EXTERNALIZATION OF SCHLEMM'S CANAL (SINUSOTOMY) IN GLAUCOMA*†

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It is evident that ocular hypertension in glaucoma is usually due to an increased resistance to the outflow of the intra-ocular fluid. In about two-thirds of all patients there is no visible obstacle to the outflow in the anterior chamber angle (so-called wide-angle glaucoma); these pathological changes in the intramural pathways, starting from the trabecular meshwork, are usually held responsible for the circulatory disturbance.

Some authors consider the trabecular zone as the site actually affected (Teng, Katzin, and Chi, 1957; Speakman, 1961). Grant (1958) pointed out that this area accounted for about 75 per cent. of the normal resistance to outflow, but this is not necessarily the site of the pathological process. There are sound arguments in favour of the theory that the outflow is affected in the region of the intrascleral collectors between Schlemm's canal and the anterior ciliary veins (Duke-Elder, 1955; Dvorak-Theobald and Kirk, 1956).

Each theory is probably valid in certain cases. The results of histochemical studies carried out in our clinic on fifty scleral specimens obtained during glaucoma surgery confirm the existence of pathological changes in early wide-angle glaucoma. This particularly applies to abnormal mucopolysaccharide distribution. Similar data have already appeared in the literature (Unger, 1963; Larina, 1966). It should be noted, however, that different layers of the sclera are not equally affected. Whatever its nature, the process usually spreads within the sclera "sandwich-wise", affecting some strata and leaving others apparently undamaged, full-thickness involvement being exceptional. The middle layers are most commonly affected, the deep ones less frequently, and the superficial areas very rarely. This supports the hypothesis that the outflow is sometimes obstructed in the trabecular meshwork, and sometimes (more often) in the intrascleral collectors; in other words the obstruction may be either distal or proximal to Schlemm's canal. One may thus speak of an "intrascleral" and a "trabecular" form of glaucoma.

These considerations seem to justify a new approach to the surgery of glaucoma, confining the intervention to a very limited region where the outflow is obstructed. Glaucoma may thus be classed into four main types: angular (iris-block), trabecular, intrascleral, and hypersecretional. The methods of surgical management applicable to this pathogenically-oriented system have been described elsewhere (Krasnov, 1965), and this paper deals with only one of the operations which is in practice the most important.

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The so-called "intrasccleral" form of glaucoma appears to be the most common, and a new type of operation has been devised for it, to which the term "sinusotomy" seems to be appropriate, Schlemm's canal being often referred to as a "scleral sinus". Sinusotomy entails the opening of Schlemm's canal from outside, its principle being the opposite of goniotomy (Fig. 1). It is designed to restore the normal outflow when this is obstructed somewhere between Schlemm's canal and the anterior ciliary veins.

FIG. 1.—External approach to Schlemm's canal.

Selection of Cases

The proper selection of cases is of utmost importance. Only cases of open-angle glaucoma should be considered, and two gonioscopic signs are helpful in distinguishing between the "trabecular" and "intrasccleral" types of obstruction:

- (1) A heavy inner pigmentation of Schlemm's canal is common to the intrasccleral form. It is probably due to particles of pigment gaining access into the canal *via* the trabecular pores (which are large enough to let them pass), and being subsequently prevented from leaving it through the affected collector net.
- (2) The appearance of blood in Schlemm's canal (spontaneously or provoked, for example, by moderate pressure on the jugular veins) indicates the existence of free communication between Schlemm's canal and the anterior ciliary veins, in which case there is no sense in trying to restore it.

These signs appear to be quite reliable in practice, but the differential diagnosis may be finally confirmed at the time of the operation itself, when the lumen of Schlemm's canal has just been reached, and the intensity of flow through the trabecular pores can be estimated.

Surgical Technique

The operation is performed under local anaesthesia, and a wide conjunctival flap is prepared.

The method requires the resection of a very narrow (1.5 mm. wide) scleral lamella directly over Schlemm's canal and deep enough to externalize its lumen. A part of the canal from 10 to 2 o'clock is usually opened, *i.e.* about one-fourth to one-third of its circumference (Fig. 2, opposite).

The most difficult and most important phase of the operation is the localization of Schlemm's canal in the scleral tissue. This is greatly facilitated by determining the exact projection of the position of the canal onto the scleral surface, and can best be done under gonioscopic control with the aid of an operating microscope. Having tried several methods, we found the following to be most convenient.

A small corneo-scleral needle is passed through the outer two-thirds of the scleral thickness just beyond the limbus and parallel to it. In wide-angle glaucoma Schlemm's canal is often readily seen. The length of the needle is visible gonioscopically owing to its metallic lustre and serves as a guiding line, whilst the distance

FIG. 2.—Opening part of the circumference of Schlemm's canal.

between the needle and the canal (or their coincidence) shows where incisions should be made to reach the lumen of the canal.

A diaphanoscope may be used for the same purpose, the spot of light at the tip acting in the same way as the length of the needle. Without gonioscopic control the procedure takes longer and is less exact.

The canal having been located, two non-perforating incisions about 1.5 mm. apart are made in the sclera: one just in front of the canal and one just behind it. If gonioscope localization has not been successful, the anterior incision is made at the posterior border of the limbus.

The incisions are followed by a lamellar resection of the outlined scleral strip. Schlemm's canal is usually clearly discernible amidst the scleral layers as a narrow darkish line, and this in itself indicates the depth of the resection cleavage. Some care is required not to damage the inner wall of the canal, *i.e.* the trabecular zone. Its perforation may lead to prolapse of the iris and may eventually require an iridectomy. Though not very harmful this often makes the operation a purely fistulizing procedure. If the lumen of the canal is not externalized over the entire resection area and bridges of scleral tissue overlap it, then a very fine metallic probe is introduced into the canal through its opened points, and a dissection is made along the probe.

The operation is completed by closing the conjunctival wound with an uninterrupted suture.

Discussion

The moment of reaching Schlemm's canal is crucial in sinusotomy. Should the diagnosis of "intrasccleral" glaucoma prove correct, there should be a constant flow of fluid through the undamaged trabecular meshwork. In cases of trabecular insufficiency, however, Schlemm's canal is more or less "dry", and some other surgical procedure must be used.

The first sinusotomy operation was performed in 1962 (Krasnov, 1964); the idea of surgically opening the outer wall of Schlemm's canal has also been described by Walker and Kanagasundaram (1964), but their technique differs from ours and they do not seem to be aware of previous work in this field. Our experimental and clinical data suggest that the intrasccleral form of glaucoma is the most common, constituting approximately 55 per cent. of all cases. Accordingly, sinusotomy has now become our method of choice in more than half of all our patients treated by surgery.

Over a thousand such operations have now been performed, 340 of them by the author himself during the last 5 years. The results after 1 to 5 years demonstrate stable normalization of the intra-ocular pressure in about 83 per cent. of cases, the tonographic coefficients

after successful surgery on Schlemm's canal being closer to physiological (normal) limits than with conventional fistulizing operations.

The value of "C" (facility of outflow) recorded in repeated examinations 3, 6, 12, and 18 months after 23 successful sinusotomies averaged 0.25 ± 0.29 , and that in 21 eyes examined at the same intervals after fistulizing surgery averaged 0.30 ± 0.19 . Hence the root-mean-square deviation in the latter group is twice as high as in the former. This suggests that the outflow was either too low or too high, and that the dynamics of the aqueous outflow are more favourable after sinusotomy, though this needs further confirmation after several years follow-up.

The main advantage of sinusotomy lies in the fact that it causes only minor trauma to the eye. Unless the anterior chamber is emptied in the course of the operation (which normally should not happen), no serious complication ensues. If the hypotensive effect of sinusotomy proves insufficient, there is no difficulty in resorting to a more conventional procedure since the eyeball remains practically undamaged.

A permanent normal tension after the externalization of Schlemm's canal is usually associated with clearly visible filtration from its opened lumen under the conjunctiva. As a rule, this area is more diffuse than after a conventional fistulizing procedure, and its conjunctival covering is also considerably thicker.

Two of our patients developed small staphylomata in the resected region following a blunt injury to the eye soon after sinusotomy. These were excised surgically without damage to either the visual function or the equilibrium of the intra-ocular circulation.

In a few cases an iris prolapse occurred during the first week after sinusotomy, necessitating a small basal iridectomy; in these cases the inner wall of Schlemm's canal had probably been injured during the operation.

We have now almost completely abandoned conventional fistulizing surgery in glaucoma, apart from exceptional cases.

Surgical manipulations on Schlemm's canal are more delicate and require greater technical skill than the generally accepted procedures, especially when the operating microscope is used, but this technique (microsurgery) is both safe and effective in the majority of cases of glaucoma.

Summary

In about 55 per cent. of all glaucoma patients the aqueous flow is obstructed in the intrascleral collectors between the canal of Schlemm and the anterior ciliary veins.

To deal with this most common "intrascleral" form of glaucoma, a new type of operation has been devised—termed "sinusotomy"—which entails externalization of Schlemm's canal.

The results of over a thousand sinusotomies performed during the last 5 years show the operation to be highly effective in suitable cases.

One of its principal advantages is the minimum of surgical trauma inflicted upon the eye, since the globe is not subjected to perforation.

It is highly advisable that surgery on Schlemm's canal be performed with the aid of the operating microscope.

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This technique of externalization of the canal of Schlemm may be compared with its internalization (cutting through the trabecular aspect) into the anterior chamber as described by Redmond Smith (*Brit. J. Ophthalm.* (1960), **44**, 370; *Trans. ophthalm. Soc. U.K.* (1962), **82**, 439) and L. Allen and H. M. Burian (*Amer. J. Ophthalm.* (1962), **53**, 19)—Ed.

The author prefers trabeculotomy in cases of the so-called trabecular form of glaucoma which is seen in 10 to 20 per cent. of all patients.