Aqueous-venous shunt and intraocular pressure. Preliminary report of animal studies

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A method is described for creating a shunt between the anterior chamber and a vortex vein. This procedure increases the outflow facility of aqueous humor and reduces intraocular pressure in the normal pigmented rabbit. The average value for outflow facility was 0.27 µl per minute per millimeter of mercury prior to operation and 0.43 µl per minute per millimeter of mercury after the operation. The statistical difference between preoperative and postoperative values for average intraocular pressure and outflow facility was significant. It is essential to maintain the plastic capillary tube in the lumen of the vein in order to keep the shunt functioning and to minimize postoperative complications.

During the past decade, neurosurgeons have successfully relieved hydrocephalus by performing a ventriculooiriuculostomy or ventriculovenous shunt.1-3 Using the same principle, a shunt between the anterior chamber and a vein has been satisfactorily performed in 10 rabbits. This paper is a preliminary report of the method and results.

Materials and procedure

Thirteen normal pigmented rabbits with body weight of over 2 kilograms were used for the experiments. Tonometry, tonography, gonioscopy, and biomicroscopy were carried out prior to operation and repeated within 2 days and at 2, 4, 8, and 12 weeks after the operation. All measurements of intraocular pressure and outflow facility were performed under general anesthesia with intravenous pentobarbital sodium (Diabutal), 30 mg. per kilogram of body weight. The V. Mueller electronic tonometer was used for all examinations and the table of Wistrand4 was used in calibration. An attempt to evaluate the scleral rigidity was carried out by doing tonometry with 5.5 and 10.0 Gm. weights in all measurements. Manometric pressure decay curves were recorded by means of anterior chamber perfusion with normal saline and Sanborn pressure transducers, Model No. 267B, in conjunction with a Sanborn four-channel recorder unit (Series 350).

The operative procedure consisted of establishing a shunt between the anterior chamber and a vein located under Tenon’s capsule by means of a small plastic polyethylene tube having an outside diameter of 0.25 to 0.3 mm.

All statistical data in this report were evaluated by testing the mean and standard deviation by the chi square method. They were called statistically significant when the probability was less than 5 per cent that the event considered was due to chance.

Operative technique. A conjunctival incision was made 7 mm. from the limbus superiorly. All subsequent steps were performed with a Zeiss operating microscope. Tenon’s capsule was incised and undermined with blunt scissors anterior to the limbus and posterior to a vortex vein.

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The vein was exposed, freed, and held with an arterial clamp (Fig. 1). A scratch incision, parallel to the limbus, was made 2 mm. anterior to the entrance of the vortex vein into the sclera. The intrascleral course of the vortex vein was exposed and only then was the anterior wall of the vein incised with a Wheeler knife. The polyethylene capillary tube was inserted into the vein in the direction of the blood flow. At this moment, it was noted that the lumen of the plastic tube was either half filled with venous blood, or that blood was receding from the capillary tube back into the vein and no further bleeding from the venous incision occurred. In order to immobilize the implanted capillary, a double-arm No. 7-0 black silk suture was placed over the capillary tube 2 mm. anterior to the scleral incision.

Next, a small limbal incision was made with a Wheeler knife and the anterior portion of the capillary tube was introduced carefully into the anterior chamber, avoiding to scratch or damage the corneal endothelium. No instrument was allowed to enter the anterior chamber, and there was no irrigation of the anterior chamber. When the anterior chamber collapsed during the insertion of the capillary tube, no attempt was made to refill it. The limbus-based conjunctival flap was then closed with a continuous No. 5-0 plain absorbable gut suture. The length of the capillary tube in the anterior chamber was 3 to 5 mm. and that in the vortex vein was 7 to 10 mm. in all rabbits. At the end of the operation, no medication was used except when moderate fibrin formation was noted in the pupillary region; in that case a combined mydriatics solution (10 per cent phenylephrine HCl and 1 per cent cyclopentolate) was used.

The above procedure was carried out in one eye of each rabbit while the other eye served as a control. In 3 other rabbits the posterior end of the polyethylene capillary tube was simply buried under Tenon's capsule, as a second control.

Results

A shunt between the anterior chamber and a vortex vein was created in 10 rabbits. Drainage between the anterior chamber and the space under Tenon's capsule was established in 3 rabbits. The postoperative follow-up period ranged from 6 to 12 weeks.

In 9 of 10 eyes, the shunt between the anterior chamber and the vortex vein appeared to be effective in increasing the outflow facility and reducing the intraocular pressure. The average value for outflow facility was 0.27 $\mu l$ per minute per millimeter of mercury prior to operation, 0.43 $\mu l$ per minute per millimeter of mercury 8 weeks after the operation. These postoperative averages include some eyes in which the shunt was still patent and others in which the shunt was not functioning any more because the plastic tube had pulled out of the vein. Therefore, the eyes were divided in two groups: those in which the plastic capillary tube was stabilized after operation, and those in which the tube slipped out of the vein.

Plastic capillaries in position. In 3 eyes, the aqueous-venous shunt was still patent 12 weeks after operation. The average value for aqueous outflow facility in these
eyes was 0.31 μl per minute per millimeter of mercury prior to operation and 0.44 μl per minute per millimeter of mercury after operation (Fig. 2). The average differences between the preoperative and postoperative values for intraocular pressure and outflow facility were statistically significant. A typical manometric pressure decay curve obtained in one of these 3 eyes 6 weeks after operation is shown in Fig. 3. The intraocular pressure fell smoothly toward the steady-state level, which was attained faster than in the unoperated fellow eye. The patency of the capillary tube was tested postoperatively by means of a fluorescein injection into the anterior chamber. The dye appeared in the lumen of the vortex vein immediately after injection. Microscopic dissection after tonography showed that the posterior end of the capillary tube was within the lumen of the vein in 2 eyes; in the third eye, the vein was cut accidentally during dissection and the location of the posterior end of the tube in the vein could not be checked visually.

**Plastic capillaries migrated.** In 7 eyes the aqueous outflow facility and intraocular pressure returned to their preoperative levels. This occurred after 2 weeks in one eye, after 8 weeks in 4 eyes, and after 12 weeks in 2 eyes. These eyes were enucleated after the pressure had returned to its preoperative level. Dissection showed that in all cases the plastic capillary tube had slipped out of the venous lumen and moved further into the anterior chamber. In 2 cases the posterior end of the plastic capillary tube was encapsulated, and in 5, it was blocked by subconjunctival cicatricial tissue. The intraocular pressure and outflow facility were measured postoperatively and at intervals postoperatively in these 7 eyes. The average values for these measurements are plotted in Fig. 4. There is no difference between the values obtained preoperatively and 12 weeks after operation. The return of the intraocular pressure to a preoperative level appeared somewhat earlier than that of the outflow facility.

No change in intraocular pressure or outflow facility was found either in the control eyes or in the 3 eyes in which the posterior end of the capillary tube was
Fig. 4. Average values of the aqueous outflow facility and intraocular pressure of 7 eyes in which the capillary tube had spontaneously slipped farther into the anterior chamber and out of the venous lumen, 8 to 12 weeks postoperatively. • = Eyes operated upon; ▲ = control eyes.

placed under the Tenon's capsule. No significant change in scleral rigidity was observed in any rabbit. The depth of the anterior chamber was somewhat decreased in the operated eye, but actual measurements of the anterior chamber depth were not performed in this series.

It is important to note the degree of reaction observed in eyes operated on by this technique. In all cases a minimal to moderate postoperative congestion associated with signs of mild anterior uveitis were observed, which usually subsided in 2 to 3 days. The fibrin which was present in the aqueous at the end of the operation absorbed within 2 or 3 days. Subsequently, varying degrees of edema and deep vascularization of the cornea developed along the implanted capillary. Occasionally, this reaction occurred as late as 7 days after operation. These changes were limited to a small corneal area and usually they did not extend to the pupillary zone of the cornea. Marked to severe inflammatory reaction occurred only when the capillary tube had spontaneously moved further into the anterior chamber. In those cases, the tube either came in contact with the corneal endothelium or moved across the pupil and pushed against the trabeculum on the opposite side of the eye. Slippage of the tube was the sole cause for termination of the experiment in 4 rabbits. In the other eyes, the implanted capillary tube was well tolerated and no medication was required. No keratic precipitates or lens changes were observed. Localized synechiae formed between the iris and the capillary tube after operation. These synechiae were due to wound leakage and were therefore located at the site of limbal incision. Iris prolapse, wound leakage, infection, and hyphema were not encountered. In no case did the capillary tube move backward and out of the anterior chamber.

Discussion

Various materials have been implanted in the eye, for the relief of glaucoma, by other investigators. More than 29 different methods have been described, most of which were attempts to establish drainage between the anterior chamber and the subconjunctival space or the suprachoroidal space. No report has been found in the literature which describes the establishment of a shunt between the anterior chamber and an extraocular vein.

In the treatment of hydrocephalus, neurosurgeons have successfully established ventriculovenous shunts using silicone rubber valves. This permits only unidirectional flow of cerebrospinal fluid to the venous system since the valve allows flow only when the pressure of the cerebrospinal fluid is 35 mm H2O or more. A comparable drainage system between the anterior chamber and an extraocular vein, such as a vortex or large episcleral vein, might eliminate the formation of connective tissue around the posterior end of the plastic capillary, which has been the main cause of failure of the seton operation. Since the intraocular pressure is higher than the extraocular venous pressure, unidirectional flow of aqueous humor into the venous channel is ex-
pected, and an increase of the outflow facility must result.

Our tonographic and manometric studies show that there was a significant increase in the outflow facility and decrease in intraocular pressure as long as the aqueous-venous shunt functioned. Both the intraocular pressure and outflow facility returned to preoperative levels within 2 to 5 days when the implanted plastic capillary slipped out of the vein. The slippage of the capillary tube and the gradual return of intraocular pressure and outflow facility to preoperative levels were observed within 8 weeks after operation. On the other hand, the intraocular pressure and outflow facility of 3 eyes in which the capillary tube was not implanted in a vein returned to its preoperative level within 3 days after operation. These findings indicate that a plastic capillary tube implanted intravenously is more effective than one implanted only under the conjunctiva or Tenon's capsule.

The importance of permanent anchoring of the plastic capillary tube is demonstrated by this study. Marked to severe postoperative inflammation occurred only in those eyes in which the plastic capillary tube moved further into the anterior chamber.

It is essential that a large series of animals be followed for a considerably longer period of time in order to determine what late complications may occur and whether or not the capillary tube will remain patent. Experiments are now underway with a modified technique for the immobilization of the plastic capillary and with a longer postoperative follow-up. Histopathologic studies will be carried out at a later stage of this experiment.

REFERENCES


