attention to it. In addition to the drugs mentioned by Dr. Friedenwald, there are several others that are poorly absorbed. One of these which we are investigating is procain hydrochlorid. In relation to the sulfanilamide group of drugs, Dr. J. H. Allen and I have been making some experiments with ointment bases containing zephiran, and we will publish our results.

We have not observed edema of the cornea following the use of doryl.

Dr. Stieren has raised an important question. There are several hundred choline derivatives which are pharmacologically active. We are working in conjunction with Merck & Co. and our department of chemistry on several of these new synthetic compounds. As yet we have not found a choline derivative which is surface-active or lipoid-soluble, or which at any pH becomes a free base, such as the alkaloids used in ophthalmology.

CYCLODIATHERMY: AN OPERATION FOR THE TREATMENT OF GLAUCOMA

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In this article it has been our purpose—(1) To draw attention to a method recently developed for the treatment of glaucoma; (2) to present a new, hitherto undescribed technique, which, we believe, possesses many advantages over earlier procedures; (3) to report our experience, with this form of treatment, together with the indications for its use, the complications that may occur, and the results attained, based on operations performed in 32 cases. In addition, we

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have made some comments on the possible mode of action of this operation, and reported the results of our experimental work.

The concept of treatment of glaucoma by reducing the amount of aqueous formed is by no means a new one. In 1890 Wagenmann,[1] working with rabbits, observed that a reduction in intra-ocular pressure occurred when he divided the long posterior ciliary arteries. Recently, Fortin[2] drew attention to a similar observation. Heine,[3] in 1905, first made clinical use of this theory when he performed cyclodialysis. He believed—and there are many who are still of the same opinion—that the reduction in pressure which follows the use of this procedure is due to an inhibition of the aqueous producing action of the ciliary body.

Shahan and Post,[4] in 1921, discovered that application of the thermophore near the limbus caused a relatively permanent reduction in pressure in normal rabbit eyes, and also in two human eyes afflicted with glaucoma.

In 1924 Verhoeff[5] reported a new method of attacking the ciliary body directly. He called this operation "cyclectomy," since it was literally an excision of a portion of the ciliary body. Although the operation has been too formidable to be employed generally, its rationale is valuable, and is based on the following considerations:

"1. The well-known fact that injuries and inflammation of the ciliary body have a marked tendency to lower intra-ocular pressure.

"2. Drainage into the subchoroidal space might be established by the operation.

"3. Drainage might take place through the scleral wound if the uveal tissue was removed from its vicinity.

"4. The vascular conditions in the ciliary body might be altered in such a way as to reduce the blood-pressure therein.

"5. Section of some of the ciliary nerves might reduce the intra-ocular pressure.

"6. The operation might reduce the intra-ocular pressure

in some unknown way, just as iridectomy lowers the pressure in glaucoma in some way not certainly known."

In 1925 Curran[6] reported an operation which consisted in cauterizing with the galvanocautery an area over the ciliary body from 8 to 10 mm. in diameter. However, it appeared that the essential condition for the success of this operation was the establishment of good filtration. Any effect resulting from damage to the ciliary body seemed to be only temporary.

Hamburger,[7] in discussing Preziosi's paper at the International Congress of Ophthalmology held in Amsterdam in 1929, expressed the belief that any inflammatory process in the ciliary body causes a temporary reduction of intra-ocular pressure. Verhoeff[5] had previously expressed the same opinion.

Fiore,[8] also at the meeting of the International Congress of Ophthalmology in Amsterdam, reviewed his experiences and those of his father between 1909 and 1929 with a cauterization operation. This procedure consisted in the application of a galvanocautery through the sclera and ciliary body meridionally back from the limbus to the ora serrata. The method was designed, Fiore stated, to—(1) Cause a destructive coloboma of the ciliary body, in order to reduce edema; and (2) to sever the ciliary muscle ring and thus permit a more free flow of the circulation. Fiore reported that he had performed this operation on 177 eyes—most of them affected with acute glaucoma. It is quite likely that any success Fiore achieved was due to the fact that there was an escape of the vitreous. Moreover, this form of operation will probably not gain wide favor because of the fact that the simple von Graefe iridectomy continues to give satisfactory results in acute glaucoma.

Recently, in several papers, Vogt[9] discussed a new procedure that has aroused considerable interest. This operation consists in destroying a portion of the ciliary body by means of multiple punctures (usually 100 or more) made with small diathermy needles of special construction. The area to be

covered includes that region extending between 3 mm. from the limbus back to the ora serrata, over one-third to one-half the circumference of the globe. This whole area is peppered with diathermy needle punctures. In 1939 Vogt's colleagues, Wagner and Richner,[10] reported that 47 cases with various types of glaucoma had received this treatment, with successful results in 72.3 per cent. These observers also included in their report a discussion of two cases that had been studied pathologically.

Having the work of Verhoeff in mind, and inasmuch as we had seen the disastrous results following the usual methods of treatment in cases of hemorrhagic glaucoma, we decided, early in 1938, to apply the principles of the present operation for separation of the retina to the cyclectomy as performed by Verhoeff. Later, Dr. David G. Cogan, having recently returned from Weve's clinic, suggested that we use the flat electrode in our work, and assisted us in making such an instrument.

We gradually developed and used two techniques in our operation of cyclodiathermy. Simply for purposes of description we have termed them "perforating" and "non-perforating" cyclodiathermy. At first we used the descriptive term "diathermy of the ciliary body"; subsequently, after becoming cognizant of the work of Vogt, we adopted the anglicized form of the term which he had introduced: "cyclodiathermy." The technique of each operation is as follows:

NON-PERFORATING CYCLODIATHERMY

The eye is anesthetized by the instillation of a 4 per cent. cocain solution and the retrobulbar injection of 1 c.c. of 2 per cent. procain with 1:1000 solution of epinephrine. It is especially advisable that epinephrine be included in the retrobulbar injection, since it combats the tendency for tension to rise during and after the operation. Inasmuch as the eyes on which this operation is performed are extremely sensitive, it is wise to wait fully ten minutes to secure good anesthesia.

The conjunctiva is incised 8 mm. from the limbus, over a little more than one-half the circumference of the globe, and the sclera is bared to within 2 mm. of the limbus. It is best to do the operation on the lower half of the eye, for later it may become necessary to work on the upper half, for example, to extract a cataract. After the sclera has been bared, the flat electrode (Weve type) is applied over one-half of the globe. It should be applied firmly against the sclera, otherwise the current will not penetrate and the only effect will be a superficial searing. Applications are made at 4 to 5 mm. from the limbus, immediately adjacent to one another, one row being sufficient. Slight superficial searing of the sclera is a good criterion by which to judge the amount of current to be used. Owing to the great variation in diathermy apparatus, it would be unwise to give exact figures in terms of milliamperes. Furthermore, the amount of current passing through the electrode is dependent upon the resistance and plate placement of the individual patient. On the Walker diathermy machine we use the setting of 35 on the dial, and run the current for from eight to ten seconds for each application.

The conjunctiva is then closed with silk sutures, a solution of 1 per cent. atropin is instilled, and a dressing is applied.

PERFORATING CYCLODIATHERMY

The preparation for this operation is similar to that employed in the non-perforating type. After the sclera has been bared, a double row of Walker points is introduced at points 3 and 5 mm. respectively from the limbus, at intervals of about 1 mm. The method of closure is the same as that for the non-perforating operation.

POSTOPERATIVE COURSE

After experimenting with miotics and mydriatics, and without any medication, we have reached the conclusion that atropin is the most satisfactory drug for use in the immediate

postoperative period. The damage to the ciliary body is sure to result in a reactive cyclitis, so that the eye should be placed at complete rest. We have never observed any untoward symptoms that could be attributed to the use of atropin.

When perforating cyclodiathermy has been performed, we apply a binocular dressing for twenty-four hours, in order to keep the eye quiet. It has been our practice to have the patient remain in bed for forty-eight hours, to obviate any sudden rise in blood-pressure which might rupture the intra-ocular vessels unsupported by normal or elevated intra-ocular pressure. In the case of patients on whom the non-perforating operation has been performed, we use only a monocular dressing, and permit the patient to leave the bed within twenty-four hours. This practice is especially advantageous in the case of older patients.

It has previously been mentioned that, when the non-perforating operation is performed, the intra-ocular pressure shows a tendency to rise. The explanation for this, we believe, is as follows: The coagulating current causes some puckering of the sclera; hence the total volume of the globe is reduced, and thus the intra-ocular pressure is raised. The late John M. Wheeler, of New York, in certain unpublished remarks several years ago, observed and explained this phenomenon in connection with the surgery of the separated retina. In cases of hemorrhagic glaucoma it is particularly true that, following non-perforating cyclodiathermy, intra-ocular pressure is reduced only slowly. The discomfort caused by the bullous keratitis which always accompanies this persistent elevation of pressure can be ameliorated by the use of hypertonic saline solution or the application of saline ointment (Cogan).[11]

COMPLICATIONS

The Cornea.—A decrease in corneal sensitivity over the area in which the operation is performed is an almost in-

variable accompaniment of cyclodiathermy. (We cannot state with certainty that such a decrease occurs in 100 per cent of the cases, for we did not observe it until several cases had been operated on.) So far as we have noticed, it appears to be transitory. In only one case did this condition lead to more serious consequences than bullous keratitis. The patient (Case No. 31), three weeks after the operation, developed a small ulcer of the catarrhal type near the limbus below, in the region of the operative site. However, when local treatment was applied, the ulcer healed rapidly.

As was mentioned previously, bullous keratitis is frequently present during the immediate postoperative period, and occasionally it may persist for several weeks if the intra-ocular pressure is elevated. There seems to be one possible explanation for this phenomenon: Inasmuch as the nerves supplying the cornea are damaged, bullous keratitis may be a manifestation of trophic disturbances. This condition is a potential source of danger if an infectious process supervenes.

In only one case did we observe a transient parenchymal opacity near the site of operation, but this persisted for only a few days.

The Iris and Ciliary Body.—If the electrode is placed too close to the limbus, hemorrhages from the iris may occur. The explanation for this may lie in the fact that the ciliary veins are occluded near their point of origin, so that the resulting venous congestion is severe enough to rupture the iris vessels. Large intra-ocular hemorrhages may arise from the iris or ciliary body, as well as from any of the other intra-ocular structures, when the perforating type of operation is employed; these are undoubtedly due to a sudden lowering of the intra-ocular pressure, with the result that delicate vessel walls rupture. Apparently a very mild iridocyclitis occurs following operation, for those patients who did not receive atropin postoperatively developed posterior synechiae.

The Lens.—Theoretically, one would expect that cataract might be caused by this procedure. The heat from the electrode may be sufficient to coagulate the lens protein, or reduction in the amount of or change in the quality of aqueous following the operation might give rise to a "cataracta complicata." We believe it unwise, however, to be dogmatic on this point, for the conditions that caused the glaucoma might also be responsible for the cataract, so we have not attempted to evaluate our cases in regard to this phase of the subject. Nevertheless we can say that none of our normal experimental animals on which the operation was performed developed a lens opacity. Further studies on experimental animals will be made in order to ascertain the amount of heat present in the lens during the operation.

The Sclera.—Vogt[9] asserts that he had one case that developed scleral necrosis. In our work we have not encountered this complication.

Sympathetic Ophthalmia.—It is generally believed that damage to the ciliary body increases the danger of development of sympathetic ophthalmia. In our series of cases we have not met this complication. Vogt[9] declares that this danger is minimal. In support of his belief he observes that thousands of similar operations for separation of the retina have been performed with damage to uveal tissue. Not one case of sympathetic ophthalmia attributable to this form of operation has ever been reported.

INDICATIONS FOR CYCLODIATHERMY

Hemorrhagic Glaucoma.—Cyclodiathermy is indicated particularly in this type of glaucoma. We prefer to use the nonperforating operation. Other forms of treatment have been entirely ineffective. Magitot[12] asserts: ". . . the only manner in which to relieve the patient is enucleation of the globe." (". . . la seule manière de soulager le patient est l'amputation du globe"). Duke-Elder[13] has expressed the same opinion. Bernard Samuels[14] and Duke-Elder[13] have

given one reason why such treatment has failed. They believe that any operation that involves opening of the eye is likely to result in hemorrhage, and thus hemorrhagic glaucoma is superimposed upon an already existent hemorrhagic glaucoma.

We have observed that, in the majority of cases of hemorrhagic glaucoma, the intra-ocular pressure decreases only gradually over a period of days or weeks. In some few instances it may remain slightly elevated for an indefinite period, but the patient continues to be comfortable. This is possibly due to destruction of the nerves leading to the anterior segment of the eye. We now believe that in this type of glaucoma cyclodiathermy of less than one-half of the globe is, more often than not, insufficient. In seven of our cases operation on only one quadrant was inadequate. In two others trephining was done instead of further cyclodiathermy (this was listed as a combined operation).

We cannot emphasize too strongly one precaution that must be observed before cyclodiathermy is attempted. *Intra-ocular tumor must be ruled out absolutely.* If there is any question as to a differential diagnosis, enucleation is the imperative procedure.

Glaucoma in Aphakia.—Cyclodiathermy is a valuable procedure to add to our surgical armamentarium for the treatment of glaucoma in aphakic eyes. Filtration operations have certainly been found to have a limited application. Cyclodialysis has been the operation of choice to date, but at times it is contraindicated. Furthermore, as a rule, hemorrhage occurs as a complication. Non-perforating cyclodiathermy obviates the complication of hemorrhage, and it is, therefore, to be recommended particularly in diabetics or in those who have marked vascular sclerosis. In order to be conservative, however, we have used cyclodiathermy only in cases in which cyclodialysis has failed or was definitely contraindicated. The following is a case in point:

CASE No. 30.—Mr. D. (from the service of Dr. John H. Dunnington, Institute of Ophthalmology, New York City), a man, aged fifty-eight years, developed glaucoma in the right eye. Medical treatment being ineffective, a corneal paracentesis was done. Vitreous escaped through the paracentesis wound, and a hyphemia developed shortly after. During the ensuing few days there were several fresh hemorrhages into the anterior chamber. The tension remained high. Due to the fact that there was vitreous in the anterior chamber, any filtration operation was contraindicated. Because he had had recurrent hemorrhages in the absence of further trauma, we decided that cyclodialysis would be dangerous, and so a non-perforating cyclodiathermy was performed on the lower half of the globe. Within forty-eight hours the tension became normal, and has remained low ever since (two and one-half months). No further hemorrhages appeared after the operation.

Other Forms of Secondary Glaucoma.—Vogt[9] is of the opinion that cyclodiathermy not only controls elevation of tension, but that it also has a beneficial effect on iridocyclitis. We agree with him in that we have observed no deleterious effect in such cases, and that in a few cases it seemed that there was some improvement which might be attributable to the operation. The following is a case in point:

CASE No. 5.—Miss M. (from the service of Dr. Paul A. Chandler, Massachusetts Eye and Ear Infirmary), a white girl, aged fifteen years, was injured in the right eye, after which a traumatic cataract developed. Linear extraction was performed. Later a persistent iridocyclitis and elevated intra-ocular pressure set in. Intensive treatment, paracentesis, and a filtering operation failed to control the elevated pressure. Cyclodiathermy was done over three quadrants of the globe at intervals. During the six months following the last operation tension has been normal. Although the visual field has suffered, vision has been 20/20 corrected. The iridocyclitis has subsided and the eye is now quiescent.

Glaucoma secondary to x-ray therapy is another type that is very resistant to the usual forms of treatment. Cyclodiathermy may offer new hope in these cases. One such case in this series was successfully treated by this means (courtesy of Dr. Algernon B. Reese of New York).

Primary Glaucoma.—Vogt[9] suggests that cyclodiathermy might compete with filtering operations in this type of glaucoma, since the danger of secondary infection or of sympathetic ophthalmia following cyclodiathermy is less than it is in other types of operation. In this respect we have remained conservative and have used cyclodiathermy only when other procedures have failed or were contraindicated. However, we agree with Vogt on one point. It is a well-known fact that filtering operations are not very successful

TABLE 1.—SUMMARY TABLE, SHOWING RESULTS IN TYPES OF GLAUCOMA WITH EACH TYPE OF OPERATION

GLAUCOMA	PERFORATING			NON-PERFORATING			COMBINED OPERATIONS			TOTALS		
	success	failure	total	success	failure	total	success	failure	total	success	failure	total
HEMORRHAGIC	5	1	6	3	2	5	1	0	1	9	3	12
SECONDARY	4	2	6	6	0	6				10	2	12
PRIMARY				3	0	3	1	0	1	4	0	4
BUPHTHALMOS				2	2	4				2	2	4
	9	3	12	14	4	18	2	0	2	25	7	32

in Negroes, the cicatrices rapidly become non-functioning. In this race, cyclodiathermy may have a greater field of usefulness.

Buphthalmos.—Two eyes were benefited by the operation and two were not. Regarded retrospectively, had one-half of the eye been treated instead of only one-fourth, success might have been achieved in the latter two eyes.

Our results are summarized in Table 1. A result was regarded as successful if the patient was rendered comfort-

TABLE 2.—SUMMARY OF CASES

Case No.	*Name and Age*	*Diagnosis and Therapy*	*Vision and Tension Before Cyclodiathermy*	*Cyclodiathermy*	*Result*
1.	McA. 69	Hemorrhagic, two weeks. Miotics ineffective.	20/100	1. ¼ U.T. p. 2. ¼ D.T. np.	12 days p.o.: T. 11. V.=8/200 3 mos. p.o.: T. 28. V.=10/200 Comfortable. Miotics.
2.	G. 81	Hemorrhagic, one week. Miotics ineffective.	F. at 1′ T. 55	¼ U.T. np.	3 mos. p.o.: T. 26. V.=F. at 4′. No medication. Mild iridocyclitis immediately p.o.
3.	P. 67	Acute attack on old chronic—eight days. Cataract. Miotics ineffective.	G.L.P. T. 48	1. ¼ U.T. np. 2. Trephine six days later	10 mos. p.o.: T. 19. No medication. Cataract extraction to be done.
4.	N. 60±	Old chronic. Recent aphakia. Vitreous hemorrhage six months later. Cyclodialysis failed. Miotics failed.	H.M. T. 50	¼ D.T. np.	3 mos. p.o.: T. 36. V.=H.M. Comfortable.
5.	M. 15	Secondary aphakia (traumatic cataract). Cyclodialysis failed. Other eye good.	H.M. T. 40	1. ¼ D.N. np. 2. ¼ U.T. p. 3. ¼ U.N. p.	Comfortable since No. 3. On miotic. 9 mos. p.o.: T. 24. V.=20/20 corrected.
6.	T. 30	Hemorrhagic. Diabetic. Miotics ineffective. Very uncomfortable.	Nil T. 48	⅓ nasal	9 mos. p.o.: T. 48. V.=nil. Comfortable.
7.	T. 30	Hemorrhagic. Diabetic. Trephine failed.	20/70 T. 45	⅓ temp.	9 mos. p.o.: T. 30. V.=10/200. Hemorrhages still in fundus. Miotic.
8.	D. 15	Secondary—old injury. Miotics ineffective. No filtering operation for fear of sympathetic ophthalmia. Other eye good.	8/200 T. 46	1. ¼ U.T. np. 2. ¼ D.N. p.	1. Held 10 mos. V.=20/100. T. 15–30. Sudden rise. 2. Held 1 mo. Massive I.O. hemorrhage. Enucleation.
9.	S. 70	Secondary aphakia. ?Hemorrhagic. Diabetic. Hemorrhages in fundus.	F. at 5′ T. 48	¼ D.T. n.	2 mos. p.o.: T. 22. 3 mos. p.o.: T. 16. V.=F. at 3′.
10.	T. 64	Hemorrhagic. Paracenteses and miotics failed.	H.M. T. 70	⅓ above n.	Enucleation 16 days p.o. Painful. Hemorrhages from paracenteses.
11.	C. 60±	Hemorrhagic. Miotics failed.	H.M. temp. T. 65	¼ U.N. p.	2 mos. p.o.: Sudden rise in tension. Hemorrhage. Enucleation.
12.	N. 60 (Negro)	Secondary aphakia. Two trephining operations before. Many paracenteses failed. Only eye.	4/200 T. 65	1. ½ above p. 2. ⅓ below np.	2 mos. p.o.: T. 22. V.=20/200. 1 year p.o.: T. 15. V.=F. at 2′. Comfortable.
13.	B. 51	Hemorrhagic in eye. Diabetic. Miotics failed.	20/200 T. 56	1. ¼ U.T. p. 2. ¼ D.T. p.	8 mos. p.o.: T. 10. L.P. 2.25 years p.o.: T. soft. Comfortable. (By letter, unable to come in.)
14.	F. 56	Glaucoma capsulare. Cataract. Two trephining operations and paracenteses failed.	L.P. T. 65	¼ D.T. p.	2 mos. p.o.: T. 10. 1 year p.o.: T. 19. 20 mos. p.o.: T. 19. V.=H.M. Cataract.
15.	O'C. 67	Secondary aphakia. Paracenteses and miotics failed.	No L.P. Stony.	¼ U.T. p.	Enucleated 4 days p.o.
16.	R. 59	Hemorrhagic and glaucoma capsulare. Miotics failed.	10/200 T. 60	¼ U.T. p.	1 mo. p.o.: T. 8. 8 mos. p.o.: Sudden bilateral keratoconjunctivitis. Eye painful. Enucleation.

17.	R. 5 mos.	Buphthalmos. Trephines and Verhoeff cannula failed.	? vision hard	⅓ above np.	8 mos. p.o.: tension down to fingers.
18.	R. 5 mos.	Buphthalmos. Trephinings failed.	? vision hard	⅓ above np.	8 mos. p.o.: tension down to fingers.
19.	S. 28 mos.	Buphthalmos. Two iridotases failed.	Hard	¼ above np.	No appreciable result.
20.	S. 28 mos.	Buphthalmos. Two iridotases failed.	Hard	¼ above np.	No appreciable result.
21.	M. 44	Secondary aphakia. High myopia with choroiditis. Miotics failed.	20/100 T. 50	¼ D.T. np.	6 wks. p.o.: T. 30. V. = 20/200. 4 mos. p.o.: T. 30. V. = 20/200. Miotic added.
22.	R. 67	Hemorrhagic. Miotics failed.	F. at 1′ T. 52	¼ U.T. np.	Paracentesis p.o.: I.O. hemorrhage. Enucleated 13 days p.o.
23.	C. 42	Secondary aphakia. Intra-ocular hemorrhage. Miotics, paracenteses, and *x*-ray failed.	G.L.P. T. 42	¼ U.T. p.	10 mos. p.o.: T. 8. V. = G.L.P.
24.	K. 54	Primary chronic. Two trephinings, two iridotases and cyclodialysis failed.	20/70 T. 48	½ nasal np.	5 mos. p.o.: Eye soft. V. = H.M.
25.	V. 58	Primary chronic aphakia. Five years of trephinings, cyclodialysis, post-sclerotomies.	5/200 T. 42	¼ D.T. n.	1 year: T. 36. V. = H.M. Comfortable.
26.	E. 51	Secondary. Irradiation for carcinoma of antrum. Sorbital failed. Refused enucleation.	Nil T. 65	½ above np.	T. down to fingers after 10 days p.o. Comfortable. Died 5 mos. p.o.
27.	D. 80	Hemorrhagic. Miotics failed.	G.L.P. T. 56	¼ D.T. np.	1 mo. p.o.: T. up again. Trephine. Under control since (3 mos.).
28.	J. 48	Hemorrhagic. Hypertension. Miotics failed. Refused enucleation.	L.P. faulty T. 85	Lateral ½ np.	Tension down after 1 mo. 2 mos. p.o.: T. 26. Comfortable. No medication.
29.	E. 52 (Negro)	Chronic primary. Two trephinings and miotics failed.	20/100 T. 40	Lower ½ np.	1 mo. p.o.: T. 15. 2.5 mos. p.o.: T. 15. Comfortable.
30.	K. 53	Hemorrhagic in only eye. Diabetic, not well controlled.	5/200? T. 90	Lower ½ np.	22 mos. p.o.: T. down to fingers. V. = F. at 2′.
31.	D. 58	Secondary aphakia. Miotics failed. Vitreous lost on paracentesis. Spontaneous hemorrhages into anterior chamber.	6/200 T. 56	Lower ½ np.	Small ulcer below 2 wks. p.o. Cleared on local treatment. 1 mo. p.o.: T. down to fingers. 1½ mo. p.o.: T. down to fingers. V. = 20/200. 2 mos. p.o.: T. 20.
32.	L. 28	Secondary aphakia. Diabetic. Only eye. Retinal detachment. Painful. Medication failed.	L.P.	Lower ½ np.	1 mo. p.o.: T. 45. 5 mos. p.o.: T. 10. Comfortable. V. = L.P.

KEY

T. = tension
U.T. = upper temporal quadrant
D.T. = lower temporal quadrant
U.N. = upper nasal quadrant
D.N. = lower nasal quadrant
np. = non-perforating cyclodiathermy
p. = perforating cyclodiathermy
p.o. = postoperative
V. = vision
L.P. = light perception
G.L.P. = good light projection
I.O. = intra-ocular
H.M. = hand movements

Cases 1 to 25 inclusive are from the Massachusetts Eye and Ear Infirmary, Boston, Mass.
Cases 26 to 32 inclusive are from the Institute of Ophthalmology, Presbyterian Hospital, New York City, N. Y.
Case 26 is published by the courtesy of Dr. Algernon B. Reese.
Case 27 supplied through the courtesy of Dr. Frank Carroll.
Case 30 is published by the courtesy of Dr. John H. Dunnington.
Case 32 supplied through the courtesy of Dr. Charles A. Perera.

able under controlled tension. (For a detailed summary of the individual cases, see Table 2.) Those cases in which the tension was not controlled and the patient was not comfortable, or, if enucleation had to be done, were regarded as failures. The column heading "Combined Operations" (Table 1) refers to cases in which trephining was done when the tension was not sufficiently well controlled with cyclodiathermy. Only one-fourth of the globe was operated on in these cases. Had one-half of the globe been treated, the subsequent operation would probably have been unnecessary.

COMMENTS

We believe that the operations here described are less traumatic than is the one which Vogt presented. In our opinion, extensive punctures are not necessary. Furthermore, we wish to emphasize the advantages of the non-perforating type of cyclodiathermy; these are dependent on the fact that the eye is not opened.

1. The anterior chamber is not collapsed. Although anterior peripheral synechiae tend to form as a result of any operative procedure, they are certainly less extensive if the anterior chamber does not become flat. Kronfeld[15] has supplied evidence to substantiate this hypothesis.

2. Since the eye is not opened, there is no sudden removal of support from the delicate walls of the blood-vessels. For this reason hemorrhage is much less likely to occur as a complication, either of the operation or during the postoperative period.

3. The aqueous is not so prone to take on a more plasmoid character. The presence of increased amounts of protein and other coagulable substances would be likely to increase the extent of anterior synechiae formed.

4. There are no passages into the interior of the eye through which infectious organisms could enter, thus making the development of exogenous infection and sympathetic ophthalmia virtually impossible.

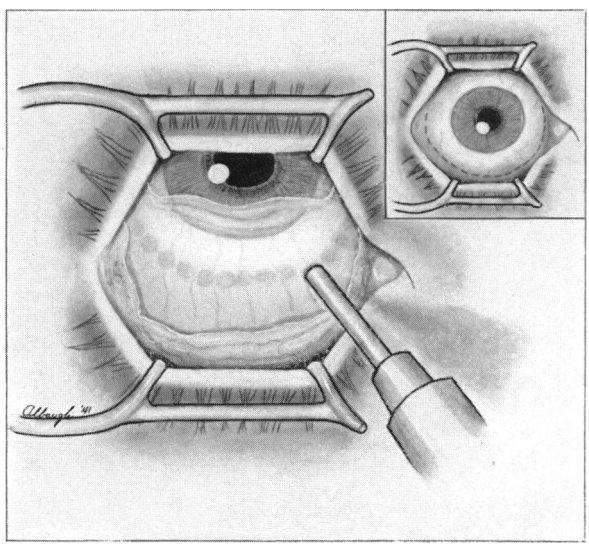

Fig. 1.—Non-perforating cyclodiathermy.

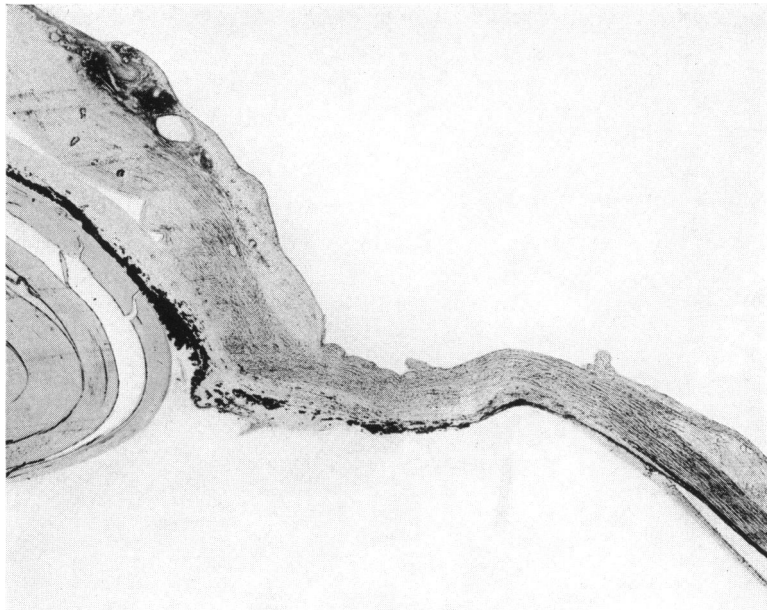

Fig. 2.—Section showing destruction of ciliary body by cyclodiathermy. (From the Terry Laboratory, Massachusetts Eye and Ear Infirmary, Boston. Photographed at the Institute of Ophthalmology, New York City.)

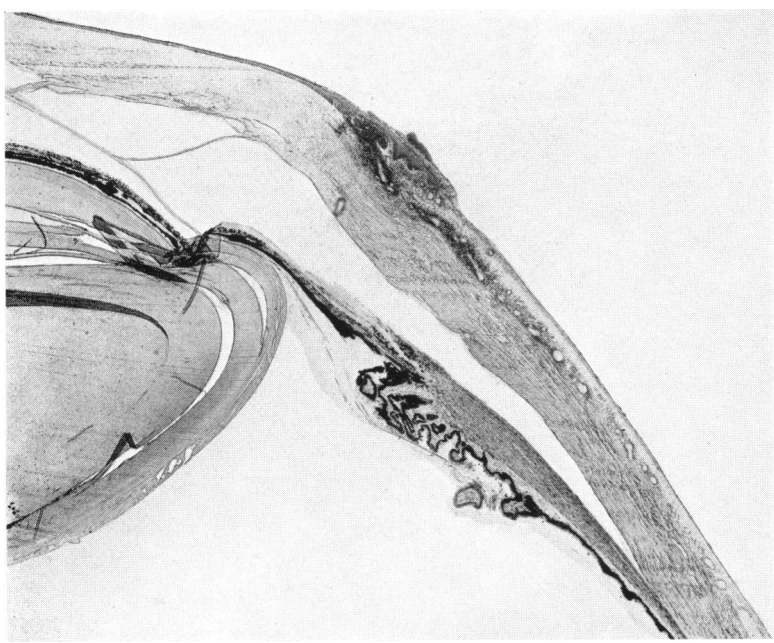

Fig. 3.—Section from the same eye in an untreated area. (From the Terry Laboratory, Massachusetts Eye and Ear Infirmary, Boston. Photographed at the Institute of Ophthalmology, New York City.)

5. Most of the patients affected with glaucoma are in the later decades of life. Close confinement for long periods brings a train of general complications, such as psychosis, pneumonia, or thrombophlebitis. It is, therefore, a distinct advantage to be able to allow patients to resume their normal activities as soon as possible.

We do not know the mechanism by which cyclodiathermy controls intra-ocular pressure. Verhoeff pointed out some of the possibilities, which were mentioned elsewhere. We have approached the problem from two angles—from the study of pathologic material and from experimental work.

PATHOLOGY*

One of our cases (from the Massachusetts Eye and Ear Infirmary) proved a good subject for study:

CASE No. 16.—Mr. R., a man, aged fifty-nine years, had hemorrhagic glaucoma in the left eye, and was treated by cyclodiathermy. Tension was controlled for eight months. At the end of that time he developed a severe bilateral keratoconjunctivitis. The left eye became painful and was enucleated.

Figures 2 and 3 illustrate the main findings. There is almost complete destruction of the ciliary body that was operated on. The mass that is present consists, for the most part, of replacement fibrous tissue. The epithelial layers of the ciliary body are disrupted, and in places are absent entirely. The destructive process is not limited to the corona ciliaris; in fact, it involves, for the greater part, the pars plana. We were unable to determine, from the sections, what effect, if any, the operation had on the ciliary nerves.

Another eye, which was removed a few days following cyclodiathermy, was studied. The earliest observable effects of the procedure appear to be on the pigment in the stroma and on the epithelial layers. The pigment in the stroma, which in the unaffected ciliary body is distributed in a net-

* Material made available by Dr. T. L. Terry.

like fashion, collects in spherical clumps. The epithelial layers are disrupted, and the pigment is displaced into the anterior vitreous. As is to be expected, there is some edema of the tissues, and small areas of necrosis in the stroma and muscle tissue are visible.

EXPERIMENTS

In order to determine what the effects of this treatment might be on normal healthy eyes, we performed non-perforating cyclodiathermy on a series of six normal rabbits. The animals were killed at various intervals up to two and one-half months, in order to discover the sequence of reaction and healing. The microscopic findings, as well as the effects on intra-ocular pressure, corresponded exactly with observations on human cases. In all experimental animals the tension was taken with the Souter tonometer, since the curvature of the cornea in these animals differs from that in the human; hence any readings taken with the Schiötz instrument would have been unreliable. In the rabbit regeneration of epithelium over the destroyed ciliary body does not occur so readily as it does in the human.

In our experimental animals we were particularly interested to learn what the effects of the operation would be on the filtration angle and on the lens. There seemed to be no observable tendency to the formation of anterior peripheral synechiae, and the angle did not appear to be disturbed. Apparently, any heat generated by the current in cyclodiathermy is carried off so rapidly that the lens is not injured. None of the six experimental animals treated in this manner developed lens opacities. In one we deliberately increased the length of application of double the usual current to ten times the routine figure. When this animal was killed two months after operation there was still no opacity of the lens. We are at present attempting, by means of a thermocouple, to measure the heat radiated to the lens by various amounts of current with different types of electrodes.

We have not as yet determined the effect of cyclodiathermy on accommodation. Pupillary reaction to light was more sluggish, and the excursion was less on the operated eye than on the normal one. However, the pupil in the operated eye was round and contracted equally in all directions, and the segment on the operated side did not lag.

It is possible that many of the structural changes that occur in the ciliary body following cyclodiathermy could be trophic in origin, due to destruction of the nerve supply. Cauterization sufficient to destroy the underlying retina was performed on three normal rabbits, both by diathermy and by the actual cautery, just at the equator, under the horizontal rectus muscle on each side of the eye. These rabbits too were killed—the last one two months after operation, and the others at varying intervals. In no case did the microscopic findings in the ciliary body resemble those present following cyclodiathermy. Apparently, then, the visible changes, at least, are the direct result of heat and are not trophic in origin.

In order to test whether the permeability status was changed, we performed cyclodiathermy on a rabbit, and then injected 0.5 c.c. of a 10 per cent. sodium fluorescein solution intravenously. Large amounts of fluorescein appeared from behind the iris in the operated eye within one and one-half minutes, and only a small quantity appeared in the unoperated eye in five and one-half minutes. A week later fluorescein was injected intravenously again. Six minutes after the injection the dye appeared in both eyes, but with definitely higher concentration in the operated eye. This suggests that the selective permeability is broken down and that fluid, as well as heavier molecules, can pass in either direction with greater ease than they do in the normal eye. However, this test must be repeated after a considerably longer lapse of time and in a greater number of rabbits before conclusions can be drawn.

CONCLUSIONS

1. The technique of cyclodiathermy is simple and requires no extraordinary skill.

2. When non-perforating cyclodiathermy is to be employed, the complications that are generally incident to opening of the globe, such as hemorrhage, secondary infection, and sympathetic ophthalmia, are practically eliminated.

3. Cyclodiathermy is the operation of choice in hemorrhagic glaucoma, and should also be used in other types of glaucoma under the following conditions:

(*a*) When other methods of treatment, both medical and surgical, have failed (particularly in Negroes).

(*b*) When opening of the globe, with consequent sudden reduction in intra-ocular pressure, is to be avoided.

4. Eyes that have been sectioned some time after operation demonstrate that definite destruction of the ciliary body has taken place. Epithelial components do not regenerate completely, hence the membrane wall is broken down.

5. Experimental observations suggest that the permeability status of the ciliary body is changed as the result of the operation.

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DISCUSSION

DR. SANFORD R. GIFFORD, Chicago, Ill.: Since Vogt's and Wagner's papers were published I have used cyclodiathermy in about 12 cases, and I am pleased that they brought out the fact, which we would not gather from Vogt's later papers, that the essayists regard this as an operation not for simple glaucoma, or for primary glaucoma, but rather for the exceptional case of glaucoma. I believe that this is something that ought to be emphasized. As Dr. Wheeler said about the combination of cyclodialysis and iridectomy, it is quite a traumatizing operation, and one which involves certain risks that are not present in the filtering operations. This procedure is especially indicated in hemorrhagic glaucoma and in secondary glaucoma following cataract operations, or in certain types of injury which would make the ordinary filtering operation impossible.

I do not have the exact details of all 12 cases that were so treated at the Cook County Hospital and in private practice, but I do remember that the results were variable, and in a few cases that they were exceedingly valuable. I can recall four cases in which this operation succeeded in keeping the tension down, with useful vision, when all other operations had failed. These were cases which had been operated on by iridectomy and other methods. There is one difficulty which I believe would occur in Dr. Albaugh's operation, namely, that in some cases the tension might increase right after the operation, since he has done nothing to reduce the tension immediately. I found a difference from Vogt's experience. Vogt asserts that when he put these punctures in close together the eye always became hypotonic at once, so that the tension was low when he finished. Apparently I used pins which were exactly like those which Vogt used, but following the punctures the fluid did not come out very much, the tension was not reduced when I got through, so that in some cases I followed this procedure with a small cyclodialysis, in which I made a small sclerectomy, enough to let the aqueous out and reduce the tension immediately. I found one interesting thing about it: though you often have hemorrhage from the usual cyclodialysis when this procedure is done, you have no immediate hemorrhage, because all the blood vessels in this area are coagulated. You may have hemorrhage later, however, and that is a complication that is exceedingly inconvenient.

DR. L. T. POST, St. Louis, Mo.: This paper has been particularly interesting to me because of the early experiences of Dr. Shahan and myself in chronic simple glaucoma. We used the method of the

application of the thermophore across the limbus at 145° F. for one minute, and in general we were successful in the early cases but unsuccessful in the late cases. We followed these patients for a maximum of two years, and in most of them the tension remained down, but the treatment had to be repeated at an average of about two months' time. The patient who needed least reapplications would retain normal tension for three months. Later we considered that we might get better results by applying the thermophore in more regions than one. As a preliminary to this method I studied the heating from 140° F. to 220° F. in rabbits' eyes, and reported the results in my thesis for membership in this Society in 1924. It was possible to destroy the ciliary body completely below the areas treated; to cut holes in the iris; and when a temperature of 220° F. was used, the cornea and sclera were badly damaged, and at these temperatures cataracts were formed in the animals. Later I made special points to be applied all the way around on the ciliary body, but even by this method we were unable to keep the tension down. Our experiments were not done in many cases, hence we have felt that perhaps further investigation at different temperatures, over longer periods, and with other variations, might make this method practical. We have used Vogt's method of diathermy puncture in only a few cases on our service at Washington University. Personally I have not used it. We have had variable success—better in patients with light irides, that is, with less heavily pigmented ciliary bodies. In the hospital for colored people we have not had much success with it. I believe this is a very interesting work, and should be carried on.

DR. J. S. FRIEDENWALD, Baltimore, Md.: I am greatly interested in this report, and should like to ask what the effect of this destruction of the ciliary body on the position of the lens and on the degree of astigmatism is. Does the astigmatism vary with accommodation after this operation? I should also be interested in learning what the gonioscopic appearance in the treated portion of the eye was.

DR. EDWIN B. DUNPHY, Boston, Mass.: I would like to supplement Dr. Albaugh's remarks and to emphasize the point that Dr. Gifford brought up, namely, that this operation which we are suggesting is not a substitute for other glaucoma surgical measures. That is what Vogt, in his original communication, suggested. We are offering it only for use in those ophthalmologic cases that we all see in which previous surgical and medical treatment has failed,

and the only alternative that remains is either continued suffering or enucleation.

Another point I wish to emphasize, which Dr. Albaugh did not have the time to bring out in the paper, a point on which we both feel strongly, is that, if there is any suspicion of intra-ocular neoplasm in these old, nearly blind eyes, we must not attempt this operation. We are very careful to exclude this condition, as far as our ability permits, before attempting this or any other type of surgery.

I believe that another question which will necessarily arise in the minds of a number of the members is just what constitutes success. As to the period of time that elapses between the operation and the reporting of the case as a success—in these 25 successful cases the average length of time was seven and one-half months. The longest period of time was twenty-seven months in which the tension remained under control and the patient was comfortable. The shortest length of time is only two months, which I admit is a somewhat short time, but due to the simplicity of this procedure it can easily be repeated. I believe it represents a sound method of attacking some of these desperate cases.

DR. C. H. ALBAUGH (by invitation), closing: I wish to thank Dr. Gifford and Dr. Post for their discussion.

In answer to Dr. Friedenwald's question concerning the matter of astigmatism, we have observed that the lens apparently is pulled over toward the operated side of the ciliary body. This would probably give rise to some astigmatism. The question concerning accommodation we cannot answer, because most of our patients were in the older age group, or, if they were not, they did not have lenses, so we do not know what the effect on accommodation was.

As to the angle, we have found no observable increased tendency to formation of anterior peripheral synechiae. The angle has remained the same. In one patient, operated on by the perforating method, hemorrhages were seen to come from the angle. This was a case of hemorrhagic glaucoma with a vascular membrane, and some of the small vessels had given rise to hemorrhage, but otherwise the angle remained unchanged.

I should like to emphasize again that this non-perforating operation is not the only form of cyclodiathermy, but that it is a method which can be used when it is inadvisable, for one reason or another, to open the eye.