A METHOD OF TRABECULOTOMY WITH SOME PRELIMINARY RESULTS*†

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IT HAS long been suspected that the cause of chronic simple glaucoma is some change in the trabecular meshwork of the angle of the anterior chamber which impedes aqueous outflow. In the past, "sclerosis" of this tissue was a popular theory (Levinsohn, 1909, Schieck, 1918). Although much work has been done on normal and pathological histology of the trabecular tissue, it is not clear whether the changes found in chronic open-angle glaucoma are the cause or the result of the disease, or whether they would provide a satisfactory explanation of the decrease in aqueous outflow.

Bárány and Scotchbrook (1954) demonstrated that, when testicular hyaluronidase was injected into the aqueous of ox eyes, the resistance to aqueous outflow fell. This effect has been interpreted as being due to the breakdown of the hyaluronic ground substance in the trabecular meshwork. In microdissection and perfusion experiments designed to find the site of resistance to aqueous outflow, Grant (1958) showed that the trabecular meshwork formed the major part of the resistance. Attempts have since been made to establish a free communication between the anterior chamber and Schlemm's canal in cases of open-angle glaucoma, by incising or rupturing the trabecular meshwork.

De Vincentiis (1893) described an operation for glaucoma in which a knife was introduced across the anterior chamber in an attempt to incise the tissue of the iridocorneal angle. The rationale for this operation was not clear at the time and the results must have been disappointing, as it soon fell into disrepute. Barkan (1936, 1937) described a similar technique, at first done "blind" as de Vincentiis had done it and later with the aid of his operating gonioscope. In the first series success was claimed in nine out of ten cases, and in the second series twenty cases were described as successful when the pressure was reduced to normal for varying intervals post-operatively, the longest being 10 months. However, Barkan later stated that the results of this type of operation were disappointing and described a new operation of cyclogoniotomy which attempted to form a cyclodialysis cleft with a goniotomy knife (Barkan, 1956).

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More recently an *ab externo* approach to this operation has been adopted by Smith (1960), Allen and Burian (1962), and Walker and Kanagasundaram (1964). Smith (1960) described a method of rupturing the trabeculae by passing a nylon thread along Schlemm's canal *via* an *ab externo* radial incision. After the thread had been passed round the whole or a part of the circumference it was drawn tight, thus severing the trabeculae. Smith's published photograph suggests that the nylon tends to cut out rather centrally taking the edge of Descemet's membrane in the flap. This would be advantageous should goniosynechiae be present, but if it occurred in a small sector of the circumference a flap-valve type of opening might result, allowing blood into the anterior chamber but not allowing aqueous to pass freely out into the efferent channels.

Allen and Burian (1962) described a method in which a specially-designed curved probe was passed along Schlemm's canal and rotated into the anterior chamber to disrupt the trabeculae. They also described a variation of this in which the trabeculae were cut by a draw-knife on the probe. To date only two living eyes operated on by this method have been reported (Burian, 1960).

Dellaporta (1959a, b, c) evolved a different approach, whereby the trabeculae were detached from their insertions by a specially-angled cyclodialysis spatula. This was rotated while being held against the sclera and the upturned leading-edge stripped off the trabeculae. The probe could be rotated on the trabeculae from an anterior or posterior position and both have been used; 95 per cent. anatomical success in cadaver eyes was claimed for the anterior approach and 94 per cent. for the posterior approach. The corneal endothelium and Descemet's membrane were not infrequently damaged but Dellaporta claimed that this was common with cyclodialysis operations in any case. Side-effects included a small cyclodialysis which is inherent in the method, and splitting of the sclera in some cases in which the anterior approach had been used.

Walker and Kanagasundaram (1964) have described yet another method of trabeculotomy in which a specially-designed curved probe-pointed knife is passed along Schlemm's canal. The clinical results have so far been encouraging but no photomicrographs showing the anatomical results of the operation have been published.

The method described below is a variant of that described by Allen and Burian (1962). It has been used on a large number of cadaver eyes and so far on seventeen occasions on patients.

It was felt that a rigid probe would give better directional control in passing along Schlemm's canal, since Smith (1962), in a very enlightening article, described how a length of nylon thread might be passed into the eye and yet not be recovered from a more distal point in Schlemm's canal. The instruments used by Allen and Burian and by Walker and Kanagasundaram had a handle at right-angles to the blade of the probe. A handle in line with the probe should give even better control over the direction in which the probe is passed and this type of instrument has been used with some success.

It was also felt desirable to keep the instrument as small and simple as possible and

a small lacrimal probe was modified for the purpose. A study of eyes with normal anterior segments which had been fixed in celloidin showed that in radial sections the long axis of Schlemm's canal measured 0.25 mm. Different measurements have been published in the past, but this may have been due to their being made on eyes fixed in paraffin when marked shrinkage may occur. In good celloidin sections, the shrinkage is only about 5 per cent.

The tip of the probe was filed down to a diameter of 0.20 mm. and this gradually tapered up to the full diameter of the probe (0.5 mm.) over a distance of 5 mm. The probe was polished with fine abrasive powder. It was found that this passed easily along Schlemm's canal in both cadaver and living eyes provided that the canal was correctly identified and entered.

Method

A Keeler dissecting microscope is used throughout the operation with $\times 15$ magnification. Retrobulbar anaesthesia, a lid speculum, and a suture in the superior rectus muscle ensure adequate exposure and immobility of the eye. A small fornix-based flap of conjunctiva is raised from the limbus (usually at 12 o'clock). There are two reasons for preferring this to a limbal-based flap: the operation is more easily performed with the conjunctiva retracted out of the way, and a filtering bleb is less likely to form. Although this latter event might be an advantage to the patient, it would render impossible any evaluation of the effects of trabeculotomy *per se*.

Next a 3-mm. radial incision is made in the cornea and sclera across the limbus and gradually deepened until Schlemm's canal appears and is entered. During this stage, bleeding is usually troublesome and, although rarely profuse, is enough to obscure the depths of the wound, thus making the identification of Schlemm's canal difficult. Both Smith (1962) and Walker and Kanagasundaram (1964) reported bleeding to be troublesome at this stage and the latter evolved a small suction apparatus to deal with the problem. It was found that the frequent irrigation of the wound with a fine jet of saline from a syringe enabled the operation to be continued without waiting for haemostasis to occur naturally, and with only a minimum of cautery being used to control bleeding points.

The canal of Schlemm is usually easy to identify as a band of any shade from a light brown to almost black appearing in the depths of the wound between white bands, the scleral septum anteriorly and the scleral spur posteriorly (Fig. 1).

Schlemm's canal is now opened and the probe is gently introduced into it (Fig. 2).

FIG. 1.—Appearance of Schlemm's canal.

FIG. 2.—Passage of probe into Schlemm's canal.

It usually passes fairly easily, along approximately one-sixth of the circumference.

The probe is now turned into the anterior chamber with that part which is in the wound of entry as the fulcrum (Fig. 3).

FIG. 3.—Probe turned into anterior chamber.

Care is taken to avoid touching the iris or corneal endothelium. If the pupil is constricted beforehand, the lens is well protected as the pupillary area can easily be avoided. So far, in an admittedly small number of patients, these structures have not been damaged, except the extreme periphery of Descemet's membrane and corneal endothelium. The direction in which the probe is rotated is of some importance. In cadaver eyes, an opening in the corneo-scleral trabeculae directly through into the anterior chamber can be made (Fig. 4).

FIG. 4.—Opening in corneo-scleral trabeculae in cadaver eye. $\times 150$.

Should goniosynechia render that procedure of doubtful efficacy, then a flap of Descemet's membrane and endothelium can be stripped off attached to the trabeculae and still give a good anatomical communication with Schlemm's canal (Fig. 5, opposite). The flap shown in the illustration has been made for purposes of demonstration but would be undesirably large in practice.

After the probe has been rotated into the anterior chamber, it is usual to see a thin line of haemorrhage appear from the opened sector of Schlemm's canal. If this does not occur, then a little aqueous may be deliberately lost to enable this to be seen. This sign provides a check that the operation has been correctly performed. Virtually no aqueous need be lost during the operation, and any deliberate loss need not cause a significant decrease in depth of the anterior chamber.

The corneo-scleral wound is sutured with two or three virgin silk sutures which are covered by a conjunctival flap, the object being to prevent any leakage of aqueous from the wound, and the consequent formation of a filtering scar.

By this method the operation takes 15 to 20 minutes to perform.

FIG. 5.—Anatomical communication made by stripping of a flap of Descemet's membrane and endothelium in cadaver eye. $\times 40$.

Preliminary Results

Fifteen eyes, all with open-angle glaucoma, have been operated upon by the above method (Table). All showed poor control of intra-ocular pressure on medical treatment pre-operatively, although this was sometimes due to the inability of the patients to administer medications regularly. Only two eyes had undergone previous surgery (Case 7—peripheral iridectomy and Case 14—Scheie's operation), and none showed goniosynechia pre-operatively.

TABLE
RESULTS IN FIFTEEN CASES

Case No.	Postoperative Haemorrhage (No. of days)	Intra-ocular Pressure 10–15 mm. Hg (No. of postoperative days)	"Satisfactory" Cleft
1	0	15*	?
2	0	0	?
3	5	70	Yes
4	26	10	Yes
5	18	5	Yes
6	15	0	Yes
7	0	12	Yes
8	2	0	Yes
9	6	7	Yes
10	1	0	Yes
11	25	3	Yes
12	7	15	Yes
13	2	20*	Yes
14	16	3	Yes
15	4	28	Yes

*Filtering bleb.

Three criteria have been used to evaluate the success of the operation in the early postoperative stage:

- (i) The appearance of a line of hyphaema at operation and its postoperative persistence;
- (ii) The reduction of intra-ocular pressure to something approaching episcleral venous pressure after the operation;
- (iii) The appearance of a satisfactory cleft between the anterior chamber and Schlemm's canal as far as this can be assessed gonioscopically.

Eleven of the fifteen eyes showed a diffuse haemorrhage from the site of the cleft at operation as described previously (Table). Hyphaemata persisted from 1 to 26 days postoperatively (mean 8.05 days). At postoperative examination a layer of fresh haemorrhage could be seen, not infrequently above the previous level of the hyphaema. Apart from transient increases, the hyphaemata in general showed a steady gradual diminution. Exceptions to this are discussed below.

In three instances, reflux of blood into the aqueous due to raised venous pressure was observed. On two occasions (in the same patient) a streak of blood was observed on the posterior surface of each cornea immediately after his return from the W.C. In the third patient, a free reflux of blood from the cleft into Schlemm's canal was observed gonioscopically 4 days postoperatively when light pressure was exerted on the eye with the goniolens.

The reduction of the intra-ocular pressure to levels approaching the episcleral venous pressure should occur if a free communication exists between the anterior chamber and episcleral veins. The criterion for success has been taken as a pressure between 10 and 15 mm. Hg, and the results are shown in the Table. Almost any intra-ocular operation will cause some postoperative lowering of pressure because of the fall in aqueous secretion. Trabeculotomy by this method causes very little ocular reaction and might be expected to show this non-specific pressure-lowering effect to only a small extent. Discounting those with a filtering bleb, nine eyes showed a postoperative reduction in pressure to these levels for periods varying from 3 to 70 days (Table). Short-term pressure reductions (say for less than 14 days) could be caused by the non-specific pressure-lowering effect of the operation. This leaves only two cases with a longer term success. Case 3 in particular followed a particularly favourable postoperative course, but this was cut short by his having a cataract extraction, after which the intra-ocular pressure rose again to pathologically high levels.

Gonioscopic assessment of the results of operation is not easy, as experience of seeing trabeculotomy sites is necessarily limited. Twelve cases, judged to be successful gonioscopically, showed a white furrow in the position of Schlemm's canal with trabecular tissue rolled up on either side. Sometimes the cleft into Schlemm's canal was oblique, and the edge of Descemet's membrane was included with the trabeculae in a flap of tissue (Fig. 5). These cases presented special features which will be discussed later. One cannot assess the effect of operation at a microscopic level with the gonioscope, and it seems likely that the state of the endothelium lining Schlemm's canal is of importance in determining the long-term success or failure of the operation. It is unlikely, however, that any pathological specimens from the early postoperative period will become available for further study of this point.

Complications.—In Case 2, it was noted at the time of operation that Schlemm's canal was difficult to identify. This could be the cause of the poor immediate result in this case as judged by the three parameters mentioned.

In three cases (4, 12, and 14), it appeared from the postoperative course and gonioscopic appearances that a "flap-valve" type of opening had been made. That is, the cleft produced by operation was oblique and included the trabeculae and a portion of Descemet's membrane in the central flap of tissue. The effect of this was

to open and allow ingress of blood from the episcleral veins but to close when the intra-ocular pressure rose above the episcleral venous pressure, thus preventing a free outflow of aqueous. These eyes showed steadily increasing hyphaemata and an increasingly raised intra-ocular pressure postoperatively in spite of the use of miotics. Gonioscopy showed a flap of tissue lying apposed to the tissues from which it had been stripped, with a line of blood at its anterior lip. This potentially serious complication was treated by performing another trabeculotomy in a different sector of the chamber angle, taking great care to rotate the probe in such a way that the opening into the anterior chamber of Schlemm's canal was made through the posterior part of the trabeculae. This had the effect of reducing the intra-ocular pressure to normal and causing the hyphaemata gradually to disappear. It is these second trabeculotomies which are assessed in the Table.

Iridocyclitis sufficient to cause posterior synechiae occurred in Cases 12 and 14; both of these patients had two trabeculotomies and also had longer-lasting hyphaemata than the others.

As already mentioned, two patients developed filtering scars, which although beneficial to the patient were undesirable in the context of this study.

Discussion

It would be expected that the three criteria used for the assessment of early success would be satisfied if the operation had been performed in an anatomically correct manner (*i.e.* as in the cadaver eye shown in Fig. 4). Any episode of raised venous pressure from whatever cause (*e.g.* coughing, straining, stooping) would be expected to lead to a small influx of blood into the anterior chamber. This was observed in three cases which have already been described. Fluctuations in the levels of post-operative hyphaemata were also observed in other patients and probably reflect similar episodes of raised venous pressure. The occurrence of the three cases with a "flap-valve" effect also indicates a successful anatomical connexion between the episcleral veins and the anterior chamber. In all cases, however, the hyphaemata had disappeared within 26 days of operation. This must be due to the functional closure of this communication, at least to the extent where it will not allow red blood cells to pass. Smith (1962) also reported that postoperative hyphaemata were a common occurrence and that a reflux of blood could be seen when pressure was exerted on the eye with Hobbs's ridged goniolens. Walker and Kanagasundaram (1964) did not report hyphaemata as a feature of their series, but they had one case (of aniridia) in which a reflux of blood was observed gonioscopically.

Smith (1962) described cases which had had trabeculotomy performed over only a short sector of the chamber angle, and in which the intra-ocular pressure rose sharply after operation for 48 hours but was controlled thereafter by miotics. These are perhaps similar to the three cases in this series which showed the "flap-valve" effect, and had raised intra-ocular pressure postoperatively for 11, 8, and 10 days which was controlled not by miotics but by a second trabeculotomy.

Gonioscopic appearances in different series are difficult to correlate in the absence of goniphotographs. From the written descriptions, the appearances of the operation site in Walker and Kanagasundaram's series are similar to the gonio-

scopic appearances in the present series. The appearances in Smith's series seem to suggest, as do his photomicrographs, that a nylon thread cuts out more centrally than a rigid instrument.

The incidence and severity of iritis are low in all three series.

The assessment of the short-term effects of trabeculotomy has shown encouraging results. The successful treatment of open-angle glaucoma requires reduction in the intra-ocular pressure, and this has yet to be shown for a series of trabeculotomy patients. In particular, a comparison of pre- and postoperative tonographies would provide a more rigorous method of evaluation.

Summary

A method of trabeculotomy is described and compared with previous methods. Three criteria of success in the early postoperative period are used to assess the results in fifteen eyes. The complications which have been found are described.

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REFERENCES

- ALLEN, L., and BURIAN, H. M. (1962). *Amer. J. Ophthalm.*, **53**, 19.
 BÁRÁNY, E. H., and SCOTCHBROOK, S. (1954). *Acta physiol. scand.*, **30**, 240.
 BARKAN, O. (1936). *Amer. J. Ophthalm.*, **19**, 951.
 ——— (1937). *Ibid.*, **20**, 1237.
 ——— (1956). *Ibid.*, **42**, 63.
 BURIAN, H. M. (1960). *Ibid.*, **50**, 1187.
 DELLAPORTA, A. (1959a). *Ibid.*, **47**, 783.
 ——— (1959b). *Ibid.*, **48**, 15.
 ——— (1959c). *Ibid.*, **48**, no. 3, pt 2, p. 294.
 DE VINCENTIIS (1893). *Quoted by Barkan (1937). Amer. J. Ophthalm.*, **20**, 1244.
 GRANT, W. M. (1958). *Arch. Ophthalm. (Chicago)*, **60**, 523.
 LEVINSOHN, G. (1909). *Arch. Augenheilk.*, **62**, 131.
 SCHIECK, J. (1918). *Ber. ophthalm. Ges. Heidelberg*, **41**, 68.
 SMITH, R. J. H. (1960). *Brit. J. Ophthalm.*, **44**, 370.
 ——— (1962). *Trans. ophthalm. Soc. U.K.*, **82**, 439.
 WALKER, W. M., and KANAGASUNDARAM, C. R. (1964). *Ibid.*, **84**, 427.