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Silicone Tubes in Glaucoma Surgery: The Effect of Technical Modifications on Early Postoperative Intraocular Pressures and Complications

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Summary
One hundred and nineteen eyes with glaucoma were treated by implantation of silicone rubber tubes draining either to encircling inverted gutters (92 eyes) or to integral plates sutured at the equator of the globe. The occurrence of persistent choroidal effusion was related significantly ($S<0.01$) to post-operative hypotony and choroidal haemorrhage appeared to occur during periods of ocular hypotony. This paper describes our surgical modifications to overcome these problems.

A one-piece integral tube and plate with a slit-valve mechanism designed to regulate post-operative intraocular pressure had a very variable response in 27 eyes, with mean pressures similar to those after unligated tube and gutters.

Ligation of the tube in 34 eyes caused significantly higher mean intraocular pressures on the first two days after surgery than that in 43 eyes without ligation and the incidence of ocular hypotony (<7 mmHg) was significantly lower after ligation. However, five eyes with ligated tubes required operative release of the suture because of uncontrollably raised intraocular pressures.

Venting of the drainage tube on the anterior chamber side of the occlusive ligation in 15 eyes caused fewer cases of raised post-operative intraocular pressures, but also a moderate increase in the frequency of ocular hypotony.

At present a combination of occlusive ligation and a venting stab into the drainage tube in a one-piece tube and plate system appears to be the best design for avoiding short-term ocular hypotony whilst achieving long-term pressure control.

A tube and sump drainage system operates by providing a tube to conduct aqueous humour to a large sump area from which aqueous absorption takes place, the sump being maintained by a template of silicone rubber (disc[1], gutter[2] or plate[3]) sutured to the sclera. The silicone rubber template becomes surrounded with fibrous tissue and aqueous diffuses through the fibrous 'capsule' and is absorbed into the surrounding capillaries in the orbit. The rate of absorption depends on, amongst other factors, the area of the plate and the resistance of the fibrous tissue 'capsule'. Before the fibrous 'capsule' forms, the aqueous can drain freely down the tube and this leads to ocular hypotony and secondary complications[4,5,6], but after its formation a steady-state is reached, preferably with normal intraocular pressures. Various methods exist to prevent this bulk overflow of aqueous and this paper describes our experience with some of these techniques.

Patients and Methods

The patients operated upon in this series have

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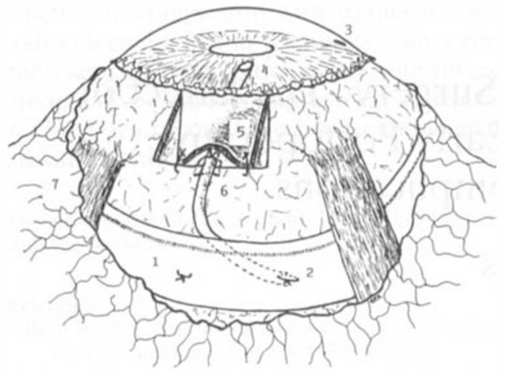

Fig. 1. *The modified Schocket procedure: An inverted gutter (1) is sutured to equatorial sclera and the silicone rubber drainage tube sutured tightly to its undersurface (2). After paracentesis (3) the tube is passed into the anterior chamber (4) under a scleral flap (5). The tube is transfixed by a suture that also fixes it firmly to the sclera (6), before the conjunctival peritomy (7) is accurately closed.*

been under the care of the Glaucoma Unit at Moorfields Eye Hospital. The indications for surgery were those eyes in which the intraocular pressure was inadequately controlled (generally >35 mmHg) on maximum tolerated medical therapy and in which conventional drainage surgery had failed, or was likely to fail.

The method used was that of a modified version of the Schocket procedure (Fig. 1), this basic technique being gradually modified according to practical experience; the basic technique and subesequent modifications have been labelled Groups I to VI. *Group I* (27 eyes of 26 patients) had, as the basic technique, a limbal conjunctival peritomy and an inverted 20S silicone rubber gutter sutured equatorially onto the sclera. A thick scleral flap was dissected, the silicone rubber drainage tube (Dow-Corning: 0.30 mm internal and 0.64 mm external diameter) was sutured tightly to the underside of the gutter and the anterior chamber end was cut obliquely to create an anterior opening to the tube. Frequently a paracentesis needle was passed at this stage, thereby allowing a slow decompression of the hypertensive globe. The tube was passed into the eye through a stab incision made with a posteriorly-directed 27 gauge, or less often a 25 gauge, needle. A 10/0 Ethilon suture was used to transfix the tube and fixate it to sclera (thereby preventing tubal angulation or migration) and the scleral flap was sutured into position loosely to cover the tube. The Tenon's capsule and conjunctiva was closed with 6/0 Collagen or 10/0 Ethilon, the anterior chamber refilled with balanced salt solution or a viscoelastic material and a subconjunctival injection of antibiotic given. Post-operatively the eyes were treated with a topical mydriatic, antibiotic and steroid preparation. If intraocular pressure was inadequately controlled, medical therapy was used as necessary, preference being given to the use of a topical β—adrenoceptor blocker, with or without the addition of a carbonic anhydrase inhibitor or other medications.

Some eyes required passage of the tube through a cyclodialysis cleft (*Group II:* 16 eyes, 16 patients), the passage of the tube along the cleft requiring a special 'introducer'.

In *Group III,* the drainage tube was ligated at a site near the scleral flap (34 eyes) using sutures of various types: 6/0 Collagen was used in 14 eyes and 6/0 Vicryl in 20 eyes. The configuration of the knot and the materials used were altered during the course of the study as attendant problems became evident.

Following practical experience with Group III patients, a slit 'safety valve' was incorporated on the anterior chamber side of the occlusive ligation—being created by the passage of a 27 gauge needle, bevel downwards, into the uppermost side of the silicone rubber tube (*Group IV:* 15 eyes, scleral flaps).

A one-piece valved tube and plate, the 'Joseph' tube[3], was implanted in 27 eyes (*Group V:* 17 scleral flaps, *Group VI:* 10 cyclodialysis clefts), these being presented for comparison with those other eyes receiving modifications of the Schocket procedure (Groups I to IV).

Data were analysed by use of one-way analysis of variance, Chi-squared testing and Fisher's exact test ('S').

Results

Ninety two tube and gutter operations were performed in 90 patients and 27 eyes (26 patients) received one-piece tube and plate devices: Table I shows the number of eyes within various diagnostic categories and the number of previous operations, whereas

Table I *The number of eyes within each diagnostic and operative category, together with the number of previous ophthalmic operations performed in each of the surgical groups*

Glaucoma diagnosis	Unligated: Scleral (I)	Unligated: Cyclodialysis (II)	Ligated scleral (III)	Ligated and vented scleral (IV)	One-piece: Scleral (V)	One-piece: Cyclodialysis (VI)
Congenital	2	2	7	5	6	5
Juvenile aphakic	8	3	6	1	2	1
Primary open angle	4	2	3	–	4	–
Adult aphakic	8	3	5	3	3	1
Rubeotic	1	2	5	1	1	1
Inflammatory	4	4	4	1	1	1
Others	–	–	4	4	–	1
Total	27	16	34	15	17	10
Previous glaucoma operations:						
Mean number	1.29	1.88	1.82	1.13	1.29	1.50
Range	0–3	0–7	0–5	0–4	0–5	0–3
Previous non-glaucoma operations:						
Mean number	1.37	0.56	1.08	1.53	1.23	0.41
Range	0–5	0–3	1–8	0–5	0–6	0–2

Table II summarises the age characteristics in the surgical and diagnostic categories. The number of intraocular pressure readings (IOPs) measured after surgery varies either because the patient was present but tonometry not possible because of infancy or lid swelling or because the patient was discharged at various times to the care of the referring ophthalmologist.

The mean IOPs are similar in the six surgical groups preoperatively (Table III), but are significantly different on the first ($P<0.05$)

Table II *The age characteristics (mean ± SD with range—in years) of the patients at the time of seton implantation, classified by operative group and diagnostic category*

Glaucoma diagnosis	Unligated: Scleral (I)	Unligated: Cyclodialysis (II)	Ligated scleral (III)	Ligated and vented scleral (IV)	One-piece: Scleral (V)	One-piece: Cyclodialysis (VI)
Congenital	33.5 ± 4.5	32.0 ± 5.0	19.4 ± 16.0	14.0 ± 11.9	15.5 ± 8.3	21.4 ± 5.9
	29–38	27–37	1–49	0.5–31	1–26	17–35
Juvenile aphakic	33.6 ± 15.0	39.6 ± 13.1	24.8 ± 11.9	46.0	29.0 ± 17.4	23.0
	15–51	21–51	14–48	—	17–41	—
Primary open angle	53.0 ± 5.5	60.0 ± 0.5	54.5 ± 8.5	—	35.5 ± 22.5	—
	48–62	59–61	46–63	—	14–67	—
Adult aphakic	42.6 ± 17.3	43.3 ± 10.6	51.4 ± 14.1	43.3 ± 24.6	52.3 ± 20.9	35.0
	23–63	37–56	25–66	15–75	24–74	—
Rubeotic	63.0	49.5 ± 14.5	27.6 ± 9.4	61.0	31.0	67.0
	—	35–64	21–41	—	—	—
Inflammatory	52.5 ± 3.9	40.2 ± 5.1	49.5 ± 12.0	42.0	53.0	46.0
	46–55	26–61	34–49	—	—	—
Others	—	—	45.0 ± 18.9	34.7 ± 17.2	—	13.0
	—	—	21–65	15–61	—	—
Total for subgroup	43.4 ± 15.9	43.2 ± 13.4	36.0 ± 20.2	32.5 ± 21.4	31.4 ± 21.4	29.1 ± 15.8
	15–63	21–64	1–66	0.5–75	1–74	13–67

Table III *Intraocular pressure characteristics in each of the six operative groups (I–VI): Values represent the mean and standard deviation of the intraocular pressures (mmHg) together with the range of pressure and the number of eyes available for analysis at each time. * Denotes values excluding one eye complicated by vitreous haemorrhage*

Intraocular pressures (Mean ± SD) (Range) (No. of eyes)	*Unligated*		*Ligated scleral (III)*	*Ligated and vented scleral (IV)*	*One-piece*	
	Scleral (I)	*Cyclodialysis (II)*			*Scleral (V)*	*Cyclodialysis (VI)*
Preoperative	36.4 ± 10.1	36.0 ± 10.8	39.4 ± 9.7	41.5 ± 7.8	36.5 ± 9.3	33.1 ± 10.5
	23–58	22–60	23–60	26–55	16–55	21–52
	27	16	34	15	17	10
Day 1	5.6 ± 5.5	9.4 ± 9.0	13.6 ± 13.4	12.4 ± 13.8	5.0 ± 5.2	9.1 ± 6.13
		(7.7 ± 6.5)*				
	1–19	1–32	1–50	1–42	1–18	3–21
		(1–20)*				
	22	14	31	12	14	9
		(13)*				
Day 2	6.1 ± 5.6	9.7 ± 11.9	16.8 ± 15.6	10.4 ± 13.9	6.0 ± 5.1	8.6 ± 6.2
		(7.0 ± 6.3)*				
	1–21	1–50	1–52	1–40	1–20	1–16
	25	16	29	12	16	10
		(15)*				
Day 3	7.3 ± 5.8	10.3 ± 13.7	9.4 ± 8.3	9.4 ± 13.1	6.2 ± 5.1	9.2 ± 6.0
		(7.1 ± 6.0)*				
	1–20	1–55	1–27	1–44	1–16	1–19
		(1–18)*				
	19	15	25	10	10	10
		(14)*				
Day 7	9.4 ± 6.2	8.1 ± 4.9	12.6 ± 7.7	11.1 ± 8.6	9.5 ± 6.5	12.1 ± 12.7
	1–22	1–14	1–35	4–23	1–23	1–38
	16	14	24	7	10	7
Day 28	20 ± 9.2	16.1 ± 13.6	18.3 ± 8.6	19.9 ± 1.9	16.9 ± 9.7	14.9 ± 5.4
	1–32	5–60	6–45	16–23	5–38	7–22
	25	14	29	11	12	9

and second (P<0.01) postoperative day; after the second day there was no such difference (Figs. 2, 3, 4 and 5).

Ocular hypotony was common on the first, second or third post-operative days (Table IV), exceeding 80% of eyes in Group I and V, 60% in Groups II, IV and VI and being 43% of Group III eyes (S = 0.001 compared with Gp.I and S = 0.003 compared with Gp.V). Raised IOPs (>25 mmHg) within three days of surgery occurred in 27% of ligated tubes (Group III eyes: S = 0.004 compared with Gp.I, S = 0.02 compared with Gp.V), in 14% of ligated and vented tubes (Group IV) and in none of the uncomplicated cases of unligated tubes (Groups I, II, V and VI); in five cases the ocular hypertension was such as to require operative division of the ligation (Figs. 3 and 4).

The addition of an occlusive tubal ligation raised the mean IOP significantly on the first and second days after surgery (Table III), as compared to unligated tubes in Group I (P<0.02 and P<0.01) and in Group V (P<0.05 and P<0.02); (see Figs. 3 and 5).

Venting of the ligated tubes (Gp. IV) resulted in a higher pressure (P<0.05) on the first day as compared to Group I eyes (those with unligated tubes; Table III). This procedure also reduced the incidence of ocular hypertension (2/15 (14%) eyes in Group IV in contrast to 9/33 (27%) eyes in Group III with ligated tubes); (compare Figs. 3 and 4).

The valved one-piece tube and plate (Groups V and VI) did *not* prevent early post-operative hypotony (occurring in 20 out of the 26 eyes) and, in addition, there were two cases of raised IOPs at one month after surgery (Table IV; Fig. 5).

Complications related to ocular hypotony. The incidence of anterior chamber shallowing

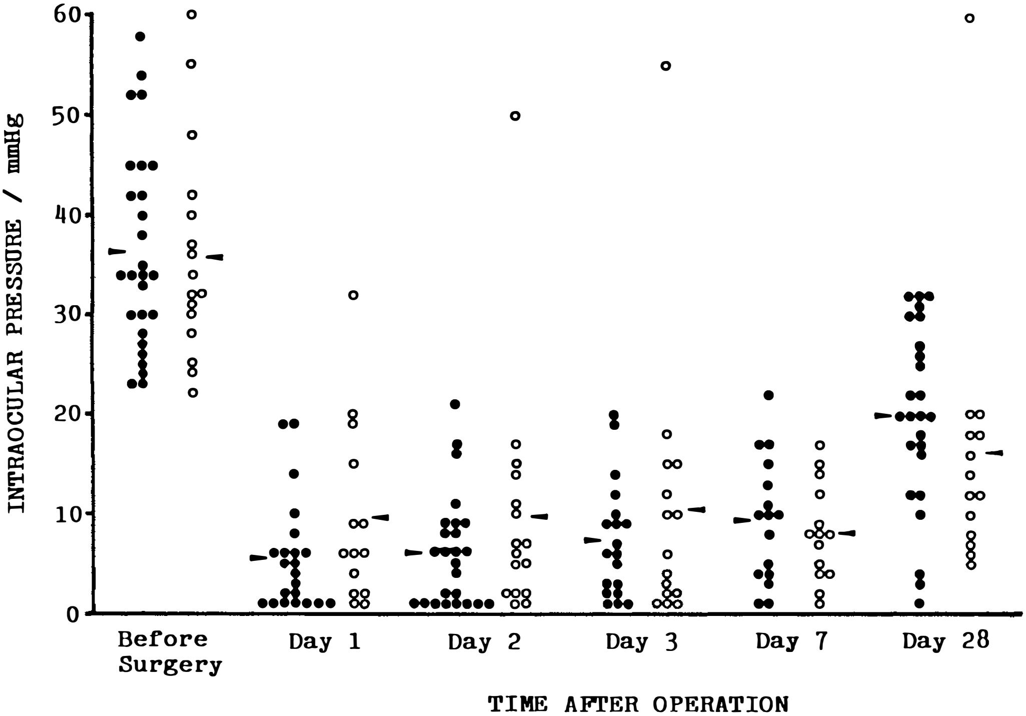

Fig. 2. *Intraocular pressures in unligated Schocket tubes passed under scleral flaps (27 eyes; closed circles) or through cyclodialysis clefts (16 eyes; open circles). Arrows denote mean intraocular pressures.*

was similar in the six groups (Table V), the tube touching the crystalline lens in two eyes or being blocked by iris (one eye) or vitreous (one eye).

Choroidal effusions, occasionally associated with serous retinal detachment, occurred in 52 of 119 (43%) eyes, the proportions in the six groups being similar (Table V). The mean reduction of IOP on the first day after surgery was similar in 45 eyes with effusion and 58 eyes without this complication (*With:* 29.1 mmHg decrease in IOP, *Without:* 27.2 mmHg drop; P>0.05), but the absolute IOPs on the first day were significantly different (*With:* Mean 6.4 mmHg, *Without:* Mean 11.9 mmHg; P<0.01).

Of the eight eyes with ocular hypotony persisting for one month or more after surgery, it is notable that seven (88%) had choroidal effusions at some time after surgery, a significantly (S<0.01) higher proportion than the ninety-four eyes without persistent hypotony in which only thirty-six (38%) had developed choroidal effusions; by implication a significant relationship between prolonged ocular hypotony and choroidal effusion, be it cause or effect.

The low incidence of choroidal haemorrhage is similar in the six treatment groups (Table V). Haemorrhage occurred by the first day in four eyes, but neither the pressure reduction on the first day, nor the absolute IOP on the first day, was atypical in these eyes (*With haemorrhage:* 34.2 mmHg IOP drop to a first day mean IOP of 4.5 mmHg in 4 eyes, *Without haemorrhage:* 27.7 mmHg IOP drop to a mean IOP of 9.6 mmHg in 95 eyes; P>0.05).

Four other eyes had choroidal haemorrhage of later onset: Three eyes with hypotony developed haemorrhage on day 1, day 3 or day 4, and one eye bled on the day of surgical release of the tubal ligation.

Miscellaneous complications

Thirteen out of 26 eyes (50%) developed hyphaema after intubation through a cyclodialysis cleft, in contrast to 8 out of 93

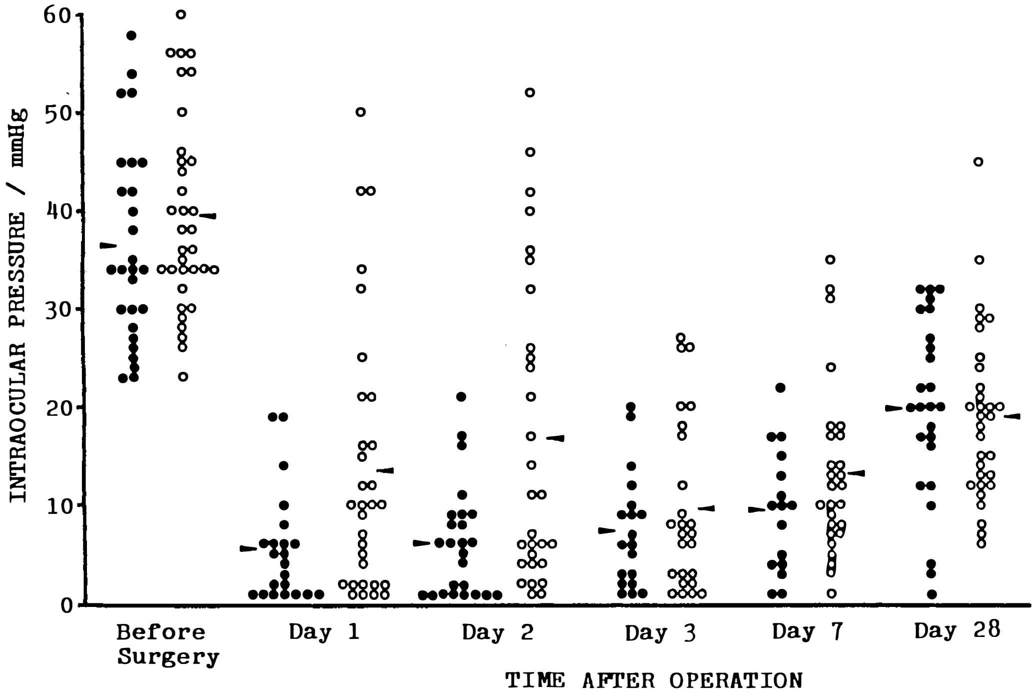

Fig. 3. *Intraocular pressures in Schocket tubes passed under scleral flaps, comparing those of unligated tubes (27 eyes; closed circles) with those of ligated tubes (34 eyes; open circles). Arrows denote mean intraocular pressures.*

(9%) eyes with scleral flaps (P<0.001) and 5 of 26 (19%) cyclodialysis implantations had tube-endothelial contact, in contrast to 2 of 93 (2%) scleral flap implantations (P<0.01).

Discussion

Although there was some variation in the frequency of the diagnoses within each surgical category, there was no evident bias in the six treatment groups with respect to aetiology of the glaucoma (Table I), the number of previous glaucoma operations (Table I) or the age of the patients (Table II). It must be recognised that some bias is inevitable with variation of follow-up, it being probable that the eyes normotensive after surgery are those most likely to be unavailable for analysis.

The results of this study show that occlusive ligation of the drainage tube and tight wound closure limits post-operative hypotony, but, in some cases, can cause ocular hypertension severe enough to necessitate reoperation. The addition of 'venting' stab incision into the tube on the anterior side of the ligation reduces this tendency to hypertension whilst causing a small increase in the incidence of hypotony.

For those eyes at particular risk of suprachoroidal haemorrhage during surgery (for example, intracapsular aphakic eyes), we recommend tight wound closure and occlusive ligation of drainage tubes (with a '3/0/0' knot configuration), the 6/0 Vicryl ligature relaxing by about four weeks after surgery and thus allowing aqueous to drain through the tube and the IOP to stabilise.

Published experience with occlusive ligation of glaucoma drainage tubes appears to be very limited: Schocket describes briefly four eyes in which the tube was temporarily ligated using 4/0 chromic sutures passed through the conjunctiva, the four eyes maintaining deep anterior chambers[7]. Molteno, Polkinghorne and Bowbyes[8] describe a series of twenty eyes in which the seton was occluded using 5/0 Vicryl ligatures, reporting good control of IOPs, without medication, in 80% of eyes at between 3 and 23 months after surgery, but not discussing in detail the early post-operative pressure changes. In our experience, liga-

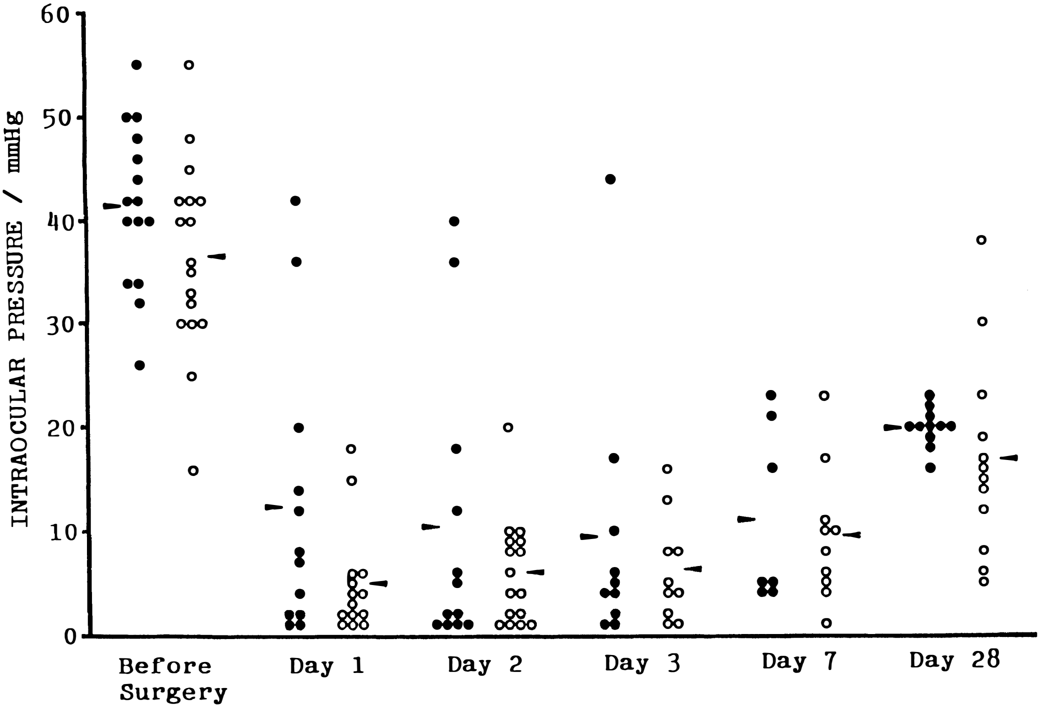

Fig. 4. *Intraocular pressures in tubes passed under scleral flaps, comparing ligated and 'vented' Schocket tubes (15 eyes; closed circles) with one-piece valved setons (17 eyes; open circles). Arrows denote mean intraocular pressures.*

tion of the drainage tube reduced significantly the proportion of eyes with early hypotony and the mean intraocular pressures on the first and second days were about 7 mmHg to 10 mmHg higher (significantly so) than that of unligated tubes.

A significant number (27%) of eyes with ligated tubes had raised IOPs shortly after surgery and five eyes required operative release. Molteno and associates record only that 'IOP was initially measured daily and any elevation treated with a combination of topical adrenaline or timolol and systemic acetazolamide as needed'[8]. The occasionally extreme postoperative hypertension (Fig. 3) was not reported by Molteno, the most probable reason for this difference being drainage of aqueous *around* the tube in the Molteno series; the tube being passed, without difficulty (Personal communication; P. J. Polkinghorne, 1987), down the track created with a *22 gauge* needle and aqueous leakage occurring at the time[8]. In contrast, it is extremely difficult to pass the tube down a 27 gauge needle track, this requiring a 'hand-over-hand' manoeuvre using two pairs of forceps and a firm eye; although passage through a 25 gauge stab is somewhat easier, such an entry site only rarely leaks and, if leakage occurs, we prevented this by placing a 'purse-string' suture.

A venting stab into the drainage tube, using a 27 gauge needle, not only reduced the proportion of eyes with early rises of intraocular pressure but also increased the incidence of hypotony, such a vent having an opening pressure of about 10 mmHg when using crystalloid fluids in air. Previous experience with a valved one-piece seton[3] suggested that it might offer some improvement over unligated two-piece systems[9], but the results during the early postoperative period were very variable in the present series.

As expected, hyphaema was commoner

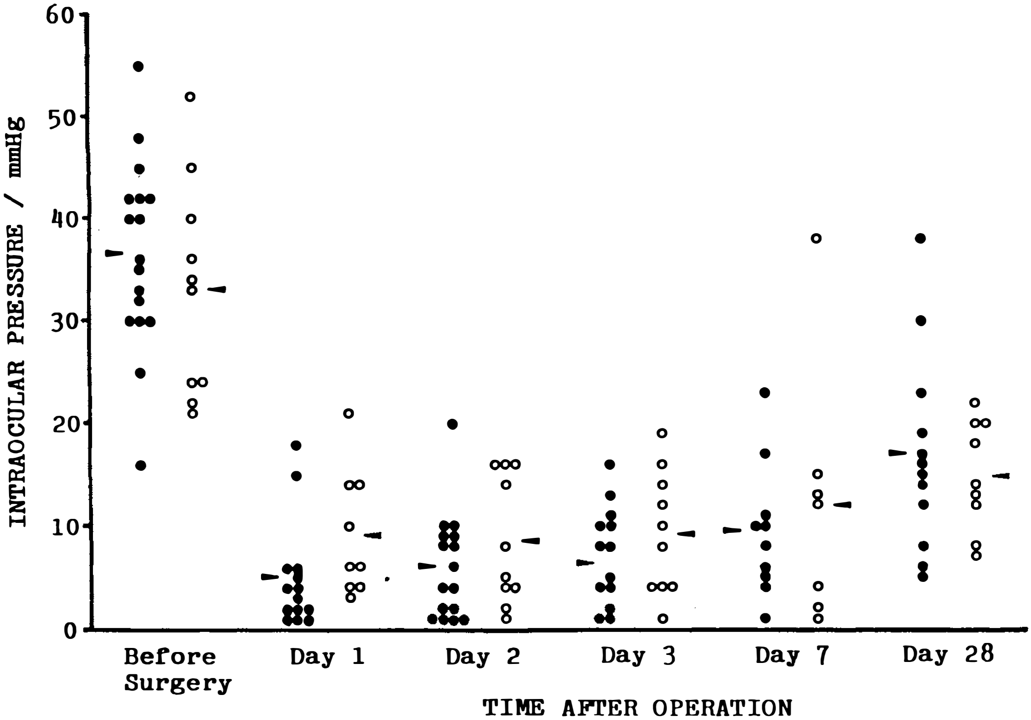

Fig. 5. *Intraocular pressures in one-piece valved setons passed under scleral flaps (17 eyes; closed circles) or through cyclodialysis clefts (10 eyes; open circles). Arrows denote mean intraocular pressures.*

with cyclodialysis cleft implantation and, with this more circumferentially directed path, tubal contact with the corneal endothelium occurred more frequently. Some choroidal effusions and the majority of choroidal haemorrhages probably begin during surgery and are an almost inevitable accompaniment to decompressive surgery in markedly diseased eyes; however, the occurrence of complications in three out of five eyes after release of the ligature suggests that ligation might reduce the late onset of such complications.

Because of the necessity to untie the ligation and the unsatisfactory IOP control in some eyes, further modifications are still required: The use of a more rapidly absorbed

Table IV *Proportion of eyes in each operative category with ocular hypotony (<7 mmHg) or raised intraocular pressures (>25 mmHg) at three times after surgery*

	Unligated		*Ligated scleral*	*Ligated and vented scleral*	*One-piece*	
	Scleral (I)	*Cyclodialysis (II)*	*(III)*	*(IV)*	*Scleral (V)*	*Cyclodialysis (VI)*
Proportion with hypotony on:						
Day 1, 2 or 3:	21/25 (84%)	10/16 (62%)	14/33 (43%)	9/14 (64%)	14/16 (88%)	6/10 (60%)
Day 7:	6/16 (38%)	5/14 (36%)	5/27 (19%)	4/7 (57%)	4/10 (40%)	3/7 (43%)
Day 28:	3/25 (12%)	2/14 (14%)	1/31 (3%)	0/11 (0%)	2/12 (17%)	0/9 (0%)
Proportion with ocular hypertension on:						
Day 1, 2 or 3:	0/25 (0%)	1/16 (7%)	9/33 (27%)	2/14 (14%)	0/16 (0%)	0/10 (0%)
Day 7:	0/16 (0%)	0/14 (0%)	3/27 (11%)	0/7 (0%)	0/10 (0%)	1/7 (14%)
Day 28:	8/25 (32%)	1/14 (7%)	6/31 (19%)	0/11 (0%)	2/12 (17%)	0/9 (0%)

Table V *The proportion of eyes in each surgical category, with post-operative complications—as recorded within one month of surgery*

	Unligated				*One-piece*	
	Scleral (I)	*Cyclodialysis (II)*	*Ligated scleral (III)*	*Ligated and vented scleral (IV)*	*Scleral (V)*	*Cyclodialysis (VI)*
Flat or shallow anterior chamber:	13/27 (48%)	6/16 (38%)	12/34 (35%)	7/15 (47%)	11/17 (65%)	5/10 (50%)
Choroidal effusions:	14/27 (52%)	5/16 (31%)	12/34 (35%)	9/15 (60%)	10/17 (59%)	2/10 (20%)
Choroidal haemorrhage:	2/27 (7%)	1/16 (6%)	1/34 (3%)	3/15 (20%)	1/17 (6%)	0/10 (0%)
Hyphaema	2/27 (7%)	10/16 (63%)	1/34 (3%)	1/15 (7%)	4/17 (24%)	3/10 (30%)

ligature (such as 7/0 Vicryl or 6/0 Fast-absorbing Catgut), the passage of a releasable occlusive ligature (10/0 nylon minimising reaction) through to the surface of the conjunctiva over the tube[7] or the use of larger gauge nylon suture material to temporarily obstruct the majority of the lumen.

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