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A Study of Eighty-Three Cases of Glaucoma Treated by Cyclodiathermy with Reference to the Facility of Outflow

Robert V. Shearer

A STUDY OF EIGHTY-THREE CASES OF GLAUCOMA TREATED BY CYCLODIATHERMY WITH REFERENCE TO THE FACILITY OF OUTFLOW

Robert V. Shearer M. D.

Introduction*

This study is an attempt to discover the mode of action and evaluate the effectivity of cyclodiathermy in the treatment of glaucoma, using the Muller electric tonometer in studies on the facility of outflow.

This series of cases represents a cross section of the advanced cases of glaucoma which were operated on by attending and resident staff at the White Memorial Hospital between January 1952, and December 1955. Eighty-nine operations were performed on eighty-three eyes of fifty-eight patients of whom, with but few exeptions, had lost field in the poorer eye to less than five degrees, and in whom medical management failed to control the tension. The cases were followed from one-half to four years. Two cases had previously had unsatisfactory glaucoma surgery. Sex is equally represented, and no children are included.

History-

Findings by Braley that one in forty past the age of forty is suffering from undiagnosed glaucoma, and Hankla's 2.2% incidence in 9,645 persons studied in Philadelphia screening tests, together with similar findings by others serve to re-emphasize the ever-present glaucoma problem, and especially is this so when one considers the fact that many of these cases have already progressed to such an advanced degree that they fail to respond to medical management, and often lose the small amount of sight remaining, when standard surgical procedures are attempted. As Sourdille says, "it is public enemy number one."

The word glaucoma is derived from the Greek word "glaukos", as used by Galenus meaning bluish green or gray, and was used in the early nineteenth century to designate so called green cataracts, which meant a complicated cataract with complete amaurosis from glaucoma. Hardness of the glove was described by Banister as early as 1622. It was in 1830 that Fredrick Schlemm reported the discovery of the circular canal at the border of the cornea and sclera. Hardness of the glove was emphasized in 1844 by MacKenzie, who recommended limbal puncture to soften it. Helmholtz' ophthalmoscope developed in 1851 paved the way for Weber to describe characteristic disc cupping noted in advanced cases of glaucoma in 1855. In 1858 Muller ascribed the histologic appearance of an excavated disc to the increased intra-ocular pressure.

The clinical relationship between symptoms and elevated pressure was explained in 1856 by Albrecht von Graefe. In 1869 Schwalbe showed that Prussian blue injected in the anterior chamber reached the anterior ciliary veins. Leber, In 1873, demonstrated the escape of the aqueous fluids at the angle of the anterior chamber. Knies and Weber in 1876 showed independantly that in glaucoma this outlet was obstructed. Prof. H. Schmidt in the 1877 Graefe-Saemach Handbuch der gesammten Augenheil kunde devoted 138 pages to glaucoma, and the summary is remarkable in that it varies little from the present concept of glaucoma.

By 1880 the venous nature of Schlemm's canal iand it's function in the outflow of aqueous was finally generally accepted. Priestly Smith stated in 1898, "For those who have investigated the subject thoroughly in the laboratory as well as in th consulting room, the evidence is complete that aqueous retention

is a factor in the morbid process."

The diurnal intraocular pressure variations normally not exceeding 5mm. Hg., and being maintained in spite of environmental variations together in both eyes was demonstrated by Maslenikow in 1904. Ascher demonstrated the aqueous veins and connections in 1941.

Definition and Classification-

Professor Schmidt's definition holds good today, and is as follows:

"In the multiform picture of glaucoma three principal tendencies can be recognized as pathognomonic, (a) the increase in intraocular pressure, (recognized by increased hardness of the globe), (b) the consecutive excavation of the optic disc, and (c) the inescapable blindness without therapeutic intervention.

"The course of the disease may be without or with inflammatory symptoms. In the former case, we have the simple glaucoma; in the latter, the inflammatory glaucoma; here again, we differentiate according to appearance and cause, an acute, a chronic, and an intermittent form, However the various forms frequently merge. For instance, a simple or chronic glaucoma suddenly may show the picture of an acute attack and, on the other hand, an acute glaucoma not infrequently changes into a chronic. Besides these genuine forms, these glaucomatous processes should be mentioned which occur in other eye affections. They are called secondary glaucomas."

Freidenwald writes: "Glaucoma is not a disease but a whole complex of diseases which have as their common feature an abnormal elevation of intraocular pressure."

Duke-Elder says, "The term glaucoma does not connote a disease entity, but embraces a composite congeries of pathologic conditions which have the common feature that their clinical manifestations are to a greater or less extent dominated by an increase in the intraocular pressure and its consequences."

Conventionally glaucoma is classified into;

1. Chronic simple (noncongested, compensated).
2. Acute congestive (incompensated, inflammatory).
3. Chronic congestive (incompensated).
4. Absolute.

Otto Barkan, after after extensive gonioscopic and other studies divides the primary glaucomas into;

1. Open (wide) angle, (non-congestive, chronic simple), and,
2. Closed (narrow) angle, (iris block, congestive) glaucoma,

on the basis of gonioscopic findings.

In the open angle type the angle is found to be open, but sclerosis of the trabeculum and pigment deposits on the endothelium of the cornea are often found. In the early dlosed or iris block glaucoma, the anterior chamber is shallow, but the iris can be seen to obstruct the angle during attacks, and to almost block the angle between attacks, the cornea being clear of deposits.

Barkan has been said to belong to the "mechanical school", and it is not the purpose of this study to defend the theories

of the causes of glaucoma, but this latter explanation of it's cause explains why a simple peripheral iridectomy will usually cure permanently an early acube congestive or narrow angle glaucoma, wheras it has little effect on the open angle, or chronic simple glaucoma, when the diagnosis has been corroborated gonioscopically. The author considers this differentiation a great advance in the diagnosis and treatment of glaucoma.

Physiology of the aqueous and intraocular pressure-

Inflow-

It is generally accepted that there is a through and through circulation of aqueous. The aqueous is formed in the ciliary body, probably by a combination of diffusion and secretion. The diffusion process takes place by dialysis and ultrafiltration according to the Gibbs-Donnan theory of equilibrium. But as Friedenwald, Kinsey and otherw have pointed out there must be, in addition, secretion, to account for characteristic findings in the aqueous.

The theories of secretion as worked out by Friedenwald, Kinsey, and others takes into account a cytochrome oxidase system such as the use of the enzyme corbonic anhydrase to promote the flow of electrolytes and fluid adross the diliary epithelium into the aqueous humor. There is good evidence that a similar mechanism of secretion exists using carbonic anhydrase as an enzyme in the stomach, kidney tubules, pancreas, and the central nervous system. The following diagram illustrated this transfer as described by Tchergi.

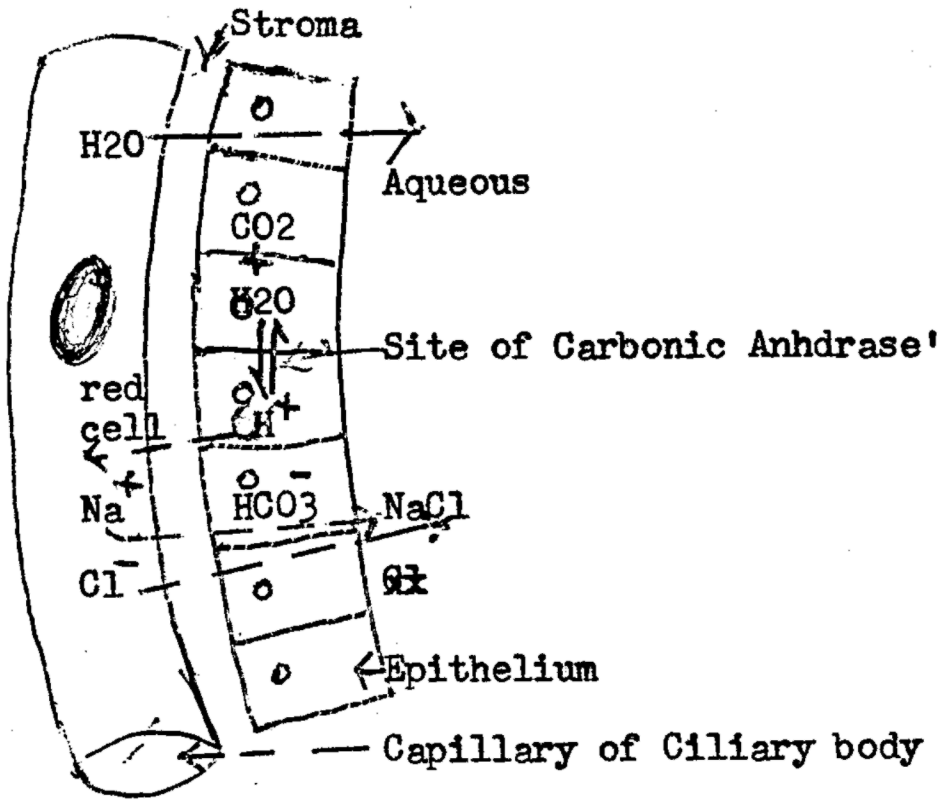


Diagram #1

Outflow-

Aqueous is constantly lost from the anterior chamber by flow through Schlemm's canal, and is discharged into the ciliary plexus adjacent to the diliary mechanism into thin veins branching off to the episclera. The emisarium cysticum may often be seen with the biomicroscope carrying the clear aqueous fluid which can subsequently be seen mixing with venous blood. Their course has been beautifully and clearly demonstrated by Ashton.

In addition th the constant loss of fluid by flow down Schlemm's canal, there is a constant loss of the various constituents of tha aqueous humor from the anterior chamber by diffusion into the tissues which bound the anterior chamber such as the iris, cornea and lens.

Intraocular Pressure-

In its simplest terms, intraocular pressure is a result

of the balance between aqueous inflow and outflow. The pressure should be elevated if either the inflow is increased or the outflow decreased from the normal, and the pressure decreased when the inflow is decreased or the outflow accelerated.

Grant, using the tonometric method of estimating the flow, estimated the outflow at about 2.4 cu. mm. per min. Goldmann, (1949), using flourescein dye changes estimated the flow at 2.2 cu. mm. per minute. It is generally considered that all constituents of the aqueous combined, enter and escape at the rate of 3 microliters per minute.

The influx of water as a result of hydrostatic and osmotic pressures, together with the hydroxyl ion exchange by the secretory mechanism of the ciliary body, is responsible for the intra-ocular pressure. Upon Kinsey's findings of the difference in concentration of bicarbonate and ascorbates in the posterior and anterior aqueous, Becker came upon the use of the carbonic anhydrase inhibitor, Diamox ("-acetylamine-1,3,4-thiadiazole-5-Sulfonamide), which has proved to be an effective agent in the lowering of the intraocular pressure, by decreasing the formation of aqueous.

The phasic or diurnal variation which never normally exdeeds 5 mm. of Hg., and is not satisfactorily understood, but which may be related to the same sort of venous pressure variation. Weinstein suggests that the pressure is dependant upom the action of numerous cortical centers, the hypothalamus, medulla, or even peripheral, the sympathetic, the carotid sinus, or the parasympathetic ganglia. Hormonal influences have also been blamed.

Etiology of Glaucoma-

The present concensus is that primary glaucoma is due to an impediment to the outflow mechanism, which in turn has been credited to be due to:

1. Trabecular sclerosis, visible gonioscopically, Grant and Trotter. Linnér measures the drop between the anterior chamber pressure and that in the canal of Schlemm as proof of same.
2. Sclerosis of aqueous veins with a decrease in number. Ascher.
3. Elevated veinous pressure acting as a trigger mechanism. Bain.
4. Hypothalamic region. Theil and Magitot feel that disturbed tension was the result of local, endocrine, and nervous factors.
5. Sympathetic system. Cristini and Strazzi were able to to decrease the intraocular pension by stellate ganglion block and postulate that increased tensions are due to an alteration of the cervical sympathetic system.
6. Allergy. Fontana felt that since the histamine content of the blood in glaucomatous subjects is increased before and normal after operation, that allergic disease may have some importance in glaucoma. Subsequently, Wiseman and Moore reported a case of congestive glaucoma precipitated by orange juice or peas.
7. Endocrine system. Radnot and Urban found a homolateral elevation in intraocular tension in 29% of rabbits following ligation of a deferent duct.. Schmerl and Steinberg have isolated two pituitary hormones from the spinal fluid of rabbits and men. Hyperpiesin, which acts on the parasympathetic system increasing the tensio n, and Miopiesin, lowering the pressure by its action on the sympathetic system.

8. Diffuse sclerosis or hyaline degeneration. Urrets Zavalia, also Brand and Sokolowski.
9. Miscellaneous factors such as electric shock and curare.

Duke-Elder summarizes the etiology of primary glaucoma as follows;

"1. A disturbance of the central mechanism regulating the complex factors maintaining the tonus of the eye at a relatively constant value.

"2. A disturbance of the membrane-system forming the tissue-aqueous barrier.

"3. A disturbance of the venous-capillary circulation. That is, essentially, of endothelial function (the blood tissue barrier).

"4. A disturbance of the drainage system of the intraocular fluids.

"It is probable that in some cases all these factors may act in consort, that in athers they may react in varying combinations, or that in others they may exert a dominating influence. It is obvious therefore, that primary glaucoma cannot be considered a single disease, but is rather a composite congeries of clinical entities which we connot yet disentangle.

Magitot, a confirmed believer in the vascular etiology of all forms of glaucoma, believes it results from engorgement of the uveal capillaries, with resultant hypersecretion of fluid.

With such a lack of knowledge as to the exact cause, is it any wonder that the methods of treatment are so variable and the results at times unpredictable? Barkan's classification together with Trotter's mechanical concept of glaucoma, based on gonioscopic findings of an open or closed angle, appear to be a great step

toward a solution of the glaucoma problem.

History of the Treatment of Glaucoma-

The treatment of glaucoma may be said to have begun with the advise of Mackenzie (1830) to relieve the tension of the eye by a paracentesis or a sclerectomy. This treatment was not to successful, the results at best being of a temporary nature, and until the time of v. Graefe, glaucoma was considered incurable, and its diagnosis was tantamount to a sentence of blindness. In 1857 v. Graefe noticed that a staphyloma receded after an iridectomy, and thus by chance inaugurated a revolution in ophthalmic surgery.

The next great advance was the discovery of the efficacy of miotics by Laquer of Strasburg,(1876), although curiously, this discovery aroused the fiercest opposition. This same year Argyll-Robertson advocated trephining of the sclera, and Bader incarcarated the iris into a scleral incision in 1881. Coccius did an iridectomy with iris inclusion in 1859, which was popularized in 1906 by Holth of Oslo, and in 1903 by Herbert of Bombay. Cyclodialysis was developed by Heine (1905) of Breslau, and the irido-sclerectomy by Lagrange (1905) of Bordeaux. The corneo-scleral trephining operation by Elliot (1909) at Madras, at once attracted universal attention, and probably did more than anything else to revolutionize the treatment of glaucoma.

Aside from the treatment of congenital glaucoma by goniotomy as advocated by Barkan, the next develope ment was that of cyclodiathermy by Vogt in 1937, and its modification is the procedure which is the object of this study.

Cyclodiathermy-

History-

Punctures with an electric needle have been used in cases of retinal detachment since 1881, (de Wecker, Abadie), and in 1921, Shahan and Post observed that the application of the thermophore near the limbus caused a relatively permanent reduction in pressure in two cases of glaucoma. In 1925 Curran reported cauterization of an area over the ciliary body, 8-10 mm. in diameter with the galvano cautery, but the effect seemed only temporary. In 1929 Fiore reviewed the results in 177 eyes which he had treated with the galvanocautery meridionally from the limbus to the orra serrata. In 1935 Gradle plunged a diathermy needle into the vitreous on the treatment of absolute glaucoma.

Technics used and results obtained by various authors-

In 1937 Vogt discussed a method which he called cyclodiathermy-puncture, in which, after reflecting the conjunctiva toward the limbus, he made one hundred or more punctures usually inferiorly, from the insertion of the medial to the lateral recti muscles, in a girdle shape between $2\frac{1}{2}$ and 6 mm. from the limbus. He used a $\frac{1}{2}$ mm. needle .16 mm. in diameter, and placed the punctures at intervals of $\frac{1}{2}$ mm. for a time period of 1 second using 60 milliamperes. He considered this operation of choice in cases in which other measures had failed, and in glaucoma secondary to uveitis. He warned that corneal necrosis might result if the punctures were placed closer to the cornea than 2 mm. In 1939 his colleagues Wagner and Richner repoted 47 operations with 72% success.

In 1942 Albaugh and Dunphy reported 18 cases of non-penetrating diathermy using a flat Weve type electrode which they applied for 8-10 seconds, placed at 4-5 mm. from the limbus, and running them adjacent to each other for a little more than one-half the circumference of the globe. They reported 14 successes and 4 failures. They recommended its use in hemorrhagic glaucomas, and in aphakic glaucomas where cyclodialysis could not be done. Weekers, in 1949 devised a technique of surface diathermy, applying the electrode for 15 seconds, making 15-20 applications 7-9 mm. from the limbus. He felt that it was effective by its action on the nerve supply.

The next year Weekers and Weekers reported a series with 68% success, and recommended its use in secondary glaucoma, absolute glaucoma, and advanced glaucoma of any type. Reiser felt its effect was due to diminution of the blood supply of the ciliary body, and advocated the placement of the punctures 8 mm. from the limbus and took great care to cauterize the insertion of the muscles to close off the ciliary arteries. Others similarly placing the punctures well back are Biozzi, Schreck, Arato, and Arruga.

Arruga directs his cuatery to the tendons of the recti muscles aiming at, not only the vessels, but also the nerves. He applies a one mm. electrode for 5-15 seconds, making 15-20 applications 9 mm. from the limbus. Acto-Peis detached the medial and lateral recti muscles, and made 8-10 punctures posterior to their insertion.

In 1952 Scheie reported a comparison of results in 17 cases with the Vogt technique, and 14 cases with Castroviejo's earlier method, i.e. 8-10 punctures with a 1 mm. needle 6-7 mm. from the limbus for a period of 10 seconds. He reported

twelve successes with the latter method, and stated that it had a more reliable effect upon ocular tension. Alajmi and Simonelli felt the procedure of value in the treatment of infantile glaucoma. Lachman and Rockwell reported their results in 39 cases, only seven in which they considered their results to have been satisfactory. They also reported 6 cases of atrophy of the globe. All cases required the use of mioties to control the tension. Bodian reported a case of sympathetic ophthalmia developing 3½ months after a partial penetrating cyclodiathermy in which a posterior sclerotomy was done and noted two other cases.

Victoria and associates used a 5 mm. electrode giving 12 punctures for aperiod of 5 seconds, 8 mm. from the limbus. They reported good results in chronic simple, and poor in congestive types of glaucoma. They felt it to be of value in infantile glaucoma. Because of its simplicity, harmlessness, and ease of repetition they felt the procedure had a very definite place in aur armamentarium.

Canka uses the nonperforating technique, together with cyclodialysis, and reports 41 out of 53 cases as qontrolled. Knobloch uses angiodiathermy, consisting of coagulation in front of and parallel with the insertions of the medial and lateral recti muscles, and reports all cases operated on for simple glaucoma permanently cured.

Viger used the Vogt technique in 10 eyes and reported success in 4 of them. He thought the procedure to be of value in buphthalmos, absolute glaucoma, and secondary glaucoma, but Urrets-Zavalia and Urrets-Zavalia perform a surface type of operation similar to Weekers, and conclude that cyclodiathermy

is the operation of choice in secondary glaucoma, but that filtering procedures should be used in chronic simple glaucoma and iridectomy for narrow angle glaucoma.

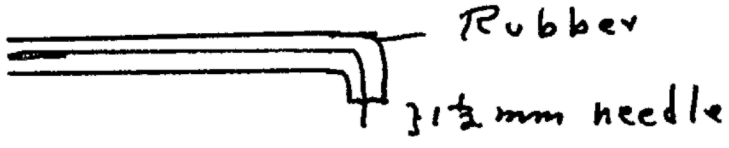
Neubauer does a type of angiodiathermy, placing the surface diathermy just in front of the rectus muscles, creating a partial obliteration of the long ciliary arteries, and reports 63% success. Arato does a similar procedure using a 1½ mm. perforating electrode. He reports no complications and recommends the procedure in chronic simple and aphakic glaucomas and buphthalmos.

Kamel describes the perforating techniques, flat electrode, scleral coagulation of Theil, Diaz and Dominiquez, and a method of freezing the ciliary body with carbon-dioxide snow, with little preference as to the type of procedure. Velissaropoulos records his experiences with Beren's electrolysis method. Sokolic obtained 100% success in 54 eyes combining cyclodiathrmy with cycloelectrolysis. Hurwitz reported to successful cases treated as outpatients in his office. Maeder reports 80-100% success in his cases of perforating cyclodiathermy, and Bartolome 50% success with nonperforating retrociliary diathermy. Sokolic in a later report using nonperforating cyclodiathermy with cyclodialysis reports only 70%success as compared withe his previous report of 100% success. Cascio beleives cyclodiathermy to be of value in infantile glaucoma. Covell and Batangbacal were unfavorably impressed with their results and warned against sympathetic ophthalmia. Szymanski prefers cycloelectrolysis to cyclodiathermy.

Blake suggests cyclodiathermy as the treatment of choice in congenital aniridia. Meesmann reported an 8 year follow up on 102 cases operated on by the Vogt technique with 50% success. Berliner reports his results on 68 eyes.

Castroveijo presented his technique of cyclodiathermy at the midwinter post-graduate course in Ophthalmology at the ~~x~~ University of Florida in 1951, and was very enthusiastic about his results at a similar lecture given at Los angeles in 1953. The technique he recommended follows:

The needle: He uses a curved, hard rubber coated, 1½ mm. needle.



Surgical technique:

Distance from the limbus: 6-7 mm.

Time: 10 seconds each.

Current: Minimum that permits the passage of the needle.

Position: All punctures limited to the quadrants.

Number: (of punctures).

1. If tension minimly elevated: 2 per quadrant (8).
2. From 35-40 on strong miotics: 4 per Quadrant.
3. If 1. (above) is not controlled he does another (8).
4. If 2. (above) is not controlled he does another (4).
5. Punctures in the second procedures are placed anterior some 4-5 mm. from the limbus.

Danger: He warned that overtreatment led to phthisis bulbi.

Failures: He said that failures would occur in (a) advanced diabetes, (b) Absolute glaucoma.

Caution: He advised to stay away from the long posterior ciliary arteries lying beneath the medial and the lateral recti muscles.

Histologic Studies-

De Walsche in a histologic study of a case treated twice by diathermy two years previously reported the finding of atrophy of the ciliary body surrounding the site of application of the electrode, which finding is in harmony with that of Van Heuven and Dunn, who, in a study of the histologic sections of rabbits after cyclodiathermy, found an eventual scarring of the ciliary processes, and early, the involved processes were necrotic, hemorrhagic, and the pigment layer edematous. They used cyclodiathermy successfully in the treatment of glaucoma secondary to delayed formation of the anterior chamber. These histologic findings are consistent with the findings of Weekers and Delmarcelle of a reduced flow of aqueous as determined by the fluorescein instillation technique following cyclodiathermy.

Results of other workers-

It can readily be seen from the above reports that the results obtained by other workers vary greatly with seemingly little regard to the type diathermy procedure used. One finding of note however is that with the passage of time the percentage of successes falls, which readily explains why the enthusiasm often felt for the procedure at first tends to deminish with time. In spite of this observation the percentage of successful results reported are encouragingly high, very few being less than 50%, and the majority over 70%.

Anatomy-

In view of the marked variance in the type and location of various cyclodiathermy procedures used, a review of the anatomy of the anterior segment of the globe is in order, and th e following diagrams will aid the visualization of the various procedures performed.

Of surgical importance is the fact that the ora serrata lies 5.9 mm. from the limbus nasally, and 6.7 mm. temporally, and the recti muscles carrying the anterior ciliary vessels insert in a spiral position with reference to the limbus, Beginning with the medial rectus at 5.5 mm., then the inferior at 6.5, the lateral at 6.9, and the superior at 7.9 mm.

The relation of these points to the area of treatment as caried out in thisseries can be readily pictured by a glance at diagram No. 3. And by referring to diagram No. 5. showing the arterial network one can easily visualize how phthisis bulbi could result from injuring the long and anterior ciliary arteries by cauterizing the area of insertion of the recti muscles. The anterior ciliary vessels are derived from the muscle branches of the ophthalmic artery, there being two branches to each of the recti muscles but the lateral which has only one. The arteries emerge from each tendon and pass anteriorly in the episclera, giving off the anterior conjunctival artery, and piercing the sclera near the corneo-scleral junction to join the major circle of the iris.

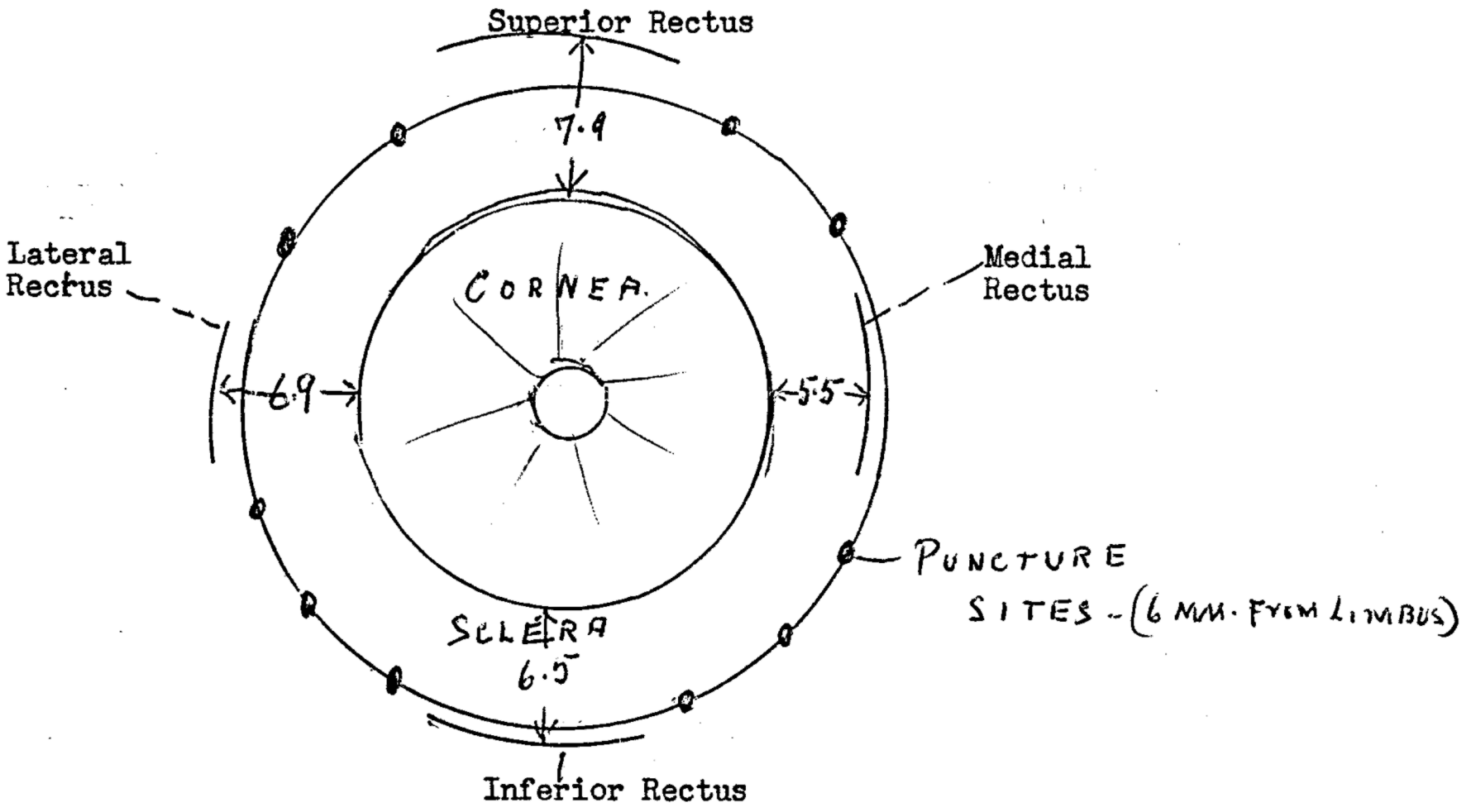
There are two long posterior arteries, nasal and temporal, entering the sclera through a 4mm. long oblique canal near the

optic nerve, passing via the supra-choroidal space in the horizontal miridian directly forward to the ciliary muscle where they each divide into two branches which anastomose with the anterior ciliary arteries and each other to form the major circle of the iris.

The cornea obtains its nutrition mainly from the marginal capillary plexus, which is derived from the anterior conjunctival vessel. Here again it is very easy to understand how corneal edema and even opacity could result vrom cauterization of these vessels as in the Vogt technique, as can be seen by a glance at diagrams No. 5 and 6.

, The nerves to the ciliary body, iris and cornea are all derived from the long and short ciliary nerves which accompany the long ciliary arteries, forming a plexus in the ciliary muscle. Hence one can readily understand how corneal sensitivity is routinely diminished following cyclodiathermy. However I have not noted any alteration in the pupillary response which could be attributed to cyclodiathermy.

When one studies the histologic appearance of the ciliary body with its numerous processes and marked vascularity, it is little wonder that the effect of the diathermy is often only temporary and that the organ tends to gradually recover its function.



Casroveijo technique site for diathermy punctures

DIAGRAM # 3

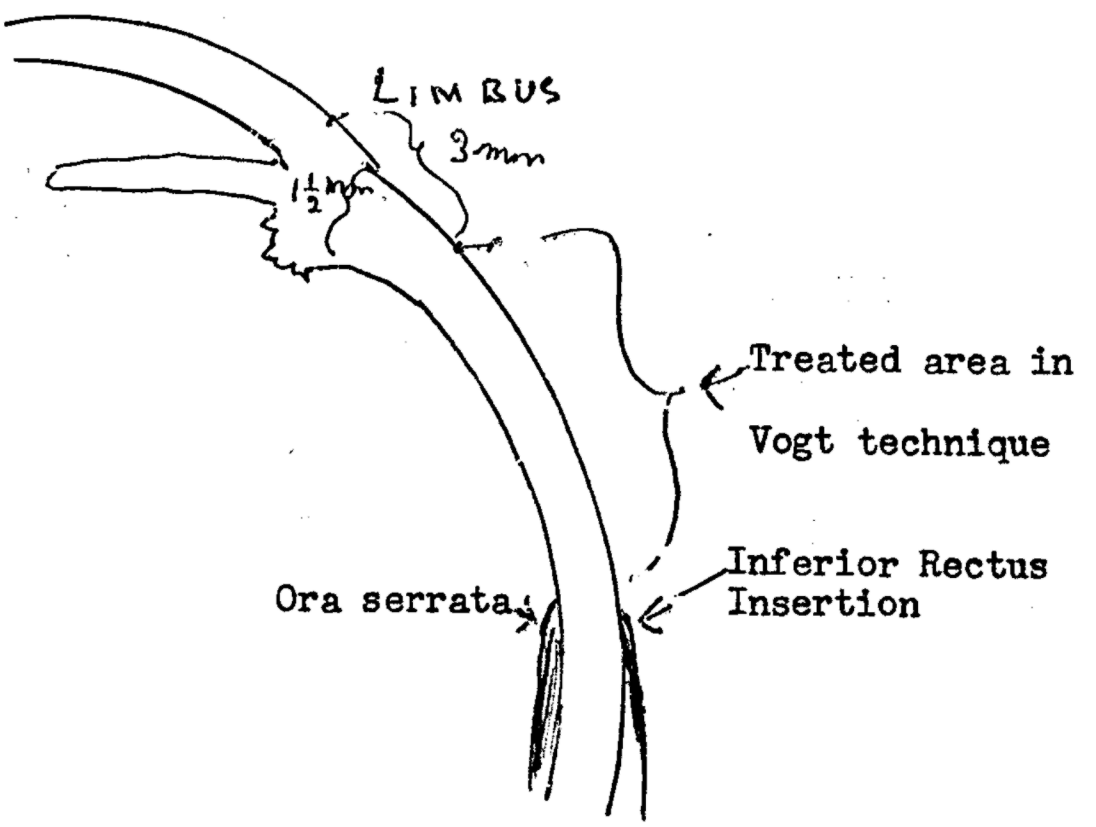


DIAGRAM # 4

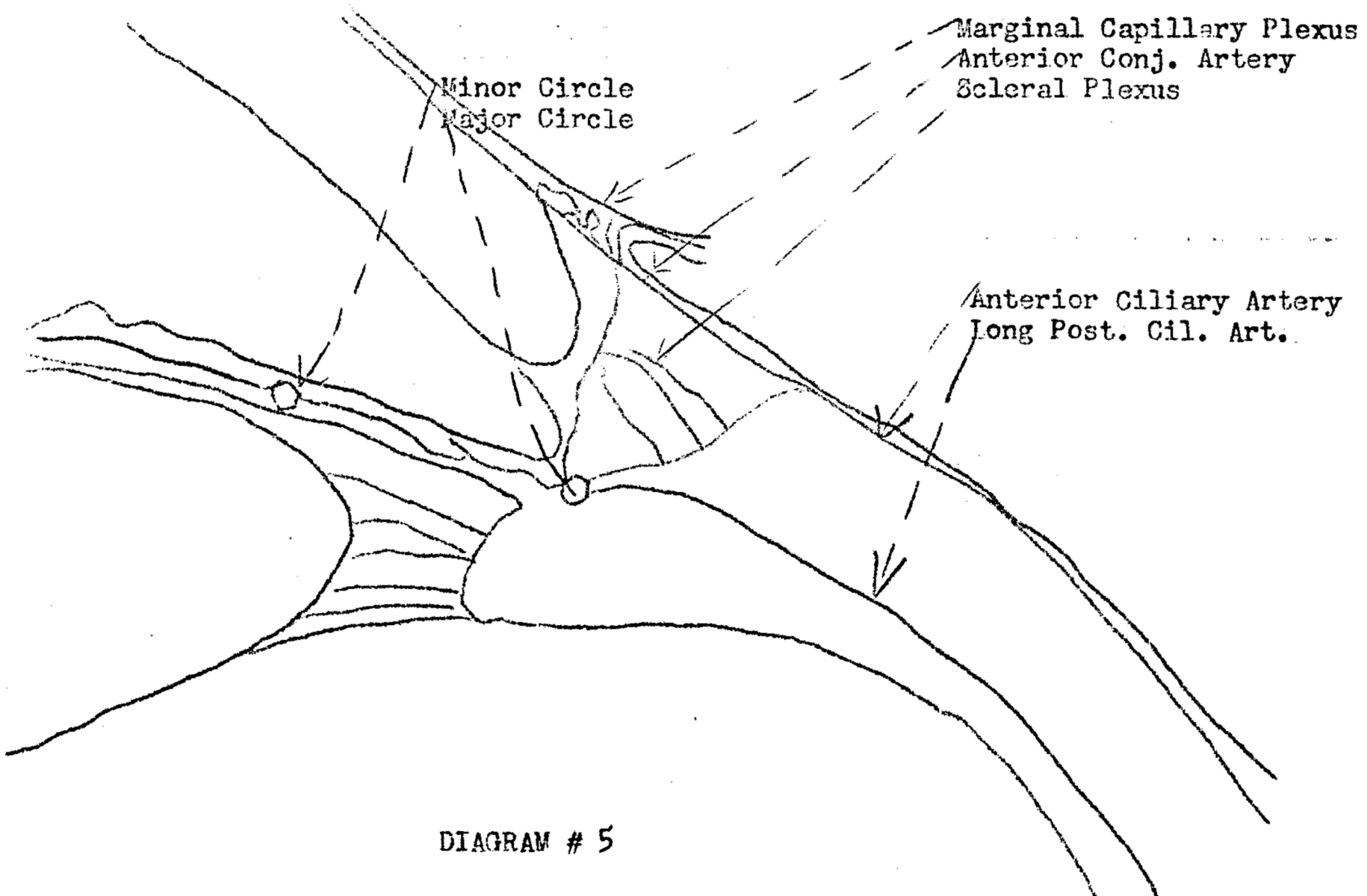
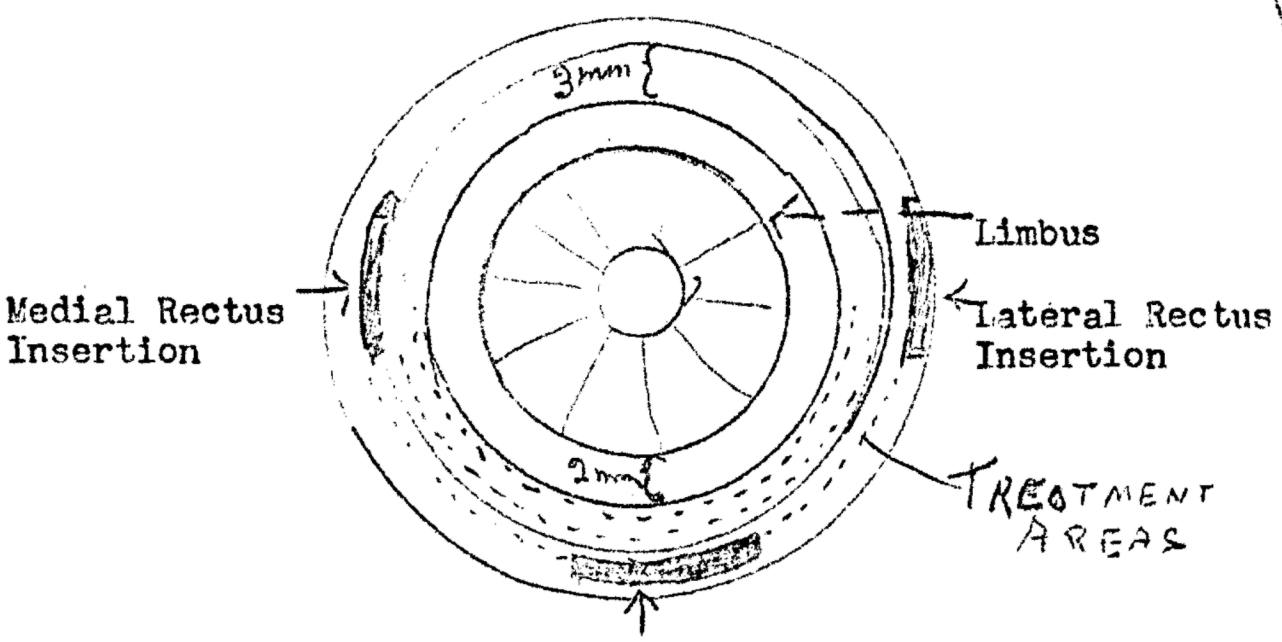


DIAGRAM # 5



VOGT TECHNIQUE

DIAGRAM # 6

The Study-

Technique used in this series-

Interest in cyclodiathermy was aroused by the enthusiastic reports given by other workers, and especially by Castroveijo, who claimed excellent success with few if any complications. His exact technique has already been described, and was followed in the majority of cases in this series. For the first 9 cases, or until 1953, 8-12 punctures with a 1 mm. needle placed 6 mm from the limbus over ½ the circumferance of the globe. Later the punctures were placed ofer the entire circumference of the globe spacing the punctures equally between the recti muscles, with a deliberate attempt to avoid the isertion of these muscles with the exception of cases 46-56 inclusive, wherin one puncture was placed centrally over the insertion of each recti muscle, and the remaining 4-8 punctures placed in the intervening areas also 6 mm. from the limbus. For the last 80 operations a 1½ mm needle was used rather than the 1 mm. used at first. I t was also .18 mm. in diameter. The current used was the Walker diathermy with the machine set between 40 and 50 milliamperes for a duration of 10 seconds each.

The patients were all treated as outpatients, with but two or three exeptions. Preoperatively they were given a barbiturate such as nembutal grs. 1½, about 45 minutes before taking them to the operating room. The eye and lids were prepared in the custmmary manner. 5% cocaine was instilled topically 3-4 times, and 2½ cc. of 4%procaine was injected slowly into the mucles cone. This was supplemented on ocasion with a Van Lint akinesia, and suconjunctival infiltration of pontacaine, but

these latter injections are rarely necessary if one is careful to allow sufficient time to permit the retrobulbar procaine, and topical cocaine to obtain its maximum effect which is usually 10 minutes.

The current is then tested on a metallic object and a small but distinct jump should be obtained with the proper setting. One must always keep in mind that in most hospitals the current will very considerably with load being used at the time and one therefore should never rely on the machine setting alone.

If desired, a speculum is then inserted, and the eyeball gently rotated with a muscle hook, toothed forceps are avoided because of the conjunctival trauma which they usually produce, and after measuring the exact 6 mm. distance from the limbus, the current is turned on and the needle directed into the sclera through the conjunctiva for its entire length. With the correct current setting some bubbles will be noted surrounding the needle and after a period of 10 seconds, the needle is withdrawn when it will be found somewat adherent to the surrounding tissues. A small amount of vitreous will often be seen to emerge from the puncture. One must be certain that the treatment area is dry or the current will short to the surface and its effect nullified. One must not hurry the procedure or the globe will become overheated, and the cornea steamy. Although the globe is not soft following the procedure, we have never found it unduly hard necessitating paracentesis as recommended by others. An antibiotic oinment is then instilled in the eye and the eye patched.

The patient remains in the recovery room for a period of about three hours after which the patch is removed from one

eye, usually the better seeing eye if both eyes were operated upon, and the patient given a prescription for a mild analgesic to be used if necessary for pain, and a tube of antibiotic ointment, which he is advised to instill in his eye twice daily. The patients are then followed at intervals of one to three days until the reaction subsides which is usually about one week.

Technique used in the study of the facilities of outflow in this series-

A Mueller electric tonometer was used, and the results t tabulated in accord with Ballantyn's booklet, 1953. Patients requiring pilocarpine or other miotics were asked to refrain from their use for 24 hrs prior to the test.

The patient was placed in a comfortable prone position on the table with any constricting articles of clothing loosened. ½% pontocaine was then instilled three times at 1 minute intervals, and this produced satisfactory anaesthesia in every instance. The machine was permitted to warm up and calibrated after which the patients eyes were directed at a colored object on the ceiling. The fingers of one hand were used to retract the lids while the other held the tonometer footplate momentarily in front of the eye before permitting it to rest vertically on the center of the cornea. Readings are then taken at 15 second intervals for a period of four minutes, after which the patient closes their eyes for a moment to permit the remaining eye to recover from the reflex action of the test while the tonometer footplate is cleansed with 1:5000 solution of bichloride of mercury. The procedure is then repeated on the remaining eye.

The results are then plotted on a graph paper and the median converted by means of Friedenwald's tables to the facility of outflow. The cornea was also examined under the slit lamp to acertain the presence of epithelial injury to the cornea. No significant injury was found in this series, neither did the patients complain.

Results of the facility studies-

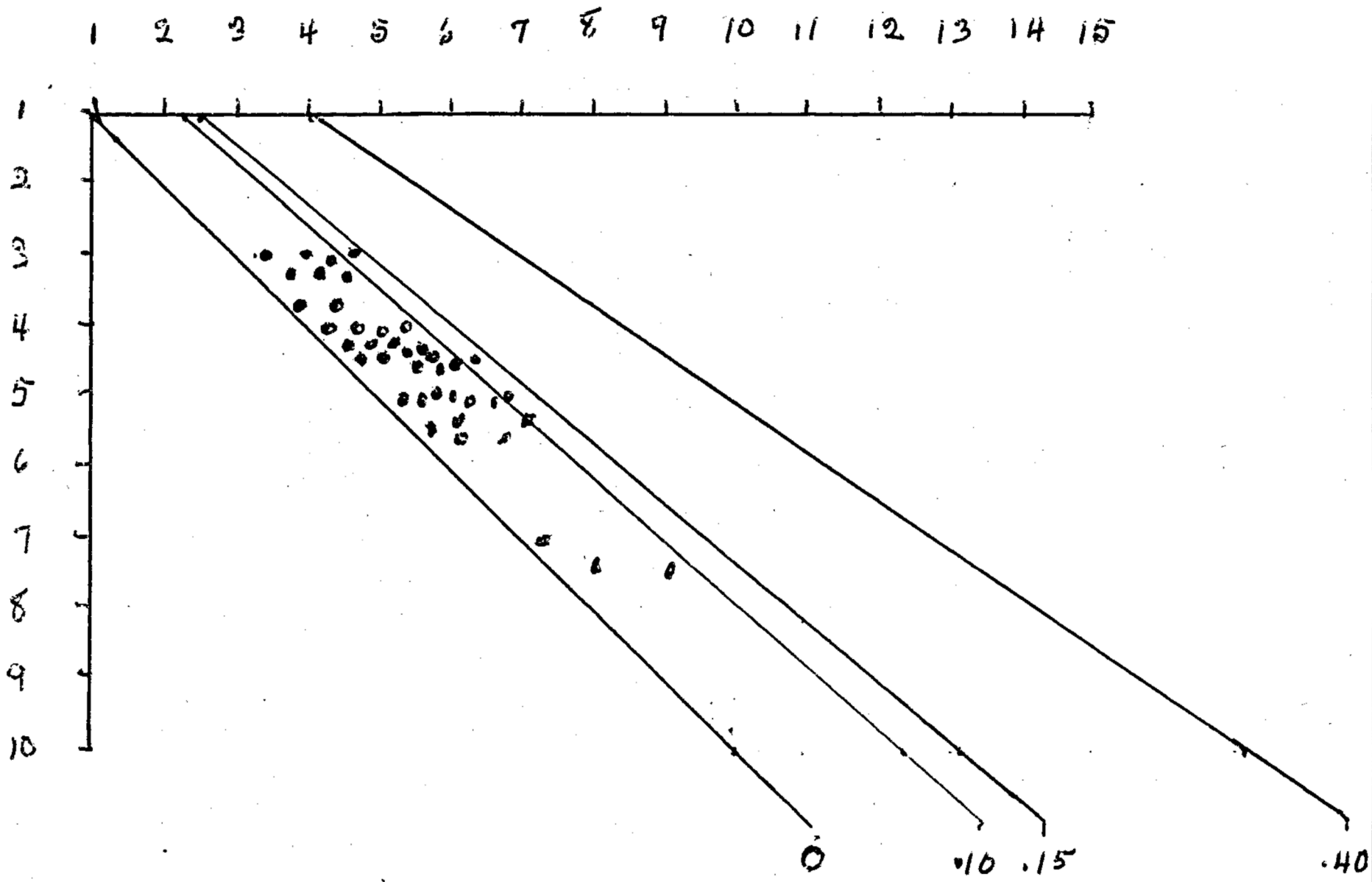
Of the fifty eyes studied following cyclodiathermy, none had a facility of over.12 cu. mm. per minute. The results are graphically tabulated on Diagram # 7. Five eyes with normalized pressure, cases # 12, 14, and 17 had flat ~~outflows~~ curves with outflows of practically nothing. The average for the group was .08. This is a marked contrast to that obtained following a successful trephine or iridencleises , which, in those I have studied run between .25 to .55 cu. mm. per minute, or around five times the flow that we find following cyclodiathermy. The normals usually fall between .15 and .45 cu. mm. per minute.

These findings are directly in harmony with thowe of Weekers and Delmarcelle, who studied the mechanism of cyclodiathermy with the fluorescein instillation technique, and concluded that a very much reduced inflow of aqueous resulted. In our cases we found the aqueous to be reduced to about 1/3 that found in the normal eye.

From these findings our deductions are that cyclodiathermy acts by inhibiting the formation of aqueous. Whether this is due to a direct action on the ciliary body itself or to its action indirectly through its effect on the nerve and blood supply to the ciliary body will be discussed later.

Facilityof Outflow in cases of Glaucoma with Pressures

Normalized by Cyclodiathermy;



The initial and final scale readings are plotted graphically to indicate the Coefficient, or facility of outflow in cu. mm./min./ mm. Hg. pressure. It can be readily seen that although the scale readings are all 3 or above indicating pressures below 24 mm. of Hg., yet the facilities are all below the normal .15 line.

Analysis of the Cases-

Of the 89 operations performed on 83 eyes of 58 different patients, there were 6 repititions, the right eye of case #21 sustaining 3 operations. Ages varied from 45 to 83 years. The sex was almost equally divided, with 30 females, and 28 males. Forty-five were left eyes, and 38 right eyes were oprated upon. A summary of the details of the cases operated upon can be found in the following table.

The first figure under "the type of operation" in the table, indicates the number of punctures made, the second, the time the current was applied, in seconds, and, the third,figure, indicates the distance in mm. from the limbus that the punctures were made. S. indicates that the tesion was controlled for the time indiaated in the follow-up, or, until the operation was indicated as having been repeated. All cases but # 23, and # 49, required additional miotic therapy to maindain a satisfactory intraocular tension. Four cases can be considered absolute failures. Three of these were cases of absolute glaucoma. The other failure, case# 21, responded well to a second procedure. No cases of phthisis bulbi resulted. Serious complications were almost nill. Anterior chamber hemorrhagesoccurred in three cases postoperatively, in # 3, # 49, and # 56. Cases # 3 and 56 were cases of absolute glaucoma, and were subsequently enucleated.

The vision in case # 49 dropped from 20/70 to hand motion postoperatively, but, over a period of three months the anterior chamber hemorrhage cleared and the lowgrade uveitis cleared permitting the vision to return to its previous level. The tension has remained normal without the use of miotics since,(over 1 year).

One of the most disturbing finding is that, although the tension may be normalized, only about 50% of the cases maintain their vision. The remainder gradually lose field for no apparent reason, and, when the field is small, may lose visual acuity quite rapidly.

Cases falling into this latter classification are #12, whose vision dropped from 20/50 to L. P. in a period of $2\frac{1}{2}$ years, # 28, whos vision O. D. 20/70, and O. S. 20/200, dropped in a period of $2\frac{1}{2}$ years to 5/200 and 1/200 respectively.

Case # 11, dropped from 20/50 to 20/200 immediately postoperatively for no apparent reason, and his vision never improved subsequently.

Ofinterest is case # 41. This was a 67 year old white female, who was first seen in the Eye Clinic on 10/26/53, with the complaint of failing vision for $2\frac{1}{2}$ years, and, with known cataracts for one year. Vision was, O. D., 3/200, O. S., H. M. A diagnosis of mature senile cataract O.D., and Hypermature senile cataract O.S., was made, and one month later an intracapsular cataract extraction was performed through a von Graefe type of corneal incision, A complete iridectomy was done, and the corneo-scleral incision was closed with five 6-0 interrupted post-placed silk sutures. There was no vitreous loss or presentation. The post-operative course seemed uneventful at first, as the anterior chamber was reformed the next day, and the media were quite clear, but the eye remained somewhat more injected than the average. The sutures were removed three weeks later and on the fourth week the tension 35 mm. Hg. Schiotz. The eye appeared very irritable, and there appeared to

be an endothelial downgrowth at the eleven o'clock suture site. Treatment with X-Ray was instituted. The eye remained irritable, and the tension elevated, in spite of all medical therapy, until 4/15/54, when cyclodiathermy was done using the technique previously described, making two punctures in each quadrant, between the muscle tendons, a distance of 6 mm. from the limbus. The tension dropped to normal, the eye whitened up, and the corneal edema, and hyperemia at the site of the downgrowth subsided, and the patient has remained asymptomatic with vision of 20/40 O. S.

Another case of interest is that of # 56, a 76 year old white female, who had had an uneventful cataract extraction from her right eye in 1945, and at which time an immature senile cataract was noted in her left eye. She was not seen again until July, 1955, when she came to the clinic with the complaint of having a sharp, severe pain, as if something had exploded in her left eye of 24 hours duration. She gave a history of having had spells of acute pain followed by redness of the left eye for the previous six months.. She had had no useful vision in the eye for over eight years. Examination revealed a very red eye with considerable corneal haze, but the lens nucleus could be clearly seen in the anterior chamber. The nucleus was removed through a medium sized corneal insision, and theanterior chamber irrigated ~~xxxxxxxxxx~~ gently with saline in an attempt to remove the remaining lens fragments, after a complete iridectomy had been done. There was no vitreous loss. The wound was closed with four interrupted 6-0 silk post-placed sutures. The wound healeduneventfully, but at about 2 weeks post-operatively the eye became increasingly injected with an elevated tension. Diamox steroids, and after mydriatics had failed, miotics were unsuccessfully

used in an attemt to control the tension. Two months later with light perception only, remaining, a cyclodiathermy was done, following which the pressure dropped, and remained around 12 mm. of Hg. Nevertheless the eye remained irritable and was removed because of the possibility of it'sproducing a sympathetic ophthalmia.

A summary of the pathologic finding follows. In addition to a 2mm. pathologic excavation of the nerve head, and almost complete absence of ganglion cells, the sclera and adjacent ciliary body show considerable evidence of scarring and necrosis around the cyclodiathermy punctures. There is definite evidence of scarring of some of the ciliary processes. The angle appeared open, although there is considerable trabecular sclerosis.

Seven of this series had complicating diabetes, 12 were aphakic glaucomas. One had suffered a central artery acclusion, and the eye required enucleation soon after the cyclodiathermy was performed. Three cases were absolute glaucomas, two of which were later enucleated. Six had L. P. only,and maintained it during the period of observation. One of the cases of L. P. was that of # 9, who had chronic congestive glaucoma. Forty-four were cases of chronic simple glaucoma, and with two exceptions, the fields were less than five degrees in thepoorer eye.

It can be seen that the result was excellent in the case of secondary aphakic glaucoma due to endothelial downgrowth, with an apparent complete cure without the use of miotics. Aphakic glaucomas on the whole, sesponded well for a period of two or three months, after which miotics were necessary to keep the tension under controll. The response of the tension

In cases with chronic simple glaucoma, was at first excellent, and then later only fair with miotics. Of the three absolute glaucomas treated, two required enucleation later. Using normalized pressure as a standard of success, we consider our results as a whole, excellent,with 95% success. If, however, we consider as well, the maintainance of the vision with no further field loss, our percentage of success drops to an almost complete failure, around 60%.

NO.	AGE	DIAGNOSIS	PREVIOUS SURGERY	VISUAL ACUITY	PRE*OP TENSION	TYPE OF OPERAT.	FOLLOW UP	DATE	RESULT
1	PT	58 Aphakic Glaucoma Diabetes	Extra Cap.Cat. Ext.	NLP	55	12x10x10	3 yrs.	1/3/52	Absolute & Enucleatin
2	AZ	78 Chr. Simple Glau.	None	OD NLP	86	10x10x8	2 yrs.	2/7/52	S
				OS 20/70	56	14x10x8		11/20/52	S
				OD NLP	50	14x10x8		11/20/52	S
3	BC	71 Occl. Central Ret. Art.,Sec. Glau.	None	OD NLP	83	10x10x7	1 mo.	10/15/52	Enucleatio
4	JK	65 Aphakic Glaucoma	Extra Cap. Cat. Ext.	OSNLP	46	10x10x8	6 mos.	4/22/52	S
5	AH	63 Aphakic Glaucoma	Intra-Cap. Cat. Ext.	OD20/25	44	10x10x8	3 yrs.	9/4/52	S 3 mos.
6	HG	60 Chr. Simple Glau.	None	OS20/50	38	10x10x8	6 mos	9/4/52	S
7	MD	53 Chr. Simple Glau.	None	OD 20/70	42	10x10x8	8 mos.	10/9/52	S
8	GH	60 Chr. Simple Glau.	None	OS 20/40	48	10x10x8	5 mos.	10/30/52	S
9	TH	65 Chr. Cong. Glau.	Iridectomy	OS LP	46	10x10x8	3 yrs	11/6/52	S
10	RO	68 Chr. Simp. Glau.	None	OS 20/80	52	10x10x8	3 mos.	1/15/53	S
11	SR	54 Aphakic Glauc.	Ext. Cap. Cat. Ext.	OS 20/50	37	12x13x7	2 yrs	11/6/52	S
12	AW	57 Chr. Simp. Glau.	None	OS 20/50	38	8x10x6	2½yrs.	2/5/53	S
13	MO	52 Chr. Simple Glau.	None	OS 20/40	36	10x10x6	6 mos.	2/24/53	S
14	JS	75 Chr. Simp. Glau.	None	OS LP	60	10x10x6	4 mos	4/30/53	S
15	VR	62 Chr. Simp. Glau.	None	OD	40	8/x10x6	6 mos	5/14/53	S
16	MC	51 Chr. Simp. Glau.	None	OD HM	55	10x10x6x	3 yrs.	5/4/53	S
				OS 20/25	43	8x10x6		5/4/53	S
				OD LP	32	10x10x6		9/22/55	S
				OS 20/25	30	10x10x6		9/22/55	S
17	MJ	62 Chr. Simp. Glau.	None	OS 20/50	38	10x10x6	4 mos	5/21/55	S

No.	Age	Diagnosis	Previous Surgery	Visual Acuity	Tension	Type of Operat.	Follow Up	Date	Result
18	MM 82	Chr. Sim. Gl.	None	OD 20/200	34	8x10x6	3 Yrs.	6/23/55	S
				OS 20/25	32	8x10x6		6/23/55	S
19	PV 76	Chr. Sim. Gl.	None	OD 20/80	40	9x10x6	6 mos.	6/18/53	S
20	SM 68	Chr. Sim. Gl.	None	OD 20/40	38	10x10x6	10 mos.	6/18/53	S
21	AM 45	Chr. Sim/ Gl.	None	OS 20/70	62	10x10x6	3 yrs.	7/14/53	Nill
				OD 20/25	67	10x10x6		7/23/53	S
				OS		9x10x6		1/13/55	S
				OD		8x10x6		1/13/55	S
				OD		9x10x6		6/23/55	S
22	MD 54	Chr. Sim. Gl.	None	OS		8x10x6	6 mos.	7/23/53	S
23	SJ 83	Aphakic Gl.	Intra.Cap. Cat.	OS 56	56	8x10x6	3 yrs.	8/6/53	Excell.
24	JJ 49	Chr. Sim. Gl.	None	OD 20/40	55	10x10x6	2 yrs.	9/10/53	S 4 mos
				OS 20/30	56	10x10x6		9/10/53	S
25	MR 54	Chr Sim. Gl.	None	OD 20/60	48	10x10x6	6 mos.	8/12/53	S
26	MM 52	Chr. Sim. Gl.	None	OD 20/70	40	10x10x6	2½yrs.	9/11/53	S
				OS 20/20038		10x10x6		9/11/53	S
27	GW 46	Chr. Sim. Gl.	None	OD 20/30	32	10x10x6	6 mos.	10/29/53	S
				Os 20/25	30	8x10x6		10/29/53	S
28	HN 80	Chr. Sim. Gl.	None	OD 20/70	28	8x10x6	2¼yrs	11/12/53	S
				OS 20/20032		8x10x6		11/12/53	S
29	MT 59	Chr. Sim. Gl.	None	OS 20/10040		8x10x6	4 mos	11/4/53	S
30	WS 52	Chr. Sim. Gl.	None	OD 20/60	36	8x10x6	1 yr.	11/19/53	S
31	MA 64	Chr. Sim. Gl.	None	OD 20/25		8x10x6	6 mos.	12/3/53	S
				OS 20/30		8x10x6		12/3/53	S
32	MB 67	Chr. Sim. Gl.	None	OS 20/40		8x10x6	9 mos	12/3/53	S
33	DF 72	Chr. Sim. Gl.	None	OS		8x10x6	7 mos.	12/3/53	S
34	VS 64	Chr. Sim. Gl.	None	OD 20/20052		8x10x6	3 yrs.	12/10/53	S
				OS HM	57	8x10x6		12/10/53	S

NO.	AGE	DIAGNOSIS	PREVIOUS SURGERY	VISUAL ACUITY	PREOP TENSION	TYPE OF OPERATI	FOLLOW UP	DATE	RESULT
35	JL	48 Chr. Sim. Gl. Diabetes	None	OD/26/25	40	8x10x6	2yrs	2/4/54	S
				OS/20/25	29	8x10x6		4/22/54	S
36	KS	54 Chr. Sim. Gl.	None	OD		8x10x6	6 mos.	3/4/54	S
				OS		8x10x6		3/4/54	S
37	AM	56 Chr. Sim. Gl.	None	OD 20/20	35	8x10x6	2 yrs	2/25/54	S
				OS 20/60	56	10x10x6		2/25/54	S
38	MA	63 Chr. Sim. Gl.	None	OD 20/30	37	8x10x6	2 yrs.	2/11/54	S
				OS 20/20	29	8x10x6		2/11/54	S
39	MH	52 Chr. Sim. Gl.	None	Os		8x10x6	5 mos.	4/8/54	S
40	ZE	57 Chr. Sim. Gl.	None	OD LP	58	8x10x6	1¼yrs	10/7/54	S 4 mos
				OS 20/400	56	8x10x6		10/7/54	S 4 mos.
41	LB	67 Aphakic Gl.with Endoth.Downgrowth	Cat. Ext. OS	OS	35	8x10x6	2Yrs.	6/10/54	S
42	WD	63 Aphakic Gla	Cat. Ext.	OD	30	8x10x6	1½yrs	6/3/54	S
43	EB	62 Aphakic Gl.	Cat. Ext.	Od	47	8x10x6	1¼yrs	9/2/54	S
44	CM	72 Chr. Sim. Gl.	None	OD 20/30	29	6x10x6	1¼yrs	10/21/54	S
				OS 20/40	30	12x10x6		10/21/54	S
45	HC	70 Chr. Sim. Gl.	None	OD 20/70	30	8x10x6	1¼yrs.	10/28/54	S
				OS 20/40	30	8x10x6		10/28/54	S
46	JT	64 Chr. Sim. Gl.	None	OD 20/40	29	10x10x6	1 yr.	3/3/55	S
				OS 20/30	31	12x10x6	1 yr.	3/3/55	S
47	AB	60 Chr. Sim. Gl. Occl.Cent. Vein Diabetes	None	OD 20/20	40	10x10x6	1 yr.	3/10/55	S
				OS LP	38	12x10x6		3/10/55	S
48	ZE	65 Chr. Sim. Gl.	None	OD 20/20	29	8x10x6	1 yr	3/10/55	S
				OS 20/25	31	8x10x6		3/10/55	S
49	ET	74 Aphonic.Simple Glaucoma O. U.	None	OD LP	30	10x10x6	1 yr.	3/17/55	S
			Ext. OD	OS 20/60	34	10x10x6	1 yr.	3/17/55	S

NO	AGE	DIAGNOSIS	PREVIOUS SURGERY	VISUAL ACUITY	PRE*OP TENSION	TYPE OF OPERAT.	FOLLOW UP	DATE	RESULT
50	CG	56 Chronic Simple Glau.	None	OD		10x10x6	8 mos.	7/20/55	S
51	IP	56 Chronic Simple Gl.	None	OD 20/25	34	10x10x6	1 yr.	3/17/55	S
			Trephine	Os 20/30	45	10x10x6		4/7/55	S
52	CG	62 Aphakic Glau.	Cat. Ext.	OD	46	10x10x6	1 yr	3/17/55	S
53	MW	64 Chr. Sim. Gl.	None	OD 20/70	50	11x10x6	9 mos.	5/5/55	S
				OS 20/100	32	10x10x6		5/5/55	S
54	MS	72 Chr. Sim. Gl.	NOne	OD		10x10x6	8 mos.	7/20/55	S
55	HB	50 Uveitis, sec. Cat. and Glaucoma	Cat. Ext.	Od	35	10x10x6	2yrs.	1/7/54	S
						10x10x6		7/28/55	S
56	LB	76 Uveitis Phakoanaph.	Cat. Ext.	OS LP	35	10x10x6		9/1/55	Enucleation
57	WT	68 Chr. Sim. Gl.	None	OD	35	12x10x6	3 mos.	12/8/55	S
				OS	40	12x10x6		12/8/55	S
58	MR	64 Chr. Sim. Gl.	None	OD	38	10x10x6	3 mos	12/16/55	S
				OS	34	10x10x6		12/16/55	S

Discussion of the results-

Inasmuch as the degree of success or failure of a procedure is difficult to assess under such varied circimstances, one can only hope to arrive at an approximately accurate opinion. From the scores of papers on cyclodiathermy reported in the past six years, it is evident that there has been a great interest aroused. But the varied results, with recommendations that cyclodiathermy is the procedure of choice in all cases of chronic simple glaucoma, to the statement that it should not be used, because of its great danger, with almost every grade of acceptance between, reflect the great care which must be taken to arrive at a proper conclusion, and a most statling observation is,that the percentage of success seems to decrease, rather than increase with the observation and experience of the surgeon.

From our own experience, we feel that, although the procedure is comparatively easy, and, almost free from serious complications, when done with care, that, because, although the tension can usually be controlled at first, that it gfadually tends to rise, and, even though it remains comparatively well controlled ~~in~~ many of our patients continue to lose field, the operation should not be used in chronic simple glaucoma, where standard filtering procedures can be tried, or, in congestive glaucoma, which should have a peripheral iridectomy early, or, an iridencleisis late. It's main value seems to lie in its use in aphakic, and secondary glaucomas. Because of the reports of sympathetic ophthalmia, we see no indication for its combination with other intra-ocular procedures, and do not think that absolute glaucoma should ordinarily be treated with cyclodiathermy.

From the results of this study we conclude, that because of the constant finding of diminished facility of outflow post operatively, even when tensions are normalized, that cyclodiathermy acts either directly or indirectly on the ciliary body causing a diminution in the formation of aqueous to produce its hypotensive effect..

A very perplexing observation is the high percentage of cases with continued field lass, even when tensions are normalized, and, it is quite possible that our surgical effort often succeeds in converting our chronic simple glaucomas into low tension glaucomas. Further studies are indicated to determine the exact cause, and, a means for the prevention of the visual loss in this latter group of cases. Is it possible that macular function is dependant on aqueous flow?

Summary

A brief history with a review of the current literature on cyclodiathermy has been presented.

Eighty-three cases using the Castroveijθ technique of cyclodiathermy on various types of advanced glaucoma are reported giving an apparent success of 95% with regard to the control of the intra-ocular tension, but when the visual field and acuity are considered the percentage drops to below 60%.

Post operative tonometric outflow studies using the Muller electric tonometer with Friedenwald and Grant's tables to determine the facility of outflow on patients with normalized tensions, reveal a greatly reduced coefficient,

It is possible from the on histoḥogic study, as well as from the findings of a reduced outflow, to deduce that the action of cyclodiathermy is to decrease the formation of aqueous , possibly because of damage directly to the ciliary body.

Although cyclodiathermy is a comparatively simple procedure, without much danger of serious complications, it should be reserved for cases in which standard prcedures have either failed, or cannot be used, and possibly in aphakic and secondary glaucomas. It should not be used in absolute glaucoma.

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