SCIENTIFIC REPORT

Changes in axial length following trabeculectomy and glaucoma drainage device surgery

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Aim: This study examines the changes in axial length (AL) after trabeculectomy and glaucoma drainage device (GDD) surgery and enabled an equation to be derived allowing prediction of AL change after filtering surgery.

Methods: This was a prospective, interventional case series from the Glaucoma Service of the Doheny Eye Institute. Patient population: One eye of 39 patients undergoing trabeculectomy and 22 undergoing Baerveldt tube shunt implantation for uncontrolled glaucoma. Intervention: These patients had AL measurements by non-contact, partial coherence interferometry preoperatively, at 1 week, 1 month, and >3 months after surgery. Main outcome measures: Axial length and intraocular pressure were compared at preoperative and postoperative visits. Postoperative intraocular pressure (IOP) was categorised as hypotonous (0−4 mm Hg), low (5−9), normal (10−17), and high (18 or more).

Results: There was a statistically significant reduction in IOP after 3 months of −12.8 (SD 1.5) mm Hg following trabeculectomy ($p<0.001$), and −10.7 (1.9) mm Hg after GDD ($p<0.001$). There was a statistically significant reduction in AL, which was similar after trabeculectomy and GDD at all time points ($p<0.001$), of −0.15 (0.03) and −0.21 (0.04) mm (1 week), −0.18 (0.02) and −0.10 (0.02) mm (1 month), and −0.16 (0.03) and −0.15 (0.03) mm (3 months). At 3 months or later the AL reduction was related to postoperative IOP and to the amount of IOP reduction ($p<0.05$, stepwise multiple regression). 10.2% (4/39) of trabeculectomy patients had hypotony after 3 months, with a mean AL reduction (−0.39 (0.11)) that was statistically significantly lower ($p<0.01$) than the other trabeculectomy eyes (−0.14 (0.15)).

Conclusions: There is a small but statistically significant decrease in AL after both trabeculectomy and GDD surgery, greater in eyes that are hypotonous after surgery. The authors suggest that AL reduction can be predicted after 3 months by the formula: AL reduction (mm) = −199+ 0.006×IOP reduction+0.008×final IOP.

Glaucoma filtration surgery with antifibrotic agents or glaucoma drainage devices (GDD), performed with or without cataract extraction, results in clinically significant lowering of intraocular pressure (IOP).[1] Well known complications of hypotony that may follow filtering surgery include choroidal effusion, haemorrhage, cataract, corneal decompensation,[2] and hypotonous maculopathy.[3–5] We postulated that IOP lowering after filtering surgery produces a decrease in axial length, which is dependent on the amount of IOP lowering. This change in axial length may be large enough to cause a clinically significant error in refractive predictions in cases where combined cataract surgery and filtering surgery are performed.[6] Quantification of the axial length decrease and correlation with IOP would enable calculation of a correction factor, assuming a stable IOP postoperatively.

METHODS

Patients were recruited consecutively over a 4 month period from those scheduled to undergo trabeculectomy or GDD surgery at the Doheny Eye Institute. Inclusion criteria were a diagnosis of primary or secondary open angle or angle closure glaucoma, and vision sufficient to allow fixation on the target of the IOL Master. Exclusion criteria were a diagnosis of traumatic or paediatric glaucoma, age less than 21 years, visual acuity insufficient for axial length measurement, and aphakia. A glaucoma specialist (BAF or DSM) performed all surgeries using the same method. The trabeculectomies were performed with a limbus based conjunctival flap with intraoperative 5-fluorouracil or mitomycin C. A Baerveldt 350 glaucoma implant (Pharmacia and Upjohn, Kalamazoo, MI, USA) was used in all GDD surgeries. The tube was occluded with a 6-0 or 7-0 Vicryl suture. In some cases a 5-0 nylon "ripcord" suture was placed inside the Vicryl ligature and looped subconjunctivally for later removal in the clinic.

The axial length measurements were performed with the IOL Master (Zeiss-Humphrey, Dublin, CA, USA) preoperatively, and at early (1 week), middle (4 weeks), and late (>3 months) postoperative periods. This non-contact optical biometry method is performed through an undilated pupil, with no anaesthesia, with the patient sitting. It is based on the principle of partial coherence interferometry, which has been employed in optical coherence tomography (OCT). Coherence describes the property of two wave fronts with a constant or regularly varying phase difference at every point in space. Because the velocity of light is too high for direct measurement of echo delay times, an interferometer must be used. In this device, a semi diode laser emits light (780 nm) of short coherence length that is split into two beams in a Michelson interferometer. Both beams illuminate the eye through a beam splitting prism and are reflected back by both the cornea and retina. The light reflected from the cornea interferes with that reflected by the retina if the optical paths of both beams are equal. The interference is detected by a photodetector, and the signals are recorded as a function of the position of the interferometer mirror. From this mirror the system determines the axial length as the path difference between the cornea surface and the retinal pigment epithelium.[7 8]

The main outcome measure was axial length measured preoperatively and postoperatively. The changes in axial length were correlated with both the amount of IOP

Abbreviations: AL, axial length; GDD, glaucoma drainage device; IOL, intraocular lens; IOP, intraocular pressure; MMC, mitomycin C; OCT, optical coherence tomography

Table 1 Baseline patient characteristics for trabeculectomy and glaucoma drainage device (GDD) groups

Characteristics	Trabeculectomy	GDD	p Value
Sex			
Male	15 (39%)	7 (32%)	
Female	24 (61%)	15 (68%)	0.8
Race			
White	16 (41.0)	11 (50.0)	
Black	49 (10.3)	3 (13.6)	
Asian	9 (23.1)	5 (22.7)	
Latino	10 (25.6)	3 (13.6)	0.8
Age (years) (mean (SD))	69.5 (11.2)	71.4 (12.2)	0.55
Surgical procedure†	MMC 36 (92%)		
	5-FU 2 (5%)	Complete 13 (59%)	
	None 1 (3%)	Stage 2 9 (41%)	
Lens status			
Phakic	15 (38%)	4 (18%)	
Pseudophakic	23 (59%)	18 (82%)	
Aphakic	1 (3%)	0 (0%)	0.17
Diagnosis‡			
POAG	32 (82%)	16 (73%)	
2OAG	1 (2.5%)	4 (18%)	
CACG	5 (13%)	0 (0%)	
NVG	1 (2.5%)	2 (9%)	0.04*
Preoperative IOP (mm Hg) (mean (SD))	22.8 (9.7)	25.2 (8.4)	0.33

†MMC, mitomycin C trabeculectomy; 5-FU, 5-fluorouracil trabeculotomy; Complete, complete Baerveldt implant; Stage 2, second stage of Baerveldt implant.
‡POAG, primary open angle glaucoma; 2OAG, secondary open angle glaucoma; CACG, chronic angle closure glaucoma; NVG, neovascular glaucoma.

reduction and the level of postoperative IOP attained. IOP was measured with standard Goldmann applanation tonometry. The level of IOP was categorised as hypotonous (0−4 mm Hg), low (5–9), normal (10–17) or high (18 or more).

The comparisons of IOP and axial length before and after surgery were made with the paired *t* test. The statistical comparisons of IOP and axial length between trabeculectomy and GDD were made with the Student's *t* test. The regression analysis of variables (age, race, sex, type of surgery, lens status, preoperative axial length, IOP change, final IOP) affecting axial length was performed using SPSS 10.1 for windows. Regression analysis was used to calculate the axial length change equation.

This study was carried out with approval from the institutional review board of the Keck School of Medicine at the University of Southern California. Informed consent was obtained from the patients before participation.

RESULTS

Patient characteristics are described in table 1. The only significant difference between the trabeculectomy and GDD groups was seen in the glaucoma diagnosis. This reflects the clinical decisions of the authors to treat a higher percentage of secondary open angle and angle closure glaucomas with GDD surgery.

The reduction in IOP following trabeculectomy and GDD surgery was statistically significant ($p<0.001$) at all time points compared to preoperatively (table 2). The reduction in IOP after trabeculectomy was −7.5 (SD 2.3) (1 week), −10.9 (1.6) (1 month), and −12.8 (1.5) mm Hg (more than 3 months). After GDD, the IOP was lowered −11.1 (2.3), −7.9 (2.2), and −10.7 (1.9) mm Hg at 1 week, 1 month, and more than 3 months, respectively.

The axial length changes following surgery are documented in table 3. Note that there was a significant reduction at all time points following both trabeculectomy and GDD. This change was similar between the two groups except at the 1 month visit, when the change was greater after trabeculectomy.

A statistically significantly ($p<0.0001$) higher proportion of patients (10.2%, 4/39) had postoperative hypotony 3 months following trabeculectomy compared with GDD (0%, 0/22). None of these eyes had choroidal fluid elevations that may inhibit optical biometry measurements. The patients with hypotony had a mean axial length reduction (−0.39 (0.11) mm) that was statistically significantly lower ($p<0.01$) than the other trabeculectomy eyes (−0.14 (0.15)). However, removing these patients from the data set did not influence the regression line. A separate regression line was not calculated for these patients because of their small number.

The stepwise multiple regression of analysis of variables showed that axial length reduction after 3 months was related to both postoperative IOP and also the amount of IOP reduction ($p<0.05$). However, it was not related to age, race, sex, type of surgery, preoperative axial length, and lens status ($p>0.1$). Using the data on axial length changes for trabeculectomy and GDD combined, we calculated that axial length reduction after IOP lowering surgery can be predicted by the formula: AL reduction (mm) = $-0.199+0.006\times$IOP reduction$+0.008\times$final IOP.

Table 2 Change in intraocular pressure (IOP) in mm Hg following glaucoma surgery

	1 week	1 month	⩾3 month
All	−8.8 (1.7)	−9.8 (1.7)	−12.0 (1.2)
Trabeculectomy	−7.5 (2.3)	−10.9 (1.6)	−12.8 (1.5)
GDD	−11.1 (2.3)	−7.9 (2.2)	−10.7 (1.9)

Table 3 Axial length (mm) before and after glaucoma surgery

	Preop	1 week	1 month	⩾3 month
All	24.06 (0.23)	23.91 (0.24)	23.84 (0.24)	23.98 (0.24)
Trabeculectomy	24.04 (0.34)	23.89 (0.34)	23.87 (0.34)	23.99 (0.34)
GDD	24.09 (0.26)	23.94 (0.28)	23.79 (0.30)	23.96 (0.27)

There were significant differences in axial length after surgery compared to preoperatively at all time points (paired *t* test, $p<0.001$) for both trabeculectomy and glaucoma drainage device (GDD).

DISCUSSION

Refinements in surgical technique, GDDs, and the use of antimetabolites have increased the potential for IOP lowering after glaucoma surgery. However, more effective lowering of IOP has increased the incidence of hypotony and its complications. Even if lower IOP does not result in hypotony complications, it may cause a decrease in the size of the globe, measured by axial length.

Unanticipated axial length changes are of particular concern given the frequency of coexisting glaucoma and cataract. With improved cataract extraction techniques such as temporal clear corneal incisions and foldable IOLs, we are able to perform cataract surgery after trabeculectomy with success rates approaching 80−90%.[9–11] In addition, the success of trabeculectomy combined with cataract extraction is reportedly comparable to filtration surgery alone.[12 13] However, because axial length is a primary determinant of intraocular lens (IOL) implant power, patients who undergo cataract extraction before, combined with, or following glaucoma surgery can undergo clinically significant changes in their refractive error. In fact, a variance of just 1 mm in the axial length can affect the IOL power calculation and postoperative refraction by 2.5–3 dioptres.[6]

In a retrospective study, Cashwell and Martin found a significant decrease in axial length (mean −0.423 mm) at various times following trabeculectomy.[14] In a cohort of 16 patients undergoing trabeculectomy with mitomycin C (MMC), Kook *et al* observed a significant induced corneal astigmatism and decrease in axial length (mean −0.9 mm).[15] Four days after trabeculectomy, Nemeth and Horoczi noted decreased axial length, increased thickness and volume of the ocular wall.[16]

While the results of these studies are consistent with ours, they showed a much larger magnitude of change in axial length following trabeculectomy. A possible explanation is that all of these studies used contact A-scan ultrasonography with an applanation biometry probe to measure axial length. Contact measurements can induce bias by probe deformation of the eye resulting in falsely low postoperative readings of axial length, especially in hypotonous eyes.[11] Our study utilised a relatively new technology, non-contact optical biometry, which is extremely accurate and reproducible, and not affected by small eye movements. It also always utilises the visual axis of the eye.[6 7] However, corneal scars, very dense cataracts, and epiretinal membranes adversely affect its accuracy. The use of this device ensures the most precise readings available, which are not affected by eye contact induced artefacts. In addition, we are unaware of any previous studies that have examined the effects of GDD surgery on dimensions of the eye.

We found a small but statistically significant decrease in axial length at all time points following trabeculectomy and GDD surgery. As stated, this difference was less than that seen in previous studies.[14 15] After 3 months, the IOP lowering and axial length changes were comparable between the trabeculectomy and GDD groups. This reduction was related to postoperative IOP and IOP reduction, but not to age, race, sex, type of surgery, preoperative axial length, and lens status.

A statistically significant difference between the trabeculectomy and GDD groups was found in the number of patients with late postoperative hypotony. After trabeculectomy, 10.2% of patients were hypotonous compared to none in the GDD group. This group had a decrease in axial length that was almost three times as great as the other trabeculectomy eyes. This could result in a refractive shift up to 1.5 dioptres in IOL power calculation. Using our data, we calculated a formula to predict axial length change after trabeculectomy or GDD surgery, which according to our data result in comparable decreases in axial length.

There are several situations in which clinical decision making may be impacted by our results. The most important scenario is a combined cataract extraction and glaucoma filtering surgery, where the axial length decrease can result in a significant postoperative hyperopic error. This would be especially important in severe or normal tension glaucoma patients where the target IOP is in the single digits or in young myopes where the risk of hypotony may be higher.[3] The second example involves glaucoma surgery performed after cataract extraction, which may again result in a significant hyperopic shift. Finally, patients in whom glaucoma surgery is performed initially followed by cataract extraction, the axial length and IOL calculations should be performed after glaucoma surgery, when the IOP is stable. However, if the eye is hypotonous and a return to normal IOP is anticipated following the cataract surgery, this must also be taken into account. Future study should focus on which patients are at a higher risk for axial length changes with IOP fluctuations. This risk may be determined by other anatomical indices such as corneal and scleral thickness and elasticity, and choroidal thickness.

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The Lighter Side

School budget cuts caused a decreased interpupillary distance with predictable adverse consequences. © Michael Balis.