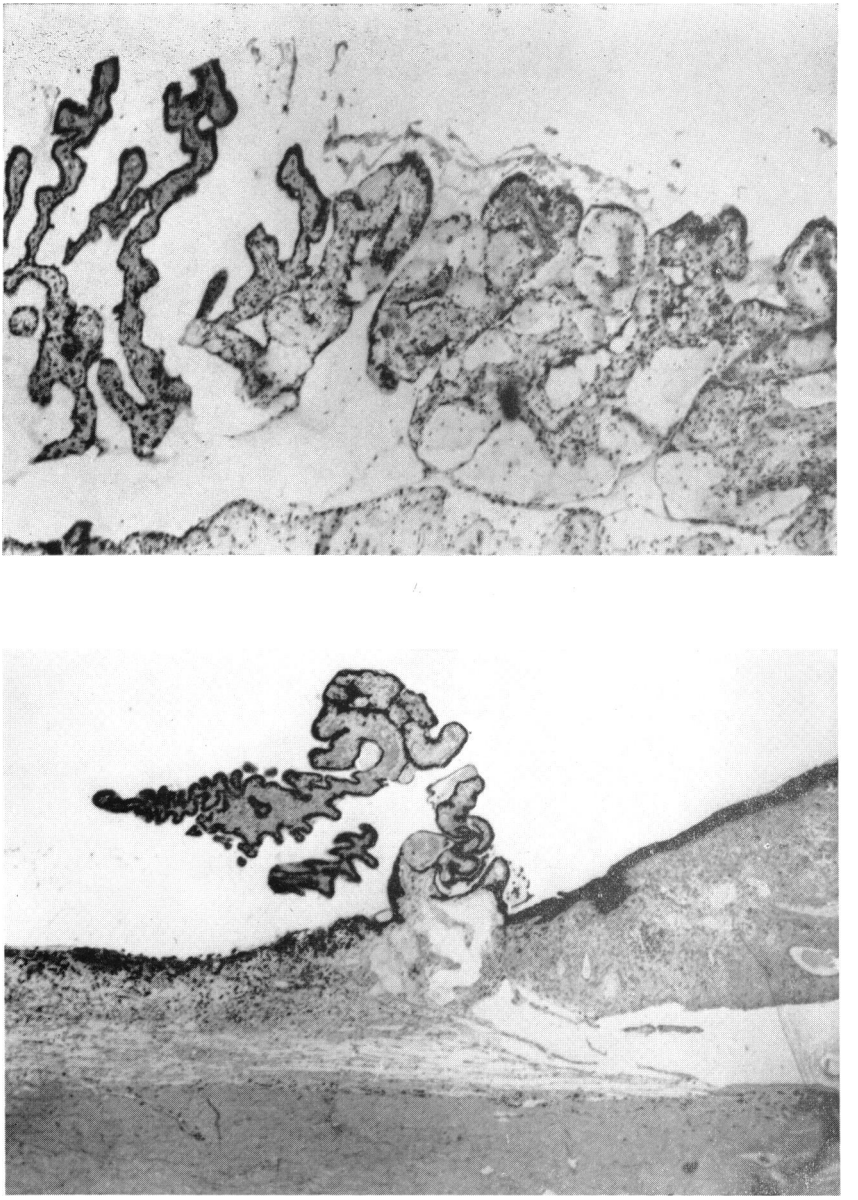


FIGURE 3

Four-day lesion showing (*top*) vacuolated epithelium, edema, congestion in albino rabbit ciliary body. *Bottom*, same with pigment dispersion in pigmented rabbit.

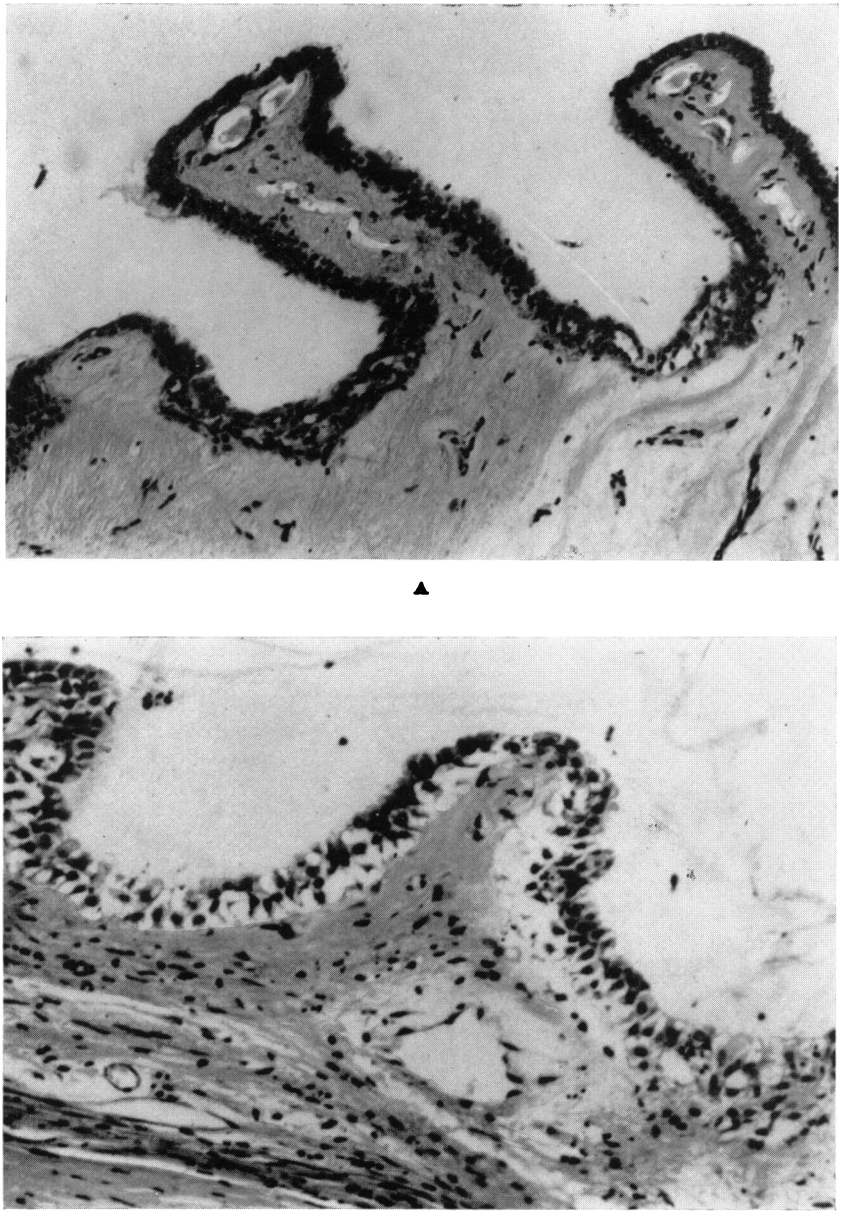
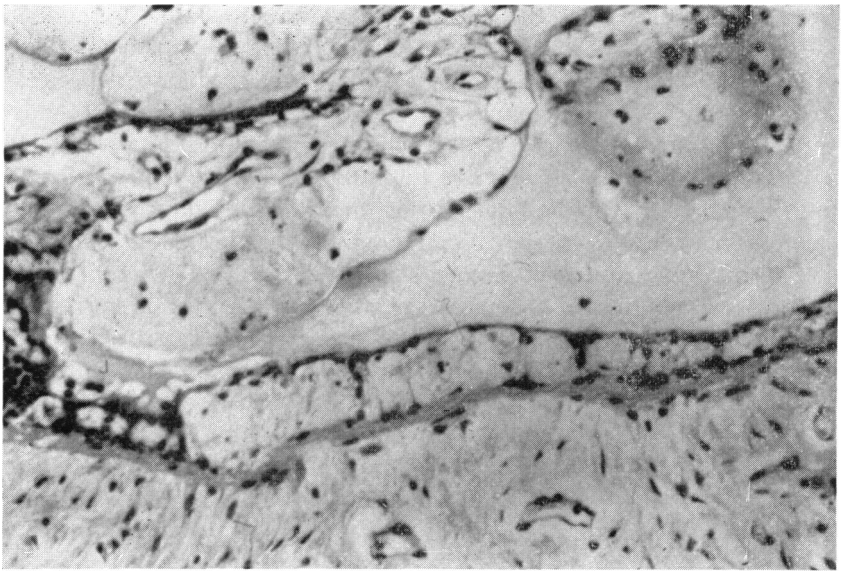


FIGURE 4. STAGES OF CYSTIC DEGENERATION OF CILIARY EPITHELIUM.
A, 2 weeks; B, 3 weeks; C, 4 weeks.



C

sufficient time for the freezing lesion to reach equilibrium; it cannot be expected to expand further beyond this time. All of the lesions caused superficial transient edema in the conjunctiva and sclera. The —40°C. application was observed in microscopic section to cause edema and congestion of the ciliary body stroma, but the epithelium was unaffected. Evidently the thickness of the ciliary body and its copious vascular supply protected the epithelium.

2. A —60°C. lesion after 30 seconds or more caused detachments of the ciliary epithelium and on occasion the white freezing effect could be seen to come through over the more posterior and thinner aspect of the ciliary body. Histologic studies confirmed that the ciliary epithelium was detached by edema and that there was mild involvement of ciliary epithelium.

3. Consistent freezing of the ciliary body was first observed with a probe temperature of —80°C. in the rabbit when applied for 10 to 20 seconds. Within a few seconds after application the ciliary epithelium was seen to detach in a balloon-like manner and there was a faint greying of the area. Suddenly, between 10 and 20 seconds, the entire area became snow white and the lesion expanded rapidly to twice the diameter of the probe, about 5 mm. When the cooling effect was turned off the white lesion disappeared and the ciliary body then looked faintly grey from edema. This is the lesion we had come to know

from our retinal work to be damaging to neuroepithelium. The sudden white response, it is thought, is the moment when the warming effects of the uveal circulation are overcome. Histologic examination of areas frozen at —80°C. and enucleated for examination within 24 hours confirmed the detachment of the ciliary epithelium (Figure 2). In addition there was congestion in the ciliary processes and edema of both layers of the epithelium. During the first four days edema and congestion were seen to increase. The epithelium became vacuolated, cell membranes ruptured, pigment granules escaped from the pigmented epithelium, and in some areas one or both layers of epithelium sloughed off (Figure 3). Thereafter there was resolution of edema. The epithelium that remained in place became cystic and flattened, the nuclei became pyknotic (Figure 4). There can be no doubt that severe damage had occurred to the ciliary epithelium. Thereafter more and more atrophy of the affected portions of the ciliary body occurred. We did not observe regeneration of ciliary epithelium as reported by Polack and de Roetth.

4. Applications of —100°C. to —120°C. caused white responses on the surface of the ciliary body of rabbits even more rapidly and when

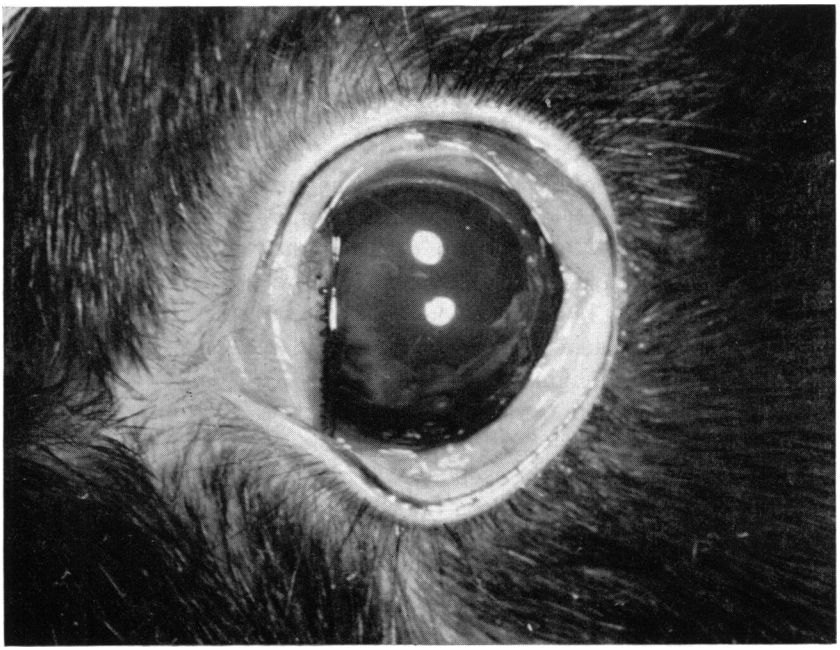


FIGURE 5. PLASTIC IRITIS (RABBIT).

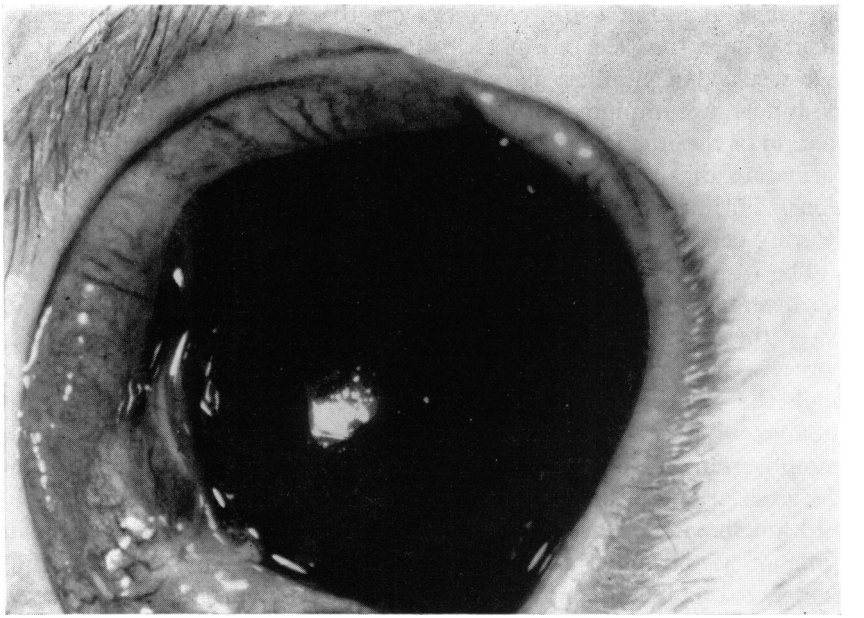


FIGURE 6. GRANULAR APPEARANCE OF RABBIT CORNEA AFTER EXTENSIVE FREEZING OF CILIARY BODY

application was maintained the lesion expanded more broadly. Histologic sections revealed a similar but more extensive picture of ciliary body destruction than seen in the —80°C.-treated animal. Where at —80°C. the epithelium on the inner ends of the villi would frequently survive, this was less likely to occur after the colder applications.

CLINICAL EFFECT

The colder and more extensive the application the more severe the iridocyclitic response. With applications in the range of —20°C. to —40°C. the cyclitic response was mild. There was moderate aqueous flare and cellular response which resolved without treatment in a few days. Lesions at —60°C. caused a more severe and persistent inflammation which nevertheless resolved in five to seven days. Lesions at —80°C. when applied over more than half the circumference of the globe caused a severe plastic iridocyclitis (Figure 5). The pupil became dilated and unresponsive. The periphery of the retina became hazy from exudate into the anterior vitreous. The cornea developed a granular appearance from changes in the superficial layers (Figure 6).

The normal rabbit eye recovered from these changes without treatment. The cornea cleared in a week, the iridocyclitis lasted as long as two weeks and pupillary paresis even longer. In pigmented animals a disappearance of pigment in the iris was seen on the second day at the margin of the iris. It expanded towards the pupillary edge in a scallop formation that corresponded to the position of the freezing applications. This was additional evidence of the sensitivity of pigment-bearing cells to freezing which had been observed in the retinal work.

The —120°C. application and to a lesser degree the —100°C. application were productive of anterior chamber hemorrhages. In some cases these absorbed, in others they caused blood staining of the cornea. There was a severe iridocyclitis. In one instance a hypopyon could be seen in the blood-filled chamber. This eye, together with another of a series of twelve so treated succumbed to the acute complications. After enucleation the gross section revealed that both the anterior and posterior chambers were filled with a dense exudative and inflammatory mass. In the eyes that recovered there was corneal damage, iris atrophy, anterior and posterior lens capsule deposits, and evidence that edema of the optic disc had occurred. All of these changes were less marked in eyes treated with —100°C. than in eyes treated with —120°C.

The aqueous of eyes treated with cyclocryothermy was aspirated and examined for protein content by precipitating with trichloroacetic acid. The aqueous of the unoperated eyes was examined in the same way as a control. The studies were done late in the healed phase, after the clinical signs of inflammation had disappeared and the anterior chamber was clear. The protein content in the operated eye was uniformly increased. The quantity of protein varied with the intensity of the cold treatment.

EFFECT ON INTRAOCULAR PRESSURE

Cyclocryothermy temporarily diminished intraocular pressure. The extent and duration of the effect varied with the degree of cold and the extent of the cold applications. There was also some indication that the effect varied with the severity of the associated iridocyclitis. Applications of the range of —20°C. to —40°C. had only the most transient effect on intraocular pressure, probably related to the vascular trauma produced. Applications of —60°C. over more than one-half the ciliary body caused the intraocular pressure to drop 3 to 5 Schiøtz scale units. Maximum depression occurred by the second or third day and thereafter the eye slowly recovered until normal pressure was

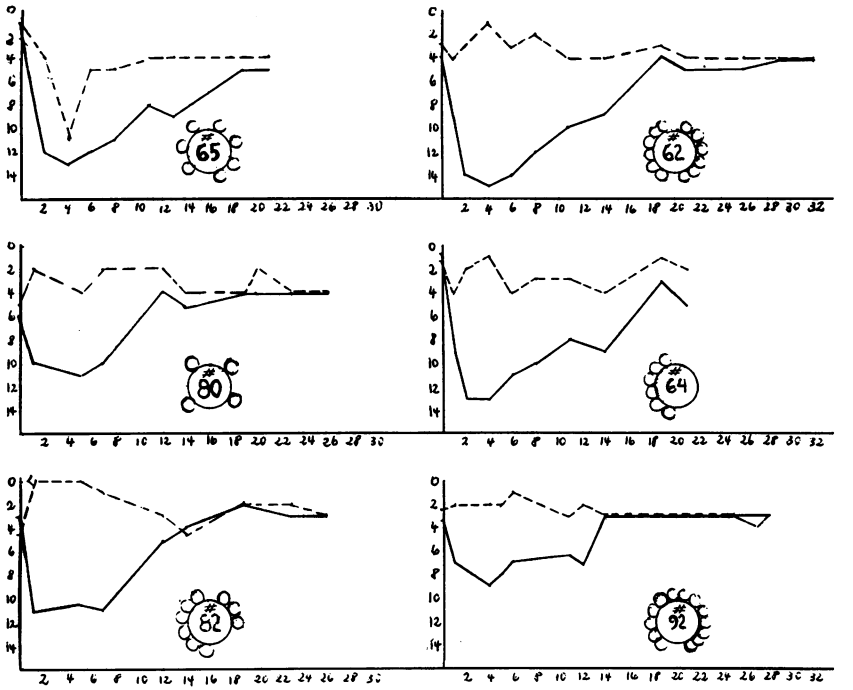


FIGURE 7

Pressure curves in rabbits after freezing at —80° C. for 20 to 30 seconds. Solid line is treated eye. Ordinate in Schiøtz scale, abscissa in days.

reached on the tenth or twelfth day. Applications of —80°C. for 20 to 30 seconds over one-quarter to three-quarters of the surface of the ciliary body caused a drop in pressure of 8 to 12 Schiøtz scale units on the first to fifth postoperative day. The response was more sustained and recovery took place in 12 to 18 days (Figure 7). In an attempt to extend the duration of the hypotonous effect, and at the same time to reduce the iridocyclitic response, a group of animals was treated with encircling operations of —80°C. applications for 10 to 15 seconds (Figure 8). The 10- to 15-second application was just sufficient to produce a white puff over the ciliary body, but not long enough to allow any spread or consolidation of the whitening effect. The result was a smaller drop in intraocular pressure with the effect only slightly more sustained. Postoperative iridocyclitis was significantly reduced. The —80°C. experiments suggested that the early postoperative drop in intraocular pressure was the result of ciliary body shock and iridocyclitis rather than of damage to the secretory epithelium. The fact

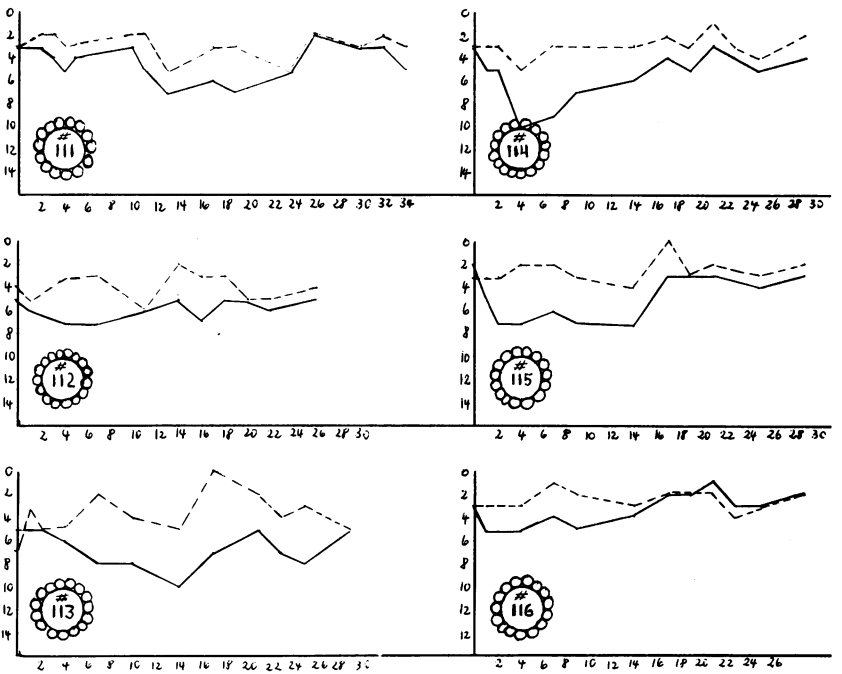


FIGURE 8

Pressure curves in rabbits after freezing at −80° C. for 10 to 15 seconds. Solid line is treated eye. Ordinate in Schiøtz scale, abscissa in days.

that one obtained the same pattern of hypotony and recovery regardless of the extent of the application over the ciliary body supports this view. The further fact that the hypotonous effect is reduced with the lesion of shorter duration, even though it encircles the globe, also points to an acute shock and inflammatory mechanism.

TONOGRAPHIC STUDIES

We were interested in knowing whether aqueous production was reduced by freezing of the ciliary body. It had been suggested that while the intraocular pressure might return to normal, this could be the result of a homeostatic mechanism, which in the presence of a reduced aqueous production caused a comparative reduction in outflow. Tonograms were done on a series of rabbits 30 to 60 days after ocular cryosurgery. The eyes had recovered from the acute iridocyclitis response. The daily intraocular pressure readings had leveled off. The

TABLE 1.
(18 rabbit eyes)

Before freezing		*After freezing*	
P_0	F	P_0	F
19.2 ±3.0	1.56 ±0.82	14.9 ±3.3	0.80 ±0.55

numerical results of these studies were somewhat erratic, as we have come to expect from rabbit tonograms. However, the values computed for aqueous production were consistently lower in the operated eye (Table 1).

PERFUSION STUDIES*

In an attempt to obtain more critical data on aqueous production, simultaneous perfusions were done in the treated and untreated eyes of rabbits that had undergone encircling operations, and the decay curves recorded were analyzed. Rabbits that had undergone the —80°C. application and had completely recovered their preoperative intraocular pressures showed identical decay curves in the operated and unoperated eyes (Figure 9). From this one must conclude that the aqueous dynamics in the recovered eyes were unchanged. The decay curves were significantly different in rabbits that had sustained hypotony from encircling operations of —120°C. The decay was more rapid in the treated eyes (Figure 10). When the decay curves had reached equilibrium the pressure in the perfusion systems connected to the two eyes was lowered simultaneously. The untreated eye recovered its equilibrium pressure rapidly, indicating normal aqueous production. There was minimum recovery in the operated eye, suggesting diminished aqueous production.

EFFECTS ON GLAUCOMA PATIENTS

Following the reported success of Polack and de Roetth in the treatment of glaucoma with six applications with a carbon dioxide applicator, we made similar lesions with the liquid nitrogen probe cooled to —80°C. for 20 to 60 seconds. The patients selected for the procedure had advanced glaucoma. All but one had had extensive

*The perfusion studies were done at the Wilmer Institute, Baltimore, under the direction of Dr. Maurice Langham.

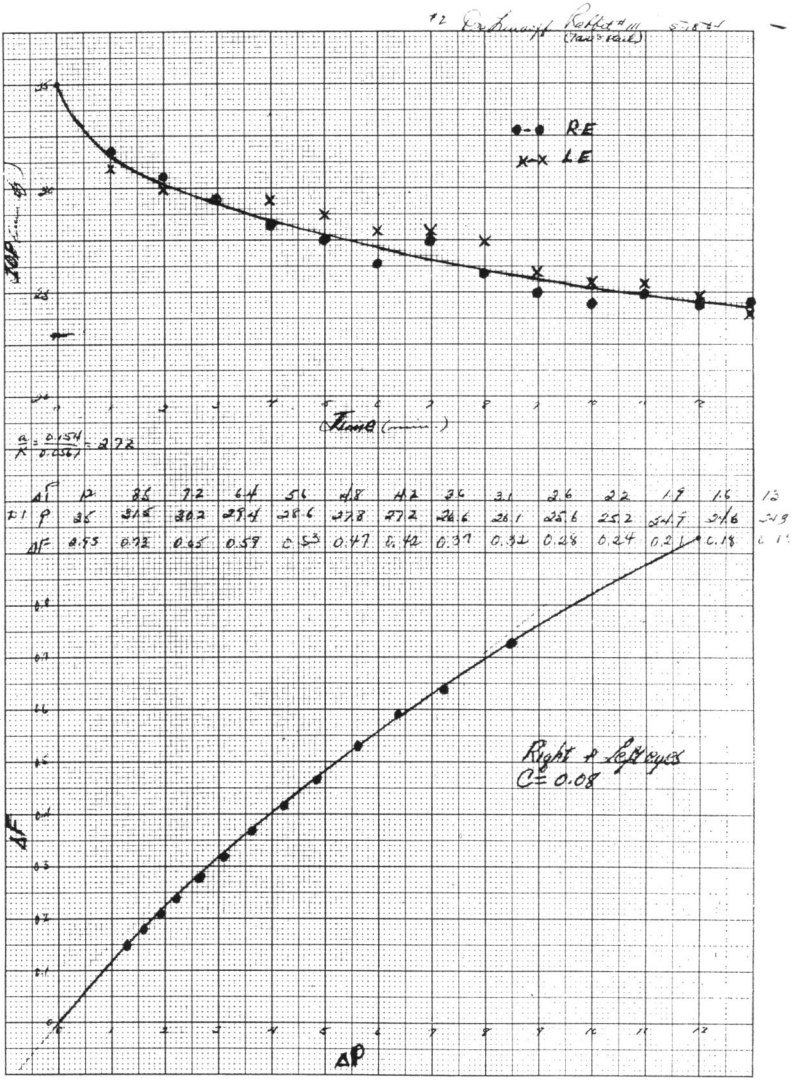


FIGURE 9

Perfusion study in rabbit that had recovered after —80° C. treatment.

glaucoma surgery and the eyes were blind or nearly so. One patient had chronic open-angle glaucoma of long duration with only a five-degree field and had refused all previous surgery. He agreed to submit to cold treatment. Five of a total of seven cases had only a transient

lowering of pressure, or none at all. In one case the pressure was lowered from 70 to 30 mm. Hg and has remained so for three months. For the case uncomplicated by previous surgery, the patient's pressure dropped from 40 to 14 mm. Hg in three days and has maintained that for two months.

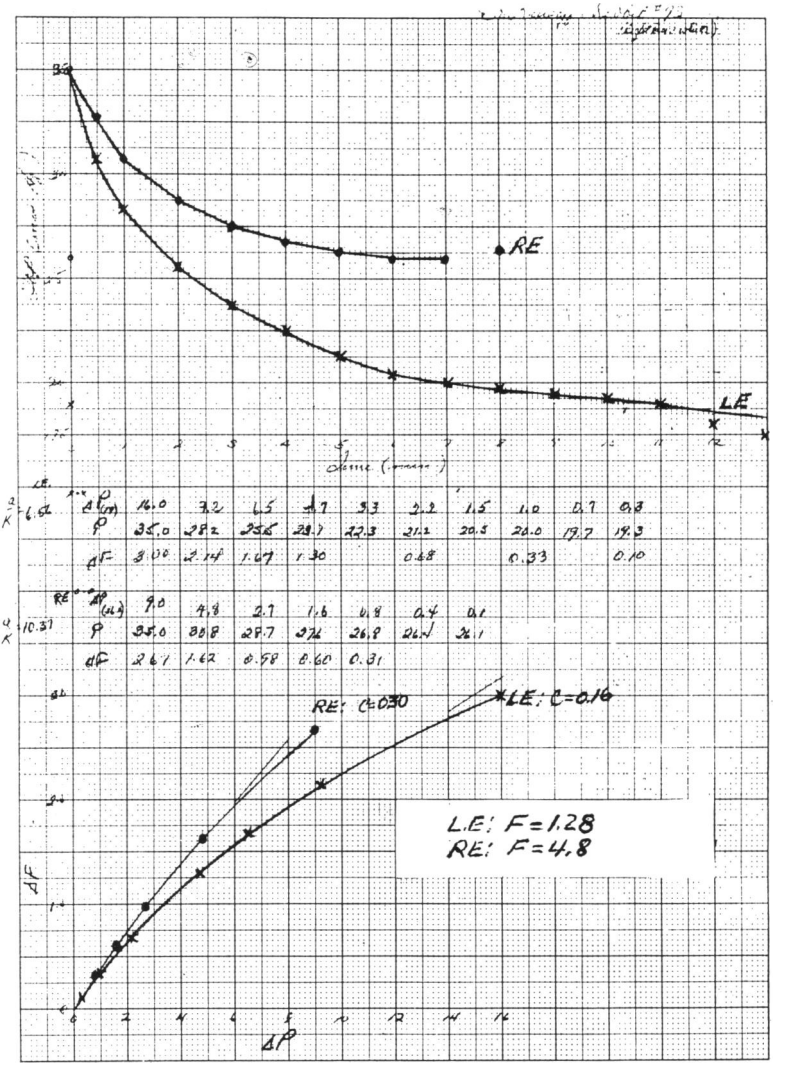


FIGURE 10

Perfusion study in rabbit whose treated eye (left) remained hypotonic after —120° C. treatment.

DISCUSSION

The most striking fact that emerged from our work is the relative resistance of ciliary body function to freezing. One is reminded of the experiences with cyclodiathermy operations of fifteen years ago. The initial enthusiastic response to cyclodiathermy has vanished because it is recognized that the effect on intraocular pressure was temporary and inconsistent. It was thought at the time that a more permanent effect might be obtained with a more extensive operation, but because of the destructive effects of heat to the sclera and vascular structure of the eye, which at a certain point caused pthisis, the extent of the operation was necessarily limited. The threat of pthisis is greatly reduced with cyclocryothermy. In no instance did an animal eye undergo invo-

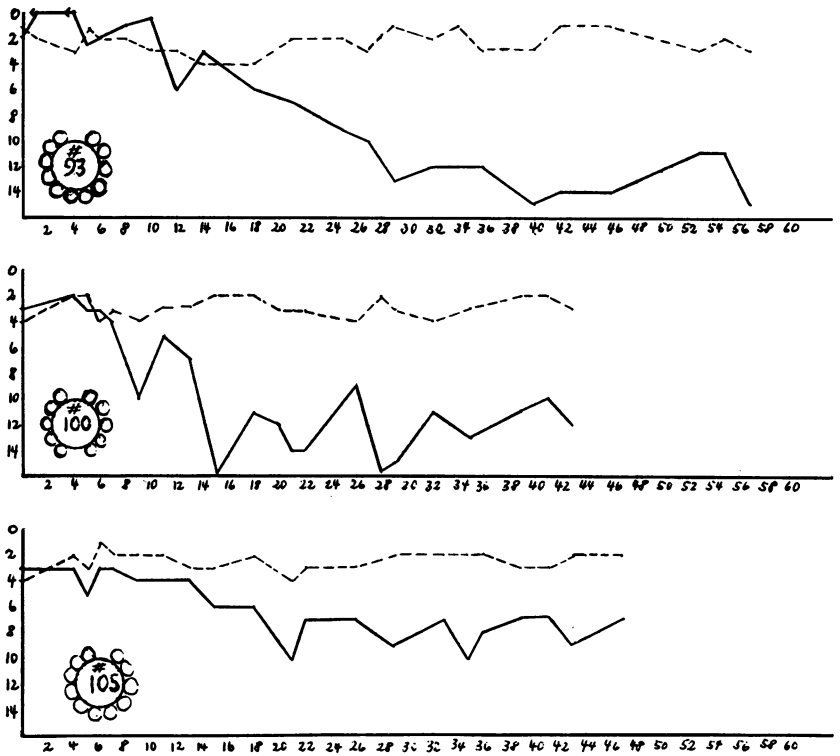


FIGURE 11

Pressure curves of rabbit eyes treated with encircling operations of −120° C. for 20 to 30 seconds. Solid line is treated eye. Ordinate in Schiøtz scale, abscissa in days.

lution with applications as low as —80°C., regardless of the extent of the operation.

Unlike Polack and de Roetth, we do not feel that regeneration of ciliary epithelium is occurring following cyclocryothermy. We think it is more likely that normal pressures are restored by the survival of even a small amount of the ciliary body. The histologic sections, as well as tonometric and perfusion data, seem to support this. If one considers the course of chronic glaucoma, where over a period of years the ciliary body undergoes great involution and yet continues to function sufficiently to maintain excessive pressure, one is encouraged in the belief that only a small portion of the ciliary body can maintain intraocular pressure.

After experimenting for ten months with gradually decreased temperature and increased time of application with no permanent effect on intraocular pressure, we began to doubt whether aqueous

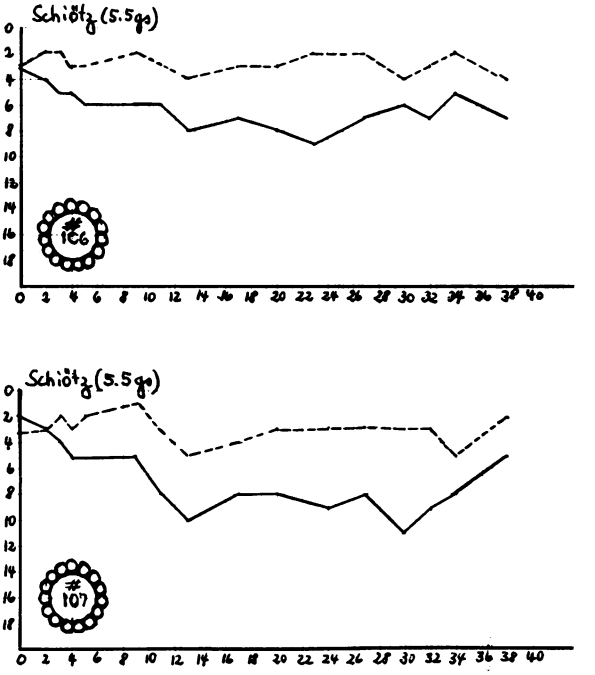


FIGURE 12

Pressure curves in rabbits treated at —100° C. for 10 to 15 seconds. Solid line is treated eye. Ordinate in Schiøtz scale, abscissa in days.

production could be permanently affected by cyclocryothermy of any degree. It was decided, therefore, to reverse our procedure, to seek a level of destruction of the eye with maximum lesions, and if this could be attained, to work back to a level of survival. We have been operating in this manner for the past three months.

Experiments to date indicate that a closely spaced —120°C. encircling operation of 20 to 30 seconds effectively destroys ciliary body function; the eyes so treated have assumed pthisical characteristics (Figure 11). Thus it is possible that a therapeutic level of treatment lies somewhere between a —80°C. encircling procedure and a —120°C. encircling procedure. To date —100°C. has effected a sustained lowering of pressure without pthisis, but this lesion causes hemorrhage and excessive iridocyclitis (Figure 12). Repeated encircling procedures at —80°C. have in some instances produced a level of hypotony similar to that which led to pthisis in the —120°C.-treated animals (Figure 13, top and bottom). In other instances recovery to preoperative levels of intraocular pressure has been complete (Figure 13, middle). The work so far indicates that the

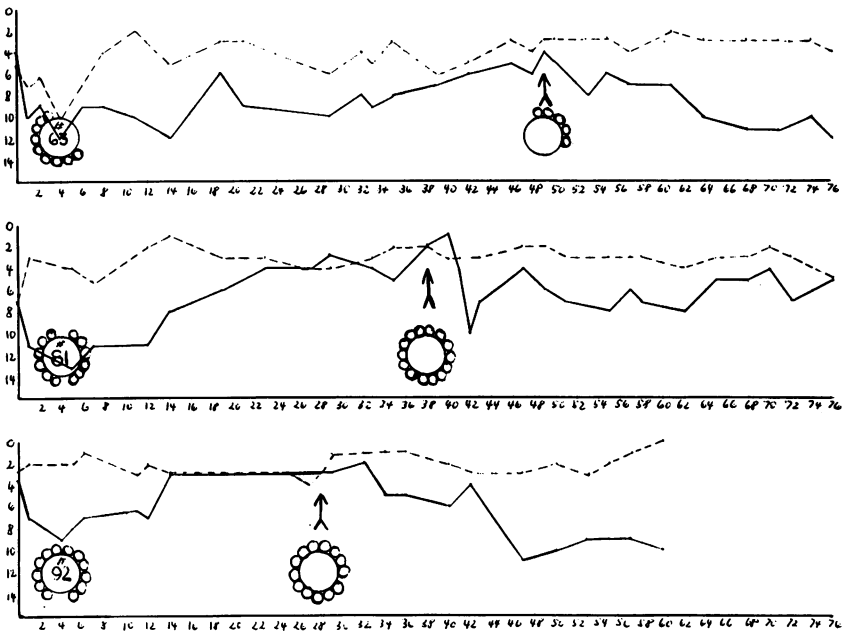


FIGURE 13

Pressure curves in rabbits that have been reoperated at —80° C. for 10 to 15 seconds. Solid line is treated eye. Ordinate in Schiøtz scale, abscissa in days.

ciliary body function following a destructive operation by cyclocryothermy either returns to a level adequate to maintain the previous intraocular pressure or is damaged to a point at which the eye is no longer viable. The stage at which the ciliary body would be damaged just enough to limit aqueous production as desired without eliminating it altogether has so far eluded us. We are inclined to think that the apparent success obtained in two of our glaucoma patients was due to the fact that they were advanced cases in which the ciliary body was already in such a state of atrophy that a relatively small amount of freezing could decompensate the aqueous dynamics of the eye. If cyclocryothermy is to become a useful procedure for glaucoma, a method of attacking the normal ciliary body in early cases must be found. This problem remains to be solved.

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DISCUSSION

DR. ANDREW DE ROETTH, JR. It is indeed a privilege and a pleasure to discuss Dr. McLean's and Dr. Lincoff's paper. They are working on a new approach to the treatment of glaucoma and are now trying to improve and perfect this novel and intriguing method. This work is of special interest to me because we have been doing similar research during this past year at Columbia-Presbyterian Medical Center in New York.

We use a very simple method; our cold applicator consists of a metal tube with a cone-shaped tip, 4 mm. in diameter. Inside the container we have a mixture of dry ice and absolute alcohol; for most of our work we employed six applications, one minute in duration, of this metal tube over the ciliary body, both in animal and in human eyes. The main disadvantage of our method is that we cannot vary the temperature, the tip of the cone having the same, constant temperature. To overcome this disadvantage we have already ordered a surgical cry-cautery machine from Union Carbide Company, similar to the one employed by Dr. McLean, but so far it has not been delivered.

There are many similarities and a few differences between the authors' results and our findings. For instance, we too were impressed by the atraumatic nature of cryocautery; these subfreezing temperatures did not harm the conjunctiva or the sclera and none of our treated eyes became

soft and atrophic. This represents an advantage over cyclodiathermy; with that procedure there was considerable permanent damage to both conjunctiva and sclera, and of course many globes finally became completely soft and atrophic.

We differ slightly from Dr. McLean's and Dr. Lincoff's findings in our clinical results. To date, we have cryocauterized 96 human glaucomatous eyes; none of these was made worse because of this treatment. In 75 per cent of these eyes the glaucoma was not improved or else beneficial results lasted only one to three months. The remaining 25 per cent of these eyes were improved, however, and the follow-up on these patients now varies from 3 to 12 months. To demonstrate what we mean by improvement, let me tell you about our very first patient, a one-eyed lady with advanced chronic simple glaucoma in her only eye. Iridencleisis was done unsucessfully on this eye three years ago and on full medical treatment, that is using Phospholine Iodide 0.25 per cent and Eppy drops twice daily and 1,000 mg. of Diamox daily, her intraocular pressure ranged from 25 to 30 mm. Hg and she was slowly losing visual field. Cryocautery was done on this eye in May, 1963. Now—one year later—she is using Phospholine Iodide and Eppy drops but no Diamox, and tension is maintained at 15 to 18. Furthermore, her visual fields have not changed for almost a year.

We wholeheartedly agree with the authors that we do not know all the effects of cryocautery on the eye in general, or the ciliary body in particular, and that a great deal more research has to be done both on animal and on human eyes. For this reason we do not encourage the widespread use of cryocautery. On the contrary, we would like to see it restricted only to research laboratories and special glaucoma clinics for the time being, until all the limitations, complications, indications, and contraindications can be properly studied and evaluated.

I would like to congratulate Dr. McLean and Dr. Lincoff for their excellent presentation of this novel and thought-provoking paper and ask two questions: In the histological sections did you look at the trabecular meshwork? At what temperature range did you find the least amount of sticking between the tip of the probe and the conjunctiva?

MAURICE LANGHAM, PH.D. I would like to add confirmation to what Dr. McLean has said. From the few studies we made for him we concluded that the pressure decreased for several weeks due to a decrease in the rate of aqueous humor formation, while the outflow facility remained unchanged.

I want to add just a few comments on the general subject of the procedure. The aim of this method is to destroy selectively the secretory non-pigmented and pigmented cells of the ciliary processes without causing major and sustained damage to the intraocular and extraocular tissues.

What can we say about the practical potentialities of the method for the control of the glaucomatous eye on the basis of our present knowledge?

First, we know that in the glaucomatous eye the rate of formation of the aqueous humor is unimpaired, even though there may be marked atrophy of the iris and ciliary processes. This reflects the fact that the ciliary processes have a marked reserve capacity to sustain aqueous humor formation. This has been evident from human and experimental surgical procedures when the iris or ciliary processes have been partially removed.

Results of the present authors provide confirmation that freezing or probable destruction of 50 per cent of the ciliary processes caused a transient decrease in the pressure and rate of aqueous humor formation. On physiological grounds this is not surprising, for in the normal eye only one per cent of the blood flow into the ciliary processes is secreted into the eye. We are therefore faced with the need to undertake extensive freezing of the eye to cause a significant fall in the intraocular pressure which involves additional damage to the circulation and the nutrition of the intraocular and avascular tissues of the eye. Even when this is achieved one is left with the probability that the outflow mechanism remains unimpaired. To my mind, the outflow mechanism remains the main object of treatment of glaucoma because if the outflow mechanism is not markedly improved even small rates of aqueous humor formation will lead to large changes in pressure.

Thus, this technique, to my mind, cannot be a substitute for present procedures designed to improve drainage. Possibly it can be an additional procedure in unresponsive glaucoma. However, in view of the extensive nature of the procedure and the many side reactions in terms of circulatory tissue and nutritional changes that may be caused, I believe strongly it should be used as a clinical glaucomatous procedure with much caution.

DR. A. EDWARD MAUMENEE. In 1948 Walter Kornblueth and I used dry ice in alcohol with a brass rod to freeze the cell to destroy the ciliary body in the rabbit, but found no permanent reduction in tension in the rabbit with this technique. When Dr. Smelser and Dr. Polack began using this technique to destroy corneal cells a few years ago, we went back to human cases and attempted to control the pressure in glaucoma patients, but were unsuccessful.

I would like to ask Dr. McLean a question about this: We used several eye-bank eyes. After cutting off the cornea and removing the lens, the brass rod, with the temperature reduced to —78° C., was placed on the eye. We found that the ciliary body did not turn white and did not appear to freeze. I wonder if Dr McLean used the thermocouple in eye-bank eyes or has studied human eyes that were going to be enucleated, to see if he is destroying the ciliary processes. In the human, as you well know, the ciliary processes are in quite a different location from that in the rabbit.

DR. FREDERICK H. VERHOEFF. I would like to ask whether there is a danger of this method causing cataract—more danger than other methods. The lens

is so near the ciliary body, might it not be affected directly by the treatment? If that is not so, could the nutrition of the lens be affected so that a cataract might develop, particularly a posterior cortical cataract?

DR. MCLEAN. We would like to thank the discussers for their many illuminating remarks, and particularly Dr. de Roetth and Dr. Langham for their support. In a sort of summary answer to the questions that have been raised, I might make several points.

First, in the human the iridocyclitis effect is very transient and can be controlled rather well with topical steroids. They do not have to be used for very long.

In answer to Dr. Langham's implied criticism, we are not beginning to advocate this as a substitute for ordinary glaucoma surgery, but though it might possibly be a substitute for a cyclodiathermy type of approach in cases where that sort of operation is indicated, and that is often in desperation. We believe it is less damaging and less dangerous than cyclodiathermy, and perhaps may be adjusted to be just as effective. We have not been as courageous as Dr. de Roetth in applying this to human eyes, and have not yet felt justified in using it on human patients who had any prospect of useful vision, but I am glad to hear of his experiences and I congratulate him on his courage.

We have looked at the meshwork, but except for the very temporary inflammatory effects in it, a few days after application, we have not noticed anything startling.

As far as the probe sticking to the eye is concerned, with the device we have used there is no problem because, as I may have neglected to mention in the beginning, there is also a heating coil at the tip of the probe which turns on instantly and automatically when you take your foot off the control pedal. It warms up very rapidly and does not remain stuck to the eye, the way a little boy's tongue sticks to an iron fence in severe winter weather. We have thought the warming coil to be a very essential part of the design of this device.

Dr. Maumenee asked about cell destruction. I cannot answer his question entirely because we have not exactly duplicated what he suggests. There is a definite white effect in the human eye and in the animal eye. When it is available, this probe can be used as a depressor and, with direct ophthalmoscopy, the area can be seen.

We are well aware of the difference in the anatomy between the rabbit and the human ciliary body, and that is the reason why in a number of these experiments we went to the cat, which has more ciliary processes farther back.

We agree completely with Dr. Langham's remarks about atrophy of the ciliary body and the tremendous reserve of this structure, but it may be that in human glaucoma which is advanced, when there is already a considerable amount of glaucomatous atrophy of ciliary body and its aqueous-

forming mechanism, a little more iatrogenically induced atrophy may be effective without as much damage as production of this effect by electric current produces.

To Dr. Verhoeff: I did not mention it, but we were very much interested in the possibility of cataract formation. We have not seen it except in the animal eyes where extensive uveitis was caused. There can be some temporary effect on the lens, but that seems to be immediately and thoroughly reversible.

Again I would like to thank the discussers, and if I have omitted answers to any one of their points I will be glad to discuss it with them privately.