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Ab-interno trabeculo-canalectomy: surgical approach and histological examination

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PURPOSE. *To evaluate, on eye bank eyes, a new surgical approach aimed at removing a quadrant of the trabecular meshwork (TM), with an ab interno approach.*
METHODS. *Gonioscopically controlled ab interno removal of the TM was done with a subretinal forcep on six human bank eyes. Serial histological sections were obtained from the treated and untreated part of each globe to assess the effect of the technique on intraocular tissues.*
RESULTS. *Under the gonioscope, the TM was easily removed in strings of varying length. Histological examination showed, unexpectedly, that this resulted in a well-defined deep furrow in the middle of the trabecular region involving both the TM and the inner wall of Schlemm's canal. The operation created a direct communication between the anterior chamber and Schlemm 's canal lumen without any evident damage to the outer canal wall and adjacent ocular structures such as the iris base and corneal endothelium.*
CONCLUSIONS. *Our small series on human bank eyes showed that the procedure involves both the TM and the inner wall of Schlemm's canal and is therefore called ab interno trabeculocanalectomy (AITC). The intraoperative findings and the histological evidence are encouraging, and suggest that the procecedure could have potential clinical application. (Eur J Ophthalmol 2002; 12: 401-5)*

KEY WORDS. *Ab-interno trabecular surgery, Irido-corneal angle surgery, Glaucoma surgery*

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INTRODUCTION

Trabecular meshwork surgery aims to increase the outflow of aqueous humor through its normal pathway and lower intraocular pressure (IOP) (1-3). The basis of this approach is to relieve the resistance to aqueous humor outflow within the TM, in juxtacanalicular tissue and the inner wall of Schlemm's canal (4-7). Many surgical and laser techniques have been proposed to boost aqueous humor outflow through the anterior chamber angle (1-3, 8-13). However, the choice remains controversial because of the lack of convincing evidence of the superiority of any one approach over the others. Theoretically, a therapeutic option that removes the resistance to aqueous outflow as far as possible, without damaging the outer outflow pathways and the surrounding ocular structures, such as the base of the iris and the corneal en-

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dothelium, offers better chances of success.
The present study was designed to evaluate, on eye bank eyes, the histological effect of a new surgical technique designed to remove TM mechanically. This procedure, uses a peeling-like approach, to remove the TM rather than cutting, disrupting or scraping the trabeculum as already described (1-3, 13).

METHODS

The procedures were carried out on six human eye bank eyes unsuitable for keratoplasty (cadaver time less than 24 hours). Surgery was done under direct observation of the anterior chamber angle with an operating microscope and a surgical gonioprism. After an 8.5 mm trephination the central cornea was removed as during a conventional keratoplasty; the anterior chamber was filled with viscoelastics and the globe was tilted so as to be able to observe the anterior chamber angle structures. The central cornea was removed because of its poor transparency; the goniopri-sm was necessary to properly visualize the fine details of the anterior chamber angle. A subretinal vi-trectomy forceps (Thomas horizontal subretinal forceps, Synergetics Inc. MO, USA) was introduced into the anterior chamber through a limbal paracente-sis and directed towards the irido-corneal angle. The trabecular membrane was then pinched and removed with a peeling-like approach. The goal of the operation was to remove one quadrant of TM (three clock hours). The part of the globe subjected to the procedure was marked so as to be able to recognize the treated area afterwards. Great care was taken while removing the trabecular membrane to avoid damaging adjacent ocular structures such as the base of the iris or corneal endothelium. At the end of the surgery the viscoelastics was removed with an automated irrigation-aspiration unit.

Histology

All the samples were (a) fixed with 2.5% formaldehyde + 2.5% glutaraldehyde in 0.1 M phosphate buffer, pH 7.4, for 24h at room temperature; (b) dehydrated in graded ethanols and (c) embedded in paraffin. Paraffin blocks were embedded and mounted in such a way that microtome cuts were made along meridional planes. Serial 5 µm thick sections were stained with hematoxylin and eosin. Serial sections were obtained from the treated and the untreated parts of each globe. Samples excised from untreated areas served as controls.

RESULTS

During the procedures the TM was apparently removed in strings longer than one clock hour (1-3 hours) in four eye globes. In two eyes the membrane was friable, resulting in strings shorter than one clock hour. Gonioscopically a membrane that apparently corresponded to the TM was easily pinched and removed from all the eyes. During the procedures no damage was detected to the structures adjacent to the TM such as the corneal endothelium and the iris base. The gonioscopically detectable effect of treatment at the end of the surgery was an apparent TM depigmentation in the treated area and some trabecular debris floating in the viscoelastics in the angular recess. On histological section of the control specimens, all the structures of the anterior chamber angle were fairly well preserved (Fig. 1). The TM appeared to be formed of intact thin sheets and the walls of Schlemm's canal were well-preserved. As usual for samples that had undergone standard processing for light microscopy, topical deformations or even sporadic detachments of the endothelium lining the canal walls were observed. Another minor artifact was some degree of corneal and/or scleral swelling due to slight separation of the collagen lamellae. The iris structure was intact but it lost its linear course causing a different angular width of the recess.
In histological sections corresponding to the regions subjected to peeling, tissue conditions were similar to the control specimens, except for the trabecular region. Here, in the middle portion of the trabeculum, there was a full-thickness lack of trabeculum involving both the trabecular meshwork and the inner wall of Schlemm's canal (Fig. 2). This deep cleft caused an evident opening of the lumen of Schlemm's canal into the anterior chamber. However, the remaining canal wall was intact and was lined by an undamaged endothelium (Fig. 2). These histological findings were evident for the whole of the trabeculum that had undergone the "procedure". In addition, the sizes of

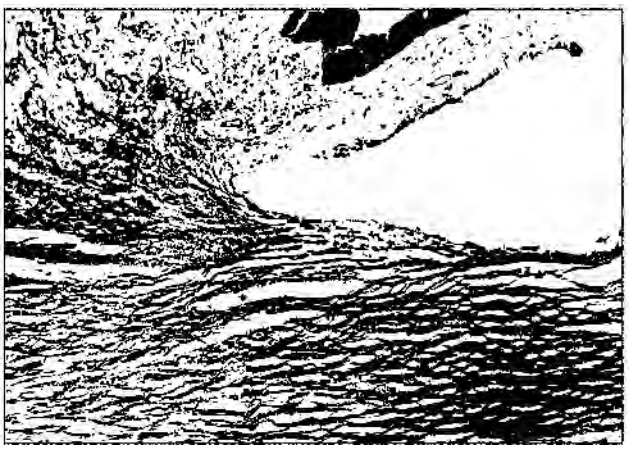

Fig. 1 - *Histological section of human irido-corneal angle (control sample). All the anterior chamber angle structures are fairly well preserved: the trabecular meshwork is formed of intact thin sheets and Schlemm 's canal (asterisk) has well-preserved walls. Staining with hematoxylin and eosin (x 170).*

Fig. 2 - *Histological section corresponding to the region subjected to AITC. A full thickness trabecular lack involving both the tra becular meshwork and the inner wall of Schlemm's canal is evi dent. This creates a direct communication between the lumen of the canal (asterisk) and the anterior chamber (curved arrows). The outer wall of the canal (double arrows) is intact and is lined with an undamaged endothelium. Staining with hematoxylin and eosin (x 170).*

the clefts were comparable to those of the membranes removed. Extremely fine trabecular debris was detectable along the peeled area but none of the specimens contained any flaps of uveal tissue capable of returning to its pre-treatment position.

This histological evidence indicated that the procedure resulted in the removal of both the TM and Schlemm's canal inner wall. It was therefore called *ab-interno* trabeculocanalectomy (AITC). Like in the control specimens, there were artifacts such as corneal-scleral swelling or different width of the angular recess.

DISCUSSION

Ab-interno trabecular surgery comprises many different procedures with the same purpose: to improve aqueous outflow through conventional pathways. The rationale for these approaches is to remove the resistance to outflow within the TM, in juxtacanalicular tissue and in the inner wall of Schlemm's canal (4-7, 14). Experimental studies have shown that incising the TM and Schlemm's canal can increase outflow (15, 16). Clinical studies confirmed that trabecular incision or trabecular scraping can reduce intraocular pressure (1-3, 12, 13).

Microsurgical dissection of the TM was first described by Tailor (17) and De Vincentiis (18). The procedure has been modified over the years (1-3, 8) and is now attracting renewed interest among ophthalmologists for the treatment of juvenile glaucoma (19, 20) and for chronic open angle glaucoma (12, 21-23). New surgical and laser approaches such as goniocurettage (13), goniopuncture (24), Erbium:YAG (10) or excimer laser trabecular ablation (11) have been proposed to reduce IOP in glaucomas. This search for novel approaches is seeking a technique that can restore a physiological route of aqueous outflow without the complications of filtering surgery.

To date there is no convincing evidence of the superiority of any one trabecular approach over the other. The creation of small holes with the goniopuncture approach or the disruption of the TM with the trabeculotomy technique removes little tissue and may be followed by filling and scarring with subsequent closure of the trabecular opening (9, 25, 26).

AITC is a new experimental surgical procedure devised to mechanically remove the TM, with the functional purpose of opening an exit route for aqueous humor into Schlemm's canal and out through the normal pathway. Histological examination showed that

our original idea of peeling away the TM alone actually removed both the TM and the inner wall of Sch-lemm's canal. This unexpected result might possibly achieve a better outflow than TM removal alone. Considering that the site of major resistance to the outflow of aqueous humor is at the juxtacanalicular portion of the TM and the inner wall of Schlemm's canal and that often, during non-penetrating filtering surgery better aqueous percolation is achieved by peeling the inner wall of the canal (27, 28), we suggest that removal of both the TM and the inner wall of Sch-lemm's canal would ensure better outflow than removal of the TM alone. However, with non-penetrating filtering surgery outflow can also be improved by an *ab externo* approach, leaving the TM intact (27-30).

We found that the histological effects of AITC were different from with the classical goniotomy and trabeculotomy procedures (25). These latter produce a deep incision in the trabecular tissue with close edges of the wound. The histological picture after AITC also differs from goniocurettage. In this procedure trabecular removal is associated with damage to the posterior wall of Schlemm's canal and collector vessels (13).

Although our histological findings on cadaver eyes are encouraging problems may be encountered in clinical application of AITC. The fine details of anterior chamber angle structures cannot be clearly visualized in every case: corneal opacities, corneal edema or the presence of blood in the anterior chamber may render gonioscopic observation inadequate.

Like other *ab-interno* procedures, other pre-requisites for AICT are a stable anterior chamber and wide irido-corneal angle. Although viscoelastics can be used to stabilize the anterior chamber, sufficient widening of the irido-corneal angle cannot be achieved in every case. Predictable risks with AITC are: lens or corneal endothelium contacts, bleeding from the trabecular vessels and/or from Schlemm's canal, early intraocular pressure rise due to retention of viscoelastics, iris root damage, inadvertent cyclodialysis, bulbar hypotony.

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