A new implant for glaucoma

Effect of removing implants

A. C. B. MOLTENO

Department of Ophthalmology, University of the Witwatersrand, and Baragwanath Hospital, Johannesburg, South Africa

A new type of draining implant and the results of 47 operations have been discussed by Molteno (1969a). This implant consists of a translimbal tube rigidly attached to, and opening onto the external surface of a thin circular acrylic plate 8 mm. in diameter. This plate is curved to fit and is sutured firmly to sclera. When covered by a flap of conjunctiva and Tenon's capsule the plate forms the floor of a unilocular bleb in free communication with the anterior chamber, which cannot shrink to an area less than that of the plate. These implants controlled the intraocular pressure in 83 per cent. of patients with medically uncontrollable glaucoma and in all nine patients who received systemic steroids to reduce bleb fibrosis. Several of the earlier cases developed excessively fibrosed blebs, and 32 per cent. of them needed long-term local steroid medication to prevent attacks of iridocyclitis.

The removal of implants was considered because, both in the rabbit and in man, a firm fibrous bleb formed around the implant so that it could be removed after a suitable lapse of time leaving both fistula and bleb intact.

This removal would avoid corneal complications from the presence of the plastic and inflammatory reaction at points of relative movement between eye and implant (Molteno, 1969b) which might be causing continuous deposition of fibrous tissue in the bleb wall. The blebs and fistulae left on removal could be expected to persist indefinitely since they would be lined by mature fibrous tissue which had already passed the stages of early contraction and late cicatrization (Walter and Israel, 1965), during which shrinkage had been forcibly prevented by the implants. Furthermore, the large diameter and unilocular nature of the blebs would result in a given intraocular pressure exerting a far larger force stretching the bleb wall than would be the case with a smaller bleb, since the force stretching the wall of a vesicle is equal to the pressure within multiplied by its radius of curvature (Young, 1805; Laplace, 1807).

The implants were accordingly removed from nineteen eyes. In three eyes (Cases 7 and 8) implants of Perspex were removed because they caused intractable uveitis; in one case a Stellan implant was removed because the bleb became overfibrosed and the glaucoma remained uncontrollable. In the remaining fifteen eyes, Stellan implants were removed in an attempt to improve adequate drainage and obviate the need for long-term local steroid medication. The surgical techniques used for removal and the results obtained are the subject of this communication.

Design of clinical trial

Patients with advanced glaucoma, in whom the visual acuity had fallen to 6/60 or less, were admitted to hospital for full evaluation and a trial of medical therapy. Those in whom the intraocular pressure could not be reduced to 20 mm. Hg had implants inserted. In most cases they remained in hospital until the removal of the implants between 5 weeks and 7 months later. Those discharged from hospital were readmitted for evaluation of their condition before the implant was removed. After the removal they remained in hospital for between 6 weeks and one year, after which they were followed as outpatients.

Diagnosis and evaluation

All cases were examined by the author and underwent a full ophthalmic examination, including applanation tonometry, tonography, and gonioscopy.

The trial of medical therapy lasted at least 7 days. The following dosages were used:

- (1) Diamox 250 mg. four times a day with potassium supplement
- (2) Glycerol 150 ml. four times a day for up to 2 weeks
- (3) Gutt. Epitrate 2 per cent. four times a day
- (4) Gutt. Phospholine iodide 0.06–0.125 per cent. or, if tolerated, Gutt. Tosmeline 0.25–0.5 per cent.

Follow-up

During hospitalization, the patients were seen daily and had at least weekly slit-lamp examinations with applanation tonometry. At outpatient visits applanation tonometry and slit-lamp examination were routine and tonography was performed at longer intervals to confirm that the changes observed in the intraocular pressure were actually due to changes in outflow.

Methods used

The intraocular pressure was measured with a Goldmann applanation tonometer fitted to a Haag-Streit 900 slit lamp. Tonography was carried out for 4 minutes using a Schwartzer electronic tonometer with continuous strip recorder (both instruments were regularly checked using the calibration standards provided by the makers).

Surgical techniques

TIME OF OPERATION

It was soon discovered that at least 3 months' delay after the insertion of an implant was needed for a firm bleb to form. Removal before 3 months (Cases 5, 6, 7, 12, and 13) gave relatively poor results, while accurate watertight closure of the incision into the bleb was very difficult. Therefore most implants were removed between 3 and 7 months after insertion, but there was no technical advantage in waiting more than 4 months as they attained their greatest thickness by the end of the third month.

ANAESTHESIA AND HYPOTONY

General anaesthesia was preferred but when it was not available, local anaesthesia and akinesia were used as for a cataract extraction. Hypotony was produced either by intravenous infusion of 10 per cent. Mannitol solution or by the administration of 500 mg. Diamox and 150 ml. glycerol by mouth.

STEPS IN SURGICAL TECHNIQUE

- (1) Exposure of the bleb was provided by a speculum and a superior rectus stitch carefully inserted to avoid the bleb.
- (2) A circumferential conjunctival incision was made 3 mm. behind the bleb and its limbal edge was retracted to expose the posterior edge of the bleb.
- (3) After all bleeding points had been lightly cauterized a Bard-Parker knife was used to make a single clean incision into the bleb cavity. This incision was placed 1 mm. anterior to the posterior edge of the inner fibrous bleb and carried across the full width of the episcleral plate.
- (4) The posterior stitch holding the implant to the sclera was cut and an iris reposer was used to ease the posterior edge of the episcleral plate away from the bleb cavity.
- (5) The two anterior sutures holding the implant to the sclera were cut by sliding a Tooke's knife forward between the episcleral plate of the implant and the sclera. The implant was then grasped with a pair of toothed forceps and gently removed (Fig. 1).

FIG. 1 *Removing implant from bleb* FIG. 2 *Bleb cavity lined by fibrous tissue.*

- (6) A sliver of tissue comprising the full thickness of the bleb wall together with overlying conjunctiva was removed from the anterior lip of the incision, using curved scissors; a watertight closure of the inner fibrous layer of the bleb was then effected by five or six interrupted edge-to-edge sutures of 7·0 silk and the anterior chamber was re-formed by injecting a medium-sized air bubble into the bleb (Fig. 2).
- (7) The conjunctiva was closed by a continuous suture of 7·0 silk and the operation was completed by the injection of Lincomycin with Depo-Medrol beneath the conjunctiva in the quadrant opposite the bleb.

During the removal of the implant the utmost care was taken to avoid stretching or otherwise injuring the inner fibrous layer of the bleb. In two cases, part of the bleb was lifted from the sclera, so demonstrating that the attachment of bleb to sclera formed a plane of weakness.

POSTOPERATIVE CARE

All eyes were single-padded for 24 hours, after which the patients were allowed up, wearing dark glasses. Gutt. Sofradex and gutt. Phenylephrine 10 per cent. were given until the eyes became quiet after 2 to 4 weeks. One patient (two eyes), a 15-year-old girl (Case 14), received systemic steroids for 4 months after the implants were removed in order to suppress fibrous tissue activity in the blebs. Two patients (three eyes) in whom Perspex implants excited a severe uveitis (Cases 7 and 8) received systemic steroids for 6 weeks and 7 months respectively after the removal of the implants.

OPERATIVE AND POSTOPERATIVE COMPLICATIONS

In this small series of nineteen operations for removal of implants no operative complications were encountered. The only postoperative complications occurred in Case 2 (two eyes) in whom malignant glaucoma developed 4 days and 7 months respectively after removal of the implants. The attacks occurred 3 days apart a week after the patient had finished a 7-day course of Orenzyme which had been given to determine whether it would improve drainage. In both eyes the glaucoma was successfully treated by withdrawing fluid posterior vitreous through a pars plana incision, combined with re-formation of the anterior chambers by means of air inserted through a single-thrust cyclodialysis. Both anterior chambers remained deep and drainage was re-established and has persisted in both eyes for a year since these episodes.

Results

BLEB BEHAVIOUR AFTER REMOVAL OF IMPLANT

In the immediate postoperative period, except for the three eyes in which Perspex implants had been used (Cases 7 and 8) the eyes remained quiet with a mild inflammatory reaction along the suture line. The blebs were all distended while the intraocular pressures rose within 10 days to the levels present immediately before removal of the particular implants. At this stage aqueous could easily be displaced from eye to bleb and *vice versa* (Fig. 5, below).

After 1 to 4 months, the blebs showed definite changes, either increasing in area with an associated fall in intraocular pressure or starting to shrink with an associated rise in intraocular pressure. (Bleb spread occurred in the eight patients aged 50 years or more when 3 or more months had passed between insertion and removal of implants (Table I)).

Table I Results in eight patients over 50 years old (eleven eyes)

Case No.	Age (yrs)	Sex	Diagnosis	+ or - 3 mths before removal (months)	Total follow-up	Intraocular Pressure (mm. Hg)	
						Before removal	Final
1	53	M	Primary glaucoma	+	19	23.1	8
2 R	79	M	Primary glaucoma	+ } Malignant glaucoma	20	18.5	19
L	79	M	Primary glaucoma		25	37	20
3	78	M	Primary glaucoma	+	7	23	75
4	61	M	Primary glaucoma	+	4	24	16
5 R	65	M	Primary glaucoma	-	17	16.5	19
L	65	M	Glaucoma secondary to trauma	-	16	18	11
6	67	M	Primary glaucoma	-	22	17	22
7 R	53	M	Primary glaucoma	- } Perspex Uveitis	20	28	12
L	53	M	Primary glaucoma		20	26	12
8	50	F	Primary glaucoma	+	6	32	25
Range	50-79				4-25	16.5-37	7.5-25
Mean	64				16	23.9	15.6

Bleb shrinkage occurred in six out of the eight eyes belonging to the six patients less than thirty years old, and in all cases in which the implants were removed before 3 months had elapsed (Table II).

Table II *Results in six patients under 30 years old (eight eyes)*

Case No.	Age (yrs)	Sex	Diagnosis	+ or - 3 mths before removal	Total follow-up (mths)	Intraocular pressure (mm. Hg)	
						Before removal	Final
9	25	F	Primary glaucoma	+	31	20	35
10	16	F	Glaucoma associated with Sturge Weber syndrome	+	29	26	38
11 R	4	F	Buphthalmos	+	19	14.6	43
L	4	F	Buphthalmos	+	19	25.8	43
12	22	F	Primary glaucoma	-	12	25	20
13	29	M	Glaucoma secondary to old perforating injury	-	15	30	42.5
14 R	14	F	Primary glaucoma	+ } Steroids	13	22	20
L	14	F	Primary glaucoma	+ } Steroids	13	22	15
Range	4-29				12-31	14.6-30	15-43
Mean	16				18.8	23.2	32

The only exceptions to the above rules were a 50-year-old woman (Case 8) with Perspex uveitis in whom bleb shrinkage occurred and two eyes in a 15-year-old girl (Case 14) who was given large doses of systemic steroids for 4 months and in whom both blebs extended in area.

BLEB SPREAD (Fig. 3)

Where this occurred, the sharply demarcated fibrosed and elevated bleb, which remained after removal of its contained implant, gradually flattened and spread posteriorly and circumferentially while becoming less fibrosed.

FIG. 3 *Bleb spread: Appearance of bleb 3 months after removal of implant*

Ultimately (after $1\frac{1}{2}$ to 3 months) a large area, sometimes a whole quadrant, became covered by the bleb which consisted of well-vascularized but oedematous conjunctival and episcleral tissue. On massage of the globe this heaped up slightly and extended peripherally.

Gonioscopy of these eyes showed at first an open fistula where the translimbal tube had been but, by the end of the third month after removal, all those fistulae which could be clearly seen had become filled by a delicate network of fibrous tissue. During this period of spread, the intraocular pressure gradually fell to a stable level of between 7.5 and 20 mm. Hg approximately 3 months after the removal of the implant.

Drainage Routes Observed

In most cases in which the bleb had spread, the obvious oedema of the episcleral tissues suggested that most aqueous escaped from the bleb *via* the subconjunctival lymphatics. However, several blebs showed signs of transconjunctival drainage: both localized thin areas with a positive Seidel sign and diffuse areas where oedema of the episcleral tissues involved the conjunctiva so that numerous tiny microcysts formed in the epithelium on massage of the eyes. In two cases prominent aqueous veins formed in addition to the routes described above.

Although one of the blebs was found to be grossly overfibrosed on removal of the implant, all blebs which spread gradually lost their fibrosed walls and ultimately (after more than a year in one case) all signs of fibrous tissues having been laid down had vanished.

BLEB SHRINKAGE (Figs 4 to 7)

This occurred in all six patients less than 30 years old who did not receive systemic steroids. The sharply-defined, well-vascularized, fibrosed and heaped bleb which remained after removal of the implant remained unchanged for several weeks, and then slowly shrank over a period of up to 18 months to leave a small nubbin of heavily-fibrosed conjunctiva over the fistula. Gonioscopy showed that the fistula became filled with a tenuous network of fibrous tissue, which gradually became denser and ultimately consolidated to leave merely a dimple in the sclera to mark the site of the fistula.

FIG. 4 *Bleb shrinkage: Appearance of bleb 4 months after insertion of implant and shortly before removal*

FIG. 5 Same bleb as in Fig. 4, 1 week after removal of implant

FIG. 6 Same bleb as in Fig. 4, heavily fibrosed and shrinking 4 months later

During the period of shrinkage, the intraocular pressure rose steadily until as the bleb disappeared the preoperative level was regained. Once all drainage had ceased the fibrosed nubbin became thinner and less fibrosed until it had reverted to the appearance of normal conjunctiva between 6 and 12 months later.

Drainage Routes Observed

Virtually no drainage of aqueous was observed from shrinking blebs, apart from a minimal amount of transconjunctival drainage over the fistulae when the blebs were almost obliterated and the intraocular pressure markedly raised.

FIG. 7 Same eye as in Figs 4 to 6, 27 months after removal of implant, showing reversion of bleb to normal conjunctiva. A second implant has been inserted in the nasal quadrant.

In all cases except those with Perspex uveitis, the eyes remained quiet and by the fourth week after removal topical steroids and mydriatics were discontinued. One patient (Case 1) developed a mild iritis 10 months after removal of the implant; this was treated with steroid and cycloplegic drops, responded rapidly, and has remained quiet without medication during a further year of follow up.

EFFECT OF EARLY REMOVAL ON TENDENCY TO IRITIS

When implants were removed before the end of the third month, the behaviour of the eye varied according to the age of the patient. In those over 50 years old the blebs persisted but were smaller and less adequate than those which remained after the implants had been left *in situ* for 3 months or more.

In the group under 30 years old there were only two cases of early removal. In one the bleb became obliterated within 8 weeks of removal, and in the other rapid shrinkage occurred but the bleb "roof" became ischaemic and transconjunctival drainage was established and has persisted.

Discussion

In the elderly the effect of removing the implant was to maintain or reduce the pre-removal intraocular pressure and to eliminate the need for long-term steroid medication. Removal after 3 months uniformly resulted in a large, flat, thick-walled, moderately-vascular bleb, which extended in all directions on massage of the eye. This type of bleb is safe and permanent and always drains well (intraocular pressure 7.5–20 mm. Hg; C values 0.20–0.46).

In young patients removal, even when delayed for several months, resulted in a higher intraocular pressure in every case, except where systemic steroids were given to the limit of tolerance for 4 months after removal. Good drainage was obtained in this particular case, with flat extensible "permanent" type blebs, but it is not safe to give steroids in this manner as a routine.

Although the results are based on small numbers of cases, the effect of age on bleb behaviour was so marked that the removal of implants in patients less than 50 years old seems to be contraindicated. Young patients fortunately tolerate implants very well.

In the elderly, removal gives an ideal result, but the reason why there should be this marked difference between the age groups is not immediately obvious.

The overall results of insertion followed by removal were:

- (1) Control of intraocular pressure without medication: twelve cases (9 over 50 years)
- (2) Control of intraocular pressure with medication: one case (over 50 years)
- (3) Failure: six cases (5 under 30 years).

POSSIBLE CAUSE OF BLEB SHRINKAGE IN THE YOUNG

The persistent vascularity and increasing fibrosis of shrinking blebs in young patients was associated with markedly raised intraocular pressures, but was followed by complete disappearance of the heavily-fibrosed bleb wall once all drainage of aqueous had ceased. This behaviour suggested that in these cases the aqueous exerted an irritant effect on the bleb wall. Epstein (1959) demonstrated histologically that the aqueous from an eye with absolute glaucoma had a fibrosing effect on the episcleral tissues, which caused failure of a seton operation in approximately 4 weeks. There is no direct evidence of the nature of the irritating factor, but ischaemia of any tissue results in the release of vasodilating factors while necrosis and autolysis of tissue releases factors which excite an acute inflammatory response followed later by fibrosis (Walter and Israel, 1965).

In these cases with nearly absolute glaucoma the pressure had been reduced by the initial insertion of the implant and in three cases in young patients the pressure had been below 30 mm. Hg for between 4 and 6 months, making it seem unlikely that tissue breakdown products from the intraocular structures would persist so long. However, in cases of rubeosis iridis, there is generally a lapse of several months between central vein occlusion and the onset of neovascularization. In this condition, a vasoformative factor produced by destruction of intraocular structures was postulated by Smith (1955, 1961), Ashton (1961), and Sanders (1961) as the cause of the neovascularization. The persistence of this factor months after the occlusion suggests that the "Epstein factor" could likewise persist for several months after normalization of the pressure and could be responsible for the fibrosis which obliterates the blebs, and that both factors have a common origin in destruction of intraocular tissue.

In older patients the glaucoma was equally advanced, but because aged tissues respond less actively to all stimuli the fibrosing response of the bleb walls was insufficient to raise the intraocular pressure or contract the blebs, and the blebs therefore remained until all tissue breakdown products had been eliminated, after which gradual loss of fibrous tissue occurred. The loss of fibrous tissue in these cases could be a manifestation of the degenerative action of normal aqueous on the episcleral tissues described by Teng, Chi, and Katzin (1959), but that it is not the only process leading to loss of collagen is shown by the defibrosis which occurred in shrunken blebs after all drainage of aqueous had ceased.

INDICATIONS FOR REMOVAL OF IMPLANTS

Since the initial publication of the results obtained by inserting implants (Molteno 1969a,b) the number of such operations has risen to eighty. The more recent cases have confirmed

the value of systemic steroids in avoiding overfibrosis of the blebs and eliminating late postoperative iridocyclitis. Thus, at present, the author routinely inserts implants under steroid cover and leaves them in. Removal is helpful in elderly patients to whom systemic steroids cannot be given for medical reasons, in elderly patients who live so far away that supervision is impossible, and to forestall perforation of a bleb if the implant has been incorrectly inserted. If guided by these indications removal will increase the usefulness of implants and further improve the overall results.

Summary

- (1) The theoretical advantages of removing the author's glaucoma implants after a suitable period are stated.
- (2) The surgical techniques for removal are described and the results obtained in a series of nineteen removal operations are reported.
- (3) The effect of the patient's age on the results is stressed and a possible causative mechanism discussed.
- (4) The present indications for removing an implant are given.

I wish to thank Prof. M. H. Luntz for his help and encouragement. My thanks are due to the Superintendents of Baragwanath Hospital and St. John's Eye Hospital for their co-operation and assistance. This work was assisted by grants from the University of the Witwatersrand and the Council for Scientific and Industrial Research.

References

- ASHTON, N. (1961) *Trans. ophthal. Soc. U.K.*, **81**, 145
- EPSTEIN, E. (1959) *Brit. J. Ophthalm.*, **43**, 641
- LAPLACE, P. S. (1807) "Traité de mécanique céleste (Supplément au X^e livre), i.e. Supplément à la théorie de l'action capillaire." Courcier, Paris
- MOLTENO, A. C. B. (1969a) *Brit. J. Ophthalm.*, **53**, 606
- (1969b) *Ibid.*, **53**, 161
- SMITH, R. (1955) "XVII Conc. Ophthalm., 1954. Canada, U.S.A. Acta", vol. 2, p. 1164
- SMITH, R. (1961) *Trans. ophthal. Soc. U.K.*, **81**, 125
- SANDERS, A. G. (1961) *Ibid.*, **81**, 125
- TENG, C. C., CHI, H. H., and KATZIN, H. M. (1959) *Amer. J. Ophthalm.*, **47**, 16
- WALTER, J. B., and ISRAEL, M. S. (1965) "General Pathology," 2nd ed., pp. 112, 151, 755. Churchill, London
- YOUNG, T. (1805) *Phil. Trans. roy. Soc. Lond.*, **95**, 65