CLINICAL SCIENCE

Ultrasound biomicroscopy and its value in predicting the long term outcome of viscocanalostomy

S Roters, C Lüke, C P Jonescu-Cuypers, B F Engels, P C Jacobi, W Konen, G K Krieglstein

Aims: To examine whether the early postoperative morphology at the site of sclerectomy, as visualised by ultrasound biomicroscopy (UBM), is an indicator of the mechanisms that lower intraocular pressure (IOP) and/or predictors of the long term outcome of viscocanalostomy.

Methods: 15 eyes of 14 patients with medically uncontrolled open angle glaucoma and no history of surgery underwent viscocanalostomy according to Stegmann’s technique. Ultrasound biomicroscopy was performed during the first month after surgery. The following parameters were assessed: dimensions of the intrascleral “lake,” presence of a filtering bleb, presence of a subconjunctival cavity or a suprachoroidal hypoechoic area, and the thickness of the residual trabeculocorneal membrane. A complete ophthalmological examination was performed the day before and the day after surgery. Follow up visits were scheduled 1 week, 4 weeks, 6 months, and 12 months after surgery.

Results: At 1 year successful control of IOP (<20 mm Hg) was achieved without further manipulation or medication in six of 15 eyes. The size of the intrascleral “lake” (average 0.62 mm) did not correlate with later IOP; however, a visible route under the scleral flap and accidental perforation of the trabeculocorneal membrane were associated with long term lowering of IOP. Normal thickness of the trabeculocorneal membrane (0.10–0.15 mm) was indicative of IOP control with and without medication. When UBM showed an early collapse of the intrascleral cavity, control of IOP was not achieved. Other UBM findings did not predict long term function.

Conclusion: In accordance with previous studies, the authors found that UBM examination is a useful method to evaluate outflow mechanisms after glaucoma surgery. This study shows that UBM imaging of external filtration during the early postoperative period can be used to predict the success of viscocanalostomy. However, to establish conclusively what parameters of UBM predict successful viscocanalostomy a larger number of patients must be studied.

Several investigators have shown renewed interest in surgical reduction of intraocular pressure (IOP) by non-perforating glaucoma surgery. Non-perforating glaucoma surgery avoids opening the anterior chamber and decompressing the eye, thus circumventing many serious complications associated with standard trabeculectomy. In open angle glaucoma, the endothelium of Schlemm’s canal and the immediately adjacent trabecular meshwork show increased resistance to aqueous outflow, resulting in increased IOP. Recently, a new technique of non-penetrating glaucoma surgery, viscocanalostomy, has been described; it results in better outflow in open angle glaucoma. In this procedure Schlemm’s canal is unroofed and Descemet’s membrane is separated 1–2 mm from the corneoscleral junction, resulting in a thinner but intact window to the anterior chamber, through which aqueous humour diffuses into a subscleral lake created by the removal of an inner scleral flap. Filtration is improved when the diameter of Schlemm’s canal is enlarged by the injection of a high viscosity viscoelastic material into the opened ostia of the canal.

The nature of the outflow pathways that lead to the lowering of IOP in viscocanalostomy surgery is controversial. Several mechanisms may be involved: these include permanent subconjunctival filtration (as in trabeculectomy), aqueous flow into the canalicular system that reaches the venous circulation or the uveoscleral space, with or without an intrascleral “lake,” and drainage from Schlemm’s canal to capillaries and veins within the intrascleral canals and subconjunctival tissue.

Morphological studies have shown varying dissection depths of the deep scleral flap that often leads to an unroofing of Schlemm’s canal. Postoperative examination with the high resolution ultrasound biomicroscope (UBM), developed by Pavlin and Foster, allows imaging of the trabeculo-descemetic membrane, the intrascleral hypoechoic cavity and subconjunctival filtration (clinically not visible during slit lamp examination) with a resolution of 50 µm. UBM examination can also detect the presence of small amount of fluid, such as subchondral effusion, between layers of the eye.

The aim of the present study was to analyse the aqueous drainage pathways under the scleral flap and to examine the presence and dimensions of the subconjunctival and suprachoroidal space in eyes that underwent viscocanalostomy. In this study UBM findings were used to evaluate potential predictive parameters with reference to long term success or failure of viscocanalostomy.

PATIENTS AND METHODS

In this retrospective study we enrolled 15 eyes of 14 patients with uncontrolled open angle glaucoma. The patients had no history of glaucoma surgery or laser treatment and all had had maximal medical therapy without success. Included were patients with pseudoexfoliation glaucoma (n = 7), pigment dispersion glaucoma (n = 4) and primary open angle glaucoma (n = 4) (Table 1). Exclusion criteria were secondary or dysgenetic glaucoma, narrow angle glaucoma, a legally blind fellow eye, or corneal abnormalities that prevented reliable applanation tonometry.
## Table 1: Patient data

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Diag = ocular diagnosis, lake = intrascleral cavity, FB = filtering bleb, chor = suprachoroidal hyporeflexive zone, subcon = subconjunctival hypoechoic cavity, route = visible aqueous route under scleral flap, TMW = trabecular meshwork and adjacent tissue, clin = clinically visible filtering bleb (FB), further manip = further manipulation, med = medical treatment.

## RESULTS

The mean preoperative IOP was 25.26 mm Hg (range 22–40 mm Hg). After 1 year, six of 15 patients reached and maintained an IOP of ≤20 mm Hg without further surgery or medication. The mean IOP after 1 week was 16.1 (n=13), after 4 weeks was 14.6 mm Hg (n=10), after 6 months was 16.6 mm Hg (n=15), and after 12 months (including those patients who required drug therapy and those requiring additional surgery) the mean IOP was 18.2 mm Hg (n=15) (Tables 1 and 2).
No serious complications or long lasting side effects were noted in the operated eyes. Intraoperative complications were perforation of the trabeculocorneal membrane in two eyes. Postoperative complications included a leaking bleb in one eye, which closed spontaneously, and transient hyphaema of 1 mm and 2 mm in two eyes. Complications due to overfiltration, such as flat anterior chamber, prolonged ocular hypotony, and choroidal detachment were not observed. Significant cataract formation with a drop in visual acuity also was not observed. IOP spikes occurred in nine eyes; five of these eyes required additional surgery, three required drug therapy, and the patient in whom the spike was observed at the last follow up visit was instructed to use drug therapy. In two patients who had laser suturelysis, IOP control could not be achieved.

UBM was performed on average 12 days after viscocanalostomy and showed seven different morphological characteristics.

### Intrascleral lake
A visible intrascleral hypoechoic zone was observed in 13 eyes (86.6%). All 13 eyes achieved an IOP of <20 mm Hg; of these, six required no additional treatment, four drug therapy, and three additional surgery.

A large intrascleral lake (>0.50 mm³) was observed in six eyes (40%). All six eyes achieved an IOP of ≤20 mm Hg; of these, three required no additional treatment, two drug therapy, and one additional surgery.

The dimension of the intrascleral lake (average 0.62 mm³) did not correlate with changes in IOP (Figs 2 and 3).

### Low reflective filtering bleb
A filtering bleb was observed in 14 eyes (93.3%). A filtering bleb was not observed in only one eye, which required drug therapy.

A large filtering bleb was observed in four of six eyes that achieved an IOP of <20 mm Hg; one of the eyes required drug therapy and two required additional surgery.

### Subchoroidal hypoechoic area
A subchoroidal space was observed in six eyes (40%); all six eyes achieved an IOP of ≤20 mm Hg; of these, three did not require additional treatment, one required drug therapy and two required additional surgery.

### Visibility of the route under the scleral flap
Separation of the scleral flap owing to a presumed fluid stream was observed in two of the eyes that achieved an IOP of...

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<th>Table 2</th>
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maximal = maximum value of IOP; rows in bold type = successful viscocanalostomy with IOP 20 mm Hg after 1 year of follow up.

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![Figure 1](http://bjophthalmol.com/)

**Figure 1** Kaplan-Meier curve for all subjects (n=15). Time lapse until IOP exceeds 20 mmHg. Cumulative probability of survival.

![Figure 2](http://bjophthalmol.com/)

**Figure 2** UBM (radial section) 28 days after viscocanalostomy. A small perforation of residual trabecular meshwork (arrow), the small intrascleral “lake” (volume 0.36 mm³), a small low reflective filtering bleb (arrowhead), and a convex iris configuration were visualised by UBM. AC = anterior chamber.


**DISCUSSION**

Non-penetrating surgery was first introduced in 1984 by Fjodorov et al.\(^\text{15}\) and in 1989 by Koslov et al.\(^\text{16}\) Stegmann et al.\(^\text{17}\) modified the procedure by injecting viscoelastic material into Schlemm’s canal. The Stegmann procedure, named viscocanalostomy, was thought to give better IOP control in black subjects than conventional filtration surgery.

Small perforations that open a hole in the anterior chamber result in a successful viscocanalostomy; however, unpublished observations indicate that large perforations lead to adhesions of the peripheral iris or collapse of the intrascleral lake and an increase in IOP.

In this study UBM of non-penetrating sclerectomy with viscocanalostomy showed seven significant postoperative findings. Of these findings, a visible intrascleral liquid, which leads to formation of aqueous veins includes:

- **thinning of the trabecular meshwork**
- **vaulting of residual trabecular meshwork vaults towards the intrascleral cavity leading to a widening of the cribiform interspace (similar to laser trabeculoplasty)**
- **opening or widening of Schlemm’s canal inner wall and of the juxtatrabecular meshwork by injection of viscoelastic.**

Other unconventional outflow mechanisms that may be improved by surgery include:

- **scleral thinning when a superficial scleral flap permits passage into the subconjunctival space**
- **formation of an intrascleral lake, which leads to formation of aqueous veins**
- **trans-scleral filtration into the supraciliary/suprachoroidal space.**

Accidental lesions that can lead to higher aqueous outflow include:

- **opening of a cycloidalysis clefts (these may only be observed by UBM examination)**
- **localised choroidal effusion**
- **opening of the anterior chamber.**

In our studies the residual trabeculo-descemetic membrane was unstable if its thickness was \(\leq 0.05\) mm. The inward vaulting into the intrascleral cavity led to collapse of the lumen of the cavity and an increase in IOP. A trabeculo-descemetic membrane is stable when the thickness is 0.13 (SD 0.02) mm.\(^\text{21}\) A visible Schlemm’s canal following viscoelastic injection was never observed, even when UBM examination was performed on the second postoperative day.

The inability to view Schlemm’s canal and its degree of patency is a limitation of commercially available UBM technology. Without that information, one aspect of the mechanism (flow into a dilated Schlemm’s canal) cannot be addressed. It would be expected that a large intrascleral lake would result in good trans-scleral and suprachoroidal filtration as well as increased contact with aqueous veins but, in fact, the size of the intrascleral lake did not correlate with IOP control.\(^\text{21}\)\(^\text{26}\)

**Figure 3** UBM (radial section) 8 days after viscocanalostomy. An intact trabeculo-descemetic membrane (0.15 mm), an intrascleral “lake” (volume 0.63 mm\(^3\) with the calipers measuring maximum radial dimension), a small “route” under the scleral flap and a subconjunctival cavity (small arrows) and a hyporeflective cribriform interspace (similar to laser trabeculoplasty) could be visualised. AC = anterior chamber.

\(\leq 20\) mm Hg without any additional treatment. A very small route (diameter \(< 0.05\) mm) occurred in one eye in each group (Fig 3).

**Thickness of remaining trabecular meshwork**

UBM examination showed perforation of the trabeculocorneal membrane (Fig 2) in two eyes that achieved an IOP of \(\leq 20\) mm Hg without additional treatment. A postoperative thickness of 0.10–0.15 mm was measured in five of six eyes that achieved an IOP of \(\leq 20\) mm Hg without additional treatment and in the four eyes that required drug therapy (66.6%). A thickened trabeculocorneal membrane (>0.3 mm) was observed in one eye that required additional surgery (13.3%).

**Collapse of trabecular meshwork**

An early collapse of the superficial scleral flap with residual trabecular meshwork was observed in four of five eyes only in the group that required additional surgery (26.6%).

A clinically visible filtering bleb was observed in nine eyes (60%). All nine eyes achieved an IOP of \(\leq 20\) mm Hg; of these, four required no additional treatment, four required drug therapy, and one required additional surgery.

Non-penetrating surgery for water and because the sites of resistance to outflow (juxtacanalicular meshwork and the inner wall of Schlemm’s canal) are kept intact throughout the procedure. Consequently other outflow pathways must be involved.\(^\text{19}\)

UBM permits visualisation of the postoperative area and measurement of the thickness of the trabeculocorneal membrane and the dimensions of the intrascleral lake.\(^\text{20}\) Despite an axial and lateral resolution capacity of 50 \(\mu\)m, imaging of the exact preparation level is not possible. In this study the volume of the intrascleral lake was determined by multiplying the maximum height by the limbus parallel and radial extension, resulting in a quadratic equation. This equation was chosen according to previous studies,\(^\text{19}\) although a more precise calculation would be that for lenticular objects.

Under physiological conditions, 85% of aqueous outflow is transtrabecular.\(^\text{21}\) Sclerectomy and viscocanalostomy lead to the reduction of outflow resistance via a number of mechanisms, which include:\(^\text{21}\):

- thinning of the trabecular meshwork
- vaulting of residual trabecular meshwork vaults towards the intrascleral cavity leading to a widening of the cribiform interspace
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The features of viscocanalostomy include preparation of a deep scleral lamella after a superficial one, and creating a “Descemet’s window” with anterior preparation of the deep lamella into the cornea just above Descemet’s membrane. Schlemm’s canal is deroofed, the deep lamella is dissected and the open ends of Schlemm’s canal are filled with viscoelastic material. Percolation of aqueous through Descemet’s window was supposed to be indicative of proper preparation.\(^\text{17}\) Early reports of favourable results were accompanied by discussions about the mechanisms by which such a procedure lowers IOP particularly because of the extremely low permeability of Descemet’s membrane for water and because the sites of resistance to outflow (juxtacanalicular meshwork and the inner wall of Schlemm’s canal) are kept intact throughout the procedure. Consequently other outflow pathways must be involved.\(^\text{19}\)

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- opening of a cyclodialysis clefts (these may only be observed by UBM examination)\(^\text{24}\)
- localised choroidal effusion
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In our studies the residual trabeculo-descemetic membrane was unstable if its thickness was \(\leq 0.05\) mm. The inward vaulting into the intrascleral cavity led to collapse of the lumen of the cavity and an increase in IOP. A trabeculo-descemetic membrane is stable when the thickness is 0.13 (SD 0.02) mm.\(^\text{21}\) A visible Schlemm’s canal following viscoelastic injection was never observed, even when UBM examination was performed on the second postoperative day.

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bimicroscopic studies have shown that blebs of the L-type (low reflective) are associated with good IOP control in trabeculotomy-treated eyes 

with adjunctive mitomycin. In this study filtering blebs were found in all but one eye 1 month after surgery; however, even a large hyporeflexive filtering bleb was not indicative of good IOP control, and in fact two eyes needed further surgical intervention. A hyporeflexive subconjunctival cavity was often found in successful viscoscanalostomies; however, two eyes with a hyporeflexive subconjunctival cavity needed additional surgery.

A UBM finding that was indicative of successful IOP control was an easy visible “route” under the scleral flap; however, if the diameter of the route was <0.05 mm, there was no guar-

antee for a long-term function. Earlier studies have shown that the thickness of the aqueous drainage route beneath the scle-

rara flap influences the development of a filtering bleb, and both are indicative of good IOP control (follow up mean 9.9 months). 

During the 1 year follow up period, control of IOP with or without the addition of drug therapy, was successful when the residual trabeculocorneal membrane measured between 0.10 mm and 0.15 mm and when a filtering bleb was observed clinically. The clinical finding of a filtering bleb was not necessarily observable from UBM imaging, and in cases with large hyporeflexive blebs shown on UBM, the clinical examination did not indicate the presence of a filtering bleb despite evaluation by four experienced ophthalmologists (two for clinical examination and two for UBM examination).

Early studies of viscoscanalostomy claimed that this procedure was not as efficient for controlling IOP in white glaucoma patients as standard filtration surgery and was therefore indicated for its safety more than for its efficacy. Comparison of trabeculectomy and viscoscanalostomy showed that during a 6 month follow up, IOP was successfully controlled in five of 10 eyes in the trabeculectomy group and in none of the eyes in the viscoscanalostomy group. However, Carassa et al. reported a success rate of 86.2% after 12 months in eyes that underwent viscoscanalostomy. In summary, these studies are difficult to compare because of differences in the criteria of successful control of IOP and varying follow up periods.

Numerous surgical modifications, such as laser gonipunc-

ture, trabecular stripping, trabecular microperforation, and various implants into the scleral space have been introduced to decrease IOP and reduce outflow resistance in trabecular meshwork and/or canaliculation of aqueous flow into the subcon-

junctival area. Johnson and Johnson identified microperforations in the trabecular meshwork after non-penetrating surgery bypassing the resistance of the juxtacanalicular meshwork, explaining why many patients who have had successful non-penetrating operations developed filtering blebs. Driæsæud et al. reported that none of the eyes in a series of 41 viscoscanalostomies with microperforation required further pressure lowering surgery, whereas five of the “perfect” surgeries needed additional surgery. These results support our findings that perforation of the trabecular meshwork and an aqueous route under the scleral flap indicate successful IOP control similar to that obtained with standard filtration surgery.

As far as the safety of viscoscanalostomy is concerned, there are certainly fewer complications, such as postoperative hipo-

tensive complications, flat anterior chamber, and choroidal detachment; however, hyaluronate detachment of Descemet’s membrane can occur.

UBM is a useful method for assessing the anatomical changes in eyes undergoing viscoscanalostomy, which may allow an understanding of the outflow mechanisms. In spite of many variations observed, it may be stated that non-penetrating viscoscanalostomy works best when ultrasound biomicroscopic observations are similar to those observed after filtration surgery. A study with later UBM is under way, in order to compare the findings with the early UBM appearance. However, a larger number of patients needs to be studied to define what parameters predict successful IOP control.

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