Chapter 11

Update on Tube-Shunt Procedures for Glaucoma

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Core Messages

- Bleb formation depends on proinflammatory substances in the aqueous, as well as tissue reaction, both of which can be controlled.
- Management of aqueous flow to the plate surface, and elimination of Tenon's capsule from the bleb, can help with the development of a functional bleb.
- Both valved and non-valved implants can be used to control hypotony, the latter by various methods of tube occlusion.
- Plate size does not seem to make a difference in IOP control in long-term studies.
- Supra-Tenon's placement of the implant is a method that can be used to control bleb fibrosis.
- Corneal graft survival is decreased in eyes with glaucoma implants.
- In neovascular glaucoma, while pressure control may be successful early, long-term results are poor as a result of the underlying disease.
- Motility disturbances are more common with Baerveldt glaucoma implants.
- Bleb fibrosis remains the main cause for glaucoma implant failure.

1976 [31]. The most commonly used implants include Molteno and Ahmed single- and double-plate implants, and the Baerveldt and Krupin implants. All implants are long-tube implants based on the original Molteno design. The Ahmed and Krupin implants are valved implants. The most recent addition to tube-shunt devices has been the Ex-Press shunt, a non-valved flow restricting implant made of stainless steel, which is discussed later. The basic concept of the long-tube implants is the creation of a filtering bleb over the distal plate.

11.1.2 Bleb Physiology

Epstein [12] showed that when aqueous comes into contact with conjunctiva and Tenon's capsule, an inflammatory reaction occurs, due to the contents of the glaucomatous aqueous. Subsequently, these factors have been identified and amongst other components, such as prostaglandins, and various eicosanoids, tissue growth factor-beta (TGF-β) has been shown to occur in glaucomatous aqueous [43]. TGF-β is strongly proinflammatory, and when glaucomatous aqueous comes into contact with subconjunctival tissue, it induces an inflammatory reaction, and if excessive, will result in bleb fibrosis and poor functioning of the filtering bleb. High pressure within the bleb results in the secretion of TGF-β by the bleb lining [17]. The higher the pressure within the bleb, the greater the amount of TGF-β is formed, resulting in inflammation of the bleb wall and subsequent fibrosis and poor bleb function; therefore, the higher the pressure within the bleb, the less likely the development of a good filtering bleb, this having significance when dealing with the hypertensive stage of the bleb which occurs 4—6 weeks after implantation in most cases.
Molteno et al. have described the histopathology of Molteno implant capsules in cases of primary and secondary glaucoma [35]. Without aqueous flow (first stage of a two-stage operation), the episcleral plates of Molteno implants were encapsulated by a very thin (20–60 μm) avascular collagen layer. The second stage of a two-stage insertion, with delayed drainage of aqueous and early temporary postoperative intraocular pressure (IOP) increase to 25–35 mmHg, produced thin (190–250 μm), permeable capsules with fewer fibrovascular than fibrodegenerative components. Insertion of nonligatured implants with immediate aqueous flow produced thicker capsules (300–600 μm) composed of an outer fibrovascular layer and an inner fibrodegenerative layer of approximately equal thickness. Three stage insertion of modified Molteno implants with postoperative IOP not exceeding 12 mmHg produced the thickest, most heavily fibrosed, and impermeable capsules composed entirely of dense fibrovascular tissue without a fibrodegenerative layer. Molteno concluded that without aqueous flow, the episcleral plate of the implant stimulates encapsulation by a thin avascular collagenous layer. With aqueous flow, an immediate inflammatory reaction develops in the episcleral connective tissues that include collagenous and vascular components. After a variable delay, a fibrodegenerative process develops in the deeper layers of the capsule, which is maintained by activation, migration, apoptosis, and production of death messengers by mesodermal cells. The fibrodegenerative process may depend on sufficient increases of IOP for aqueous to displace interstitial fluid from the deeper layers of the capsule. The final thickness of the capsule depends on the timing of these opposing processes which can be influenced by surgical technique and postoperative medications.

The understanding of bleb physiology has important significance as to the ultimate functionality of the bleb.

11.1.3 Therapeutic Options Related to Bleb Physiology

The components of the bleb that can be affected therapeutically are the aqueous and the tissue lining the bleb. This can be achieved by medical or surgical options, or a combination of both.

11.1.3.1 Medical Control of Bleb Fibrosis

Molteno recognized the need to suppress the inflammatory reaction over the plate in order to obtain a functioning bleb, and described the use of both topical and systemic anti-inflammatory medications [32, 33]. The topical regimen consisted of phenylephrine drops 0.5%, topical steroids, and atropine, used for 4–6 weeks. The systemic group consisted of prednisone 5 mg tid, diclofenac 50 mg tid, and colchicine 0.2 mg tid for 4 weeks. The disadvantages of the systemic regimen are potential side effects of the medications used. The use of topically applied mitomycin C, to prevent bleb fibrosis in glaucoma implant surgery, has been shown in most reported studies to be ineffective [2, 25].

11.1.3.2 Surgical Options for Control of Bleb Fibrosis

The surgical options consist of managing the "glaucomatous" aqueous and the tissue over the plate. The initial aqueous contains proinflammatory substances, which must be prevented from reaching the surface of the plate and thereby reacting with the overlying tissue. This can be achieved by blocking the tube with a releasable stent for a period of 10–14 days. During this time the IOP needs to be normalized resulting in the elimination of the "glaucomatous" aqueous and its proinflammatory contents. This lowering of IOP can be achieved by both the effect of the shock of the surgery and the use of anti-glaucomatous medications. Allowing "glaucomatous" aqueous to reach the plate results in a more intense hypertensive phase, and subsequently a less functional bleb, as has been reported with the use of valved implants [36].

The tissue component of the bleb may also be modified surgically. The tissue most responsible for the ultimate formation of the bleb is Tenon's capsule. In patients who have demonstrated a tendency to excessive fibrosis, as seen by previ-
ously failed filtering surgery, or glaucoma implants, Tenon's tissue may be eliminated by the placement of a subsequent glaucoma implant between Tenon's capsule and the overlying conjunctiva [15]. This technique is described later.

Summary for the Clinician

- Understanding bleb physiology plays an important role in achieving a functioning bleb. The discovery of proinflammatory components of the aqueous has highlighted the important role of aqueous control in developing a successful bleb. The combination of topical and systemic anti-fibrotic medication can result in less bleb fibrosis. Management of aqueous flow to the plate surface, and elimination of Tenon's capsule from the bleb, can help with the development of a functional bleb.

11.2 Indications for Implant Use

Initially the implants were used predominantly in those cases where previous glaucoma surgery had failed, as well as in cases known to do poorly with conventional glaucoma surgery. The latter group included: uveitic glaucoma; aphakic and pseudophakic glaucoma; neovascular glaucoma; glaucoma associated with corneal transplants; and congenital glaucoma with iridocorneal dysgenesis. With the advent of the use of antimetabolites in glaucoma surgery, many of the conditions mentioned in this group are now treated with conventional surgery first. Exceptions include neovascular glaucoma, extensive scarring of the conjunctiva, congenital glaucoma with iridocorneal dysgenesis, aphakic glaucoma, and glaucoma associated with corneal transplants, all of which do better with glaucoma implants.

11.2.1 Which Implants to Use

The choices are valved or non-valved, and size. The two implants used that are valved are the Ahmed and Krupin implants. The major advantage of the valved implant is less postoperative hypotony, in most cases. Disadvantages include valve blockage, occurring early or late following implantation. Both circumstances result in a failure of aqueous drainage. The valve systems of the Krupin and Ahmed devices are designed to open at 11 and 8 mmHg, respectively; however, this is not always the case, and hypotony can still occur with these valved implants. Another disadvantage of valved implants is a more intense hypertensive phase and subsequent thicker bleb with less pressure lowering [36].

The Molteno and Baerveldt implants are non-valved. The major disadvantage is hypotony in the immediate postoperative period, but this has been largely eliminated by occluding the tube in the immediate postoperative period. This occlusion has been achieved in a variety of ways, all of which allow the opening of the tube to be facilitated at a later time, when a fine capsule has already formed over the plate, eliminating hypotony when aqueous reaches the plate surface [11, 23, 38]. This also allows normal aqueous to reach the plate surface, resulting in a decreased hypertensive phase and a thinner, more functional bleb.

11.2.2 Significance of Plate Size

The use of double-plate implants and different-size single-plate implants was based on the concept that a larger plate area resulted in greater pressure lowering. This original concept was proposed by Molteno [30], and subsequent reports confirmed this observation [19]. Based on the concept that a larger surface was better, the double-plate implant became more used than the single plate, and larger single plates were developed, such as the various-sized Baerveldt implants. These larger-sized single-plate implants became more popular because surgical implantation is easier when compared with double-plate implants; therefore, the advantages and disadvantages of large single-plate and double-plate implants need to be examined.

The main advantage of the double-plate implant is that egress of aqueous to either plate can be controlled, by ligating the connecting tube;
thus, controlling the flow of aqueous to each plate independently can prevent excessive hypotony. This cannot be done with large-size single plates, and the larger the plates the more likely the occurrence of hypotony and associated complications such as suprachoroidal hemorrhage. This has been reported to occur with the large-surface, 500-mm Baerveldt implant [6]. The disadvantages of the double-plate implants are difficulty of insertion, and if failure occurs, the upper quadrants are no longer available for further drainage surgery or implant use.

The main advantage of the single plate is ease of insertion.

One of the disadvantages of the large single-plate implants is the development of motility problems. Several clinical studies have found that a high incidence of motility problems may occur in patients after implantation of the Baerveldt implant [3, 41, 42].

The question to be asked therefore is whether the pressure lowering obtained by the larger surface implants outweighs the various complications associated with these implants. Brit et al. [6] found no difference in the reduction of IOP between 350- and 500-mm Baerveldt implants, a finding confirmed by Stegner et al. [41]. Molteno et al. reported no significant difference between single- and double-plate implants in the control of pressure in a series of patients followed for 20 years [34].

A recent study comparing the device with the smallest surface area, the single-plate Molteno (surface area 130 mm²), to the device with the largest surface area, the Baerveldt (350 mm²), was unable to show any statistical difference in any of the parameters tested [1]. These conclusions were supported by recent studies with long-term follow-up, which included a comparison of single- and double-plate Molteno implants [16, 34].

Mills et al. [29] reported a qualified success rate of 57% at 44 months, using single- or double-plate Molteno implants. They further reported that these implants fail at a rate of 10% per year resulting in a 50% failure rate at 5 years; thus, although some increased reduction of IOP occurs with larger surface implants, certainly in the short term, this advantage seems not to outweigh the potential complications associated with the larger surfaces.

The use of smaller surface implants, i.e., single-plate Molteno implants, with tissue modification, such as supra-Tenon’s placement, may achieve a comparable pressure-lowering effect as that obtained with the larger surface implants, but with the advantage of a lesser incidence of complications, and with preservation of one of the upper quadrants for further glaucoma surgery, should it become necessary.

Hong et al. [20] attempted to answer three important questions through a review of the literature:
1. Do all the glaucoma implants lower the pressure, irrespective of their design?
2. Do larger implants lower the IOP more than smaller ones?
3. Does the design of the implant influence the complications, mainly hypotony and diplopia?

Fifty-four articles were included in their final analysis. The overall surgical success rate averaged between 72 and 79% among the five devices, i.e., Molteno single and double plate, Ahmed, Baerveldt, and Krupin implants. No statistical difference was found among the different devices in this meta-analysis. Within the Molteno group, the double-plate Molteno achieved the highest success rate, but this was only over a 12-month follow-up, whereas the other groups were followed for longer durations. All five implants significantly decrease the IOP ($p<0.001$). The percentage change was between 51 and 62%. The amounts were similar among the five implants after controlling for preoperative IOP ($p=0.27$). No difference in percent change was found within the Molteno group ($p=0.58$). There were no statistically significant differences in either the percentage change in IOP or the overall surgical success rate among the five implants, or within the subdivisions of the Molteno group based on the size of the end plate [7].

There were no statistically significant differences among the implants in the overall incidence of transient hypotony in the immediate postoperative period ($p=0.17$), chronic hypotony ($p=0.51$), suprachoroidal hemorrhage ($p=0.47$), or in the decrease of visual acuity after the surgery ($p=0.90$). The Molteno implant with modified technique to prevent hypotony had the lowest incidence of transient hypotony (12%),
followed by the Ahmed valve (14%) and the Baerveldt (15%). The Molteno implant without any surgical modification to prevent hypotony had a statistically higher rate of hypotony (26%) compared with the Ahmed implant (p = 0.04), but this was not statistically different compared with the Krupin implant. All five devices significantly reduced the number of medications in the postoperative period (p < 0.01).

The occurrence of diplopia was significantly higher with the Baerveldt implant (9%) compared with the Ahmed (3%), the Molteno implant with ligature (2%), (p < 0.01), or the Krupin implant. There was no mention of diplopia in any of the articles with the Molteno implant without the modified technique.

The overall success rate of all the implants appears to be very similar in controlling IOP and preserving vision in intractable cases of glaucoma. The double-plate Molteno had the highest success rate at 91%. This was after a 12-month follow-up, whereas the other groups were followed for a longer period (22–26 months). The success rate would probably have been similar to other devices if the double plate had been followed for a longer period, as was actually reported by Molteno et al. in a study over 20 years [34]. The life-table analysis comparing the double-plate Molteno with the Ahmed implant, by Ayala et al. [1], showed that the success rate decreases by 10–15% every year in the first 3 years. All these findings suggest that a larger end plate does not statistically lower the IOP more than standard-size single plates when followed over a long period, i.e., more than 1 year.

11.3 Surgical Techniques for Tube-Shunt Implantation

Molteno’s original description of implantation of the Tube shunt utilized a subscleral tunnel for the management of the silicone tube [31]. This has been replaced, by and large, by the introduction of the scleral patch graft, and subsequently other materials such as pericardium and dura, to cover the tube without an associated scleral tunnel [5, 13]. The advantage of using a patch was that full-thickness sclera was less likely to erode than a partial-thickness scleral covering obtained with the scleral-tunneling technique. The suturing of the patch over the tube also tends to direct the tube away from the corneal endothelium. The introduction of larger, single-plate implants, such as the Baerveldt and Ahmed implants, has resulted in lesser use of the double-plate implants, which require a more complicated surgical procedure.

One of the more recent surgical modifications of tube-shunt implantation is the placing of the shunt in a supra-Tenon’s pocket [15]. This technique is used in patients where there has been a failure of a previous glaucoma procedure or implant insertion, the failure being due to excessive bleb fibrosis. These patients have a strong fibrotic reaction to surgery, and need to have Tenon’s capsule eliminated from the ultimate bleb formation.

11.3.1 Technique for Supra-Tenon Placement of a Single-Plate Molteno Implant

 Conjunctiva and Tenon’s capsule are elevated at the limbus by injection of balanced salt solution (Fig. 11.1). A limbal incision through conjunctiva alone is made with a Bard Parker number-15 blade. Conjunctiva is then separated from underlying Tenon’s capsule (Fig. 11.2). A small relieving incision is made laterally or medially, depending on the quadrant selected for the insertion, allowing conjunctiva to be dissected posteriorly off the underlying Tenon’s capsule. A pocket for the Molteno implant is then made by pushing a Weck cell sponge between conjunctiva and Tenon’s capsule (Fig. 11.3). This creates a pocket
**Fig. 11.1** Conjunctiva and Tenon's capsule elevated by subconjunctival injection of balanced salt solution

**Fig. 11.2** Conjunctiva separated from underlying Tenon's capsule

**Fig. 11.3** Weck cell sponge being inserted between conjunctiva and Tenon's capsule

**Fig. 11.4** Tenon's capsule being pulled forward by suture

**Fig. 11.5** Tenon's capsule being removed by cautery

**Fig. 11.6** Same as Fig. 5
for the insertion of the Molteno implant. Tenon’s capsule, now lying beneath the implant plate, is dissected off the underlying sclera in front of the plate. A suture is used to pull the dissected Tenon’s capsule forward (Fig. 11.4). This Tenon’s capsule anterior to the plate is removed with cautery (Figs. 11.5, 11.6). This prevents bleeding and allows for fixation of the plate to the underlying sclera, as well as for the placement of the patch graft over the tube (Fig. 11.7). The remainder of the tube placement is then done in the routinely described manner. Inferior quadrants can be used if both upper quadrants have been scarred by previous surgery.

11.4 The Cornea and Glaucoma Implants

There are two aspects regarding the association of glaucoma implants with the cornea. There is an increased incidence of corneal decompensation in the presence of a tube shunt. Tube shunts are the preferred method of treating glaucoma associated with corneal transplants.

11.4.1 Corneal Decompensation in the Presence of a Pre-existing Tube Shunt

The causes of corneal decompensation in the presence of a pre-existing tube shunt may be multifactorial. Many of the patients exhibiting corneal decompensation are aphakic or pseudophakic. Many patients, in addition, have had previous glaucoma surgery. These multiple surgical procedures are associated with endothelial cell loss. The prolonged use of antiglaucoma medications may also result in endothelial cell loss, as the preservative used in these medications, namely benzalkonium chloride, has been shown to be toxic to rabbit endothelium when topically applied [18]. The presence of the silicone tube in the eye results in a cell loss of two cells per square millimeter per postoperative month [27]. Further endothelial cell loss as a result of the tube may occur as a result of direct tube endothelial touch, either locally or in a diffuse manner, during rubbing of the eye.

Corneal transplants in the presence of a pre-existing tube requires special attention to the tube. If the tube appears to be too close to the endothelium, the options available are as follows:

1. Tube removal and reinsertion away from the endothelium
2. Placing a suture across the anterior chamber, over the tube directing it away from the endothelium [14]
3. Placing the tube via the pars plana, a technique requiring total or subtotal vitrectomy

Of the three options, the suture placed over the tube is the least invasive.

11.4.2 Penetrating Keratoplasty May Result in Glaucoma

Many reasons have been given for the elevation of IOP post-keratoplasty, and this is particularly prevalent in patients receiving transplants for aphakic or pseudophakic bullous keratopathy [21, 37, 44].

Glaucoma implants have become the treatment of choice for the management of medically intractable glaucoma associated with corneal transplants. The incidence of graft rejection, however, remains high in these patients. In an attempt to eliminate the possible effect of the tube as a cause for this failure, a pars plana insertion of the tube has been reported in keratoplasty pa-
tients, but without a significant improvement of graft failure [40].

A unique complication that has been noted to occur with glaucoma implants and penetrating keratoplasty is the development of anterior-segment fibrosis. High pressure within the bleb associated with glaucoma implants has been shown to result in the production of TGFβ. In non-valved implants this TGFβ returns to the anterior chamber and may possibly cause a low-grade inflammation resulting in diffuse anterior segment fibrosis. This complication has not been described with the use of valved implants, where aqueous flow is one way of preventing the TGFβ from reaching the anterior chamber.

**Summary for the Clinician**

- Penetrating keratoplasty is associated with an increased incidence of glaucoma, especially in cases of aphakia and pseudophakia. Although not by any means ideal, glaucoma drainage devices are the treatment of choice for medically uncontrolled glaucoma in keratoplasty patients. Glaucoma implants are associated with an increased incidence of corneal decompensation, both prior to and after keratoplasty.

### 11.4.3 Summarized Information from Publications Regarding Success of Glaucoma Implants and Penetrating Keratoplasty

In one study which examined the results of keratoplasty and glaucoma treated with Ahmed or Baerveldt implants the grafts remained clear in 70 and 55% of eyes at 2 and 3 years with glaucoma control of 82% of patients at 3 years [22].

A second study using Ahmed implants in keratoplasty and glaucoma reported successful glaucoma control in 75.4 and 51.5% of eyes at 12 and 20 months, respectively, with 19% having graft failure. This study seemed to imply that graft failure is less with a valved implant [9].

A study reporting results of pars plana insertion of glaucoma implants in glaucoma and keratoplasty reported 12- and 24-month life-table success rates for IOP control and corneal graft clarity to be 85 and 62%, and 64 and 41%, respectively [40].

Other studies reporting graft failure associated with glaucoma implants are:
- McDonnell et al., 41% after 13 months of follow-up [26]
- Beebe et al., 43% after 24 months of follow-up [4]
- Sherwood et al., 22% after 22 months of follow-up [39]

### 11.5 Neovascular Glaucoma

Neovascular glaucoma remains the one condition in which glaucoma drainage devices are often the primary treatment option. The key to success is the early detection of the neovascular process and its subsequent treatment by pan-retinal photocoagulation before total scarring and closure of the angle has occurred. The use of pan-retinal photocoagulation, if done early, can prevent severe anterior-segment fibrosis and improve prognosis for control of the glaucoma [8].

As a result of progressive peripheral anterior synchiae formation with scarring in the chamber angle, particularly if seen at a late stage, standard glaucoma filtering surgery is less likely to be successful due to closure of the internal filter site. Glaucoma filtering surgery, in order to be successful, requires adequate pan-retinal photocoagulation to be done, followed by a period during which the eye needs to quiet down to prevent intraoperative bleeding. As this is not always possible, glaucoma implants remain the surgical treatment of choice in neovascular glaucoma [38]. The silicone tube is placed well inside the anterior chamber and away from the angle so that any progressive fibrosis will not be able to occlude the tube opening.

Prior to insertion of the glaucoma implant, pan-retinal photocoagulation should be performed to control the neovascular process. This can be done provided that a reasonable level of IOP can be obtained with medical therapy. When
pressure levels are very high and cannot be controlled medically, the treatment of choice is pars plana insertion of the glaucoma implant, coupled with total vitrectomy and laser endophotocoagulation of the retina [24].

Avoiding the neovascular tissue in the angle may necessitate placing the tube of the glaucoma implant slightly more corneal to prevent intraocular hemorrhage from iris vessels. Often when the patient is seen in the acute stage with high IOP, there are posterior synechiae, resulting in pupil block and misdirection of aqueous. Placement of a glaucoma implant in these patients should be associated with a posterior sclerotomy and removal of aqueous/vitreous thereby lowering the IOP, prior to inserting the tube into the anterior chamber. As soon as fluid is removed through the sclerotomy, the anterior chamber needs to be reformed immediately to prevent the occurrence of hyphema from iris vessels. An iridectomy should be done either intraoperatively, if this can be achieved without inducing a hyphema, or postoperatively with a laser.

The reported success rate with the use of glaucoma implants in neovascular glaucoma varies in different studies. A common trend seen in all reported studies is a progressive loss of success with time, with the result often being loss of light perception.

The poor results seen in patients with neovascular glaucoma occurs as a result of the morbidity of the underlying systemic condition associated with severe diabetic retinopathy or central vein occlusion, the main causes of neovascular glaucoma.

Long-term results of glaucoma implants in the treatment of neovascular glaucoma were reported by Mermod et al. [28]. The success rates reported in that study were 62.5% at 1 year, 52.9% at 2 years, 43.1% at 3 years, 30% at 4 years, and 10.3% at 5 years. Light perception was lost in 29 of 60 eyes (48%), and phthisis bulbi occurred in 11 eyes (18%). That study highlights the progressive nature of neovascular glaucoma, due predominantly to the underlying progression of the retinal disease.

### Summary for the Clinician
- The treatment of choice for neovascular glaucoma is pan-retinal photocoagulation and glaucoma implant.
- Placement of the tube opening distal from the angle prevents closure by fibrous neovascular tissue.
- The overall prognosis for neovascular glaucoma depends on the underlying disease.

### 11.6 Complications of Glaucoma Implants

Although glaucoma implants may be associated with complications associated with standard glaucoma surgeries, such as hypotony, choroidal effusions, flat anterior chambers, cataract, and infections (although infections are rare), there are a number of complications unique to glaucoma implants, related to the tube and the plate, as well as induced motility problems.

#### 11.6.1 Tube-Related Problems

The tube may be too anterior, resulting in corneal touch, resulting in local or diffuse corneal decompensation. If too posterior, iris or lens damage may occur. Careful positioning of the tube is therefore essential.

Tube exposure may occur as a result of scleral or patch graft erosion, and can result in intraocular infection if not remedied. Tube doubling over of what appears to be a too-thin patch, i.e., pericardium, will prevent this complication in most cases. Recurrent erosion of a patch graft can occur and may be difficult to remedy, and may necessitate tube removal.

#### 11.6.2 Plate-Related Problems

Erosion of conjunctiva and plate exposure can occur. This may be seen if the tube is blocked, allowing conjunctiva to constantly be in contact
with the plate, resulting in erosion. The dehis-
cence in the conjunctiva may be difficult to close,
and if so, the plate will need to be removed to
prevent the occurrence of severe hypotony and
endophthalmitis, as the exposed surface of
the plate is connected to the anterior chamber.

11.6.3 Motility Problems

Due to the large size of the blebs obtained with
glaucoma implants, some restriction of eye
movement may occur with any of the various
implants. Motility disturbances are more likely
to occur with inferior placement of the implant
due to restricted space in this area, resulting in
the disturbing effect of diplopia on downward
gaze. Restriction of upward gaze, as may occur
with superiorly placed implants, are less likely
to produce disturbing diplopia. Superior quadrant
placement of implants, if possible, is the pro-
cedure of choice to prevent possible diplopia. The
reported incidence of motility problems in glau-
coma implants appears to be highest with the
Baerveldt implant [3, 42]. This may be due to the
placement of the implant beneath extraocular
muscles, with subsequent scarring and muscle
imbalance. The height of the bleb may also play
a role in the motility disturbance, and as a result,
Baerveldt modified the implant by including fen-
estrations in the plate, resulting in a lower bleb
profile. The overall effect of this fenestration in
reducing diplopia has not been documented in a
comparative study.

11.6.4 The “Hypertensive Phase”

The “Hypertensive Phase,” seen commonly 4–
6 weeks after implant surgery, is unique to the
use of glaucoma shunts. The IOP may reach very
high levels and needs to be lowered both for pa-

tient comfort, protection of the optic nerve, and
long-term survival of the bleb. This may be ac-
complished by removing aqueous from the bleb
with a 30-G syringe, which may be done in the
office under topical anesthesia [16]. This may be
repeated as often as necessary, and will help the
long-term survival of the bleb.

The hypertensive phase is seen more com-
monly with Ahmed implant use, and may be due to
the early contact of “glaucomatous” aqueous with
the tissue overlying the plate [36]. As mentioned
previously, this aqueous contains proinflamma-
tory substances, resulting in a more intense reac-
tion in the bleb with the subsequent rise in IOP.
Preventing this aqueous from reaching the plate
while pressure is normalized will decrease these
proinflammatory components and produce less
bleb inflammation and subsequently a lower in-
cidence of the hypertensive phase.

Another possible explanation for the develop-
ment of the hypertensive phase may be related
to the plate material. The Molteno and Ahmed
plates are made of polypropylene, the differences
being that the Ahmed is more rigid and may in-
duce more inflammation by micro-movement of
the plate. The Baerveldt implant is flexible and
in the rabbit model induces the least amount of
inflammation. The Ahmed-designed drainage
device recently has been made available in a si-
cone (and, thus, more flexible) model. It is pos-
sible that future studies will show that this change
in material and physical properties of the implant
positively influences the hypertensive phase.

11.6.5 Bleb Fibrosis

Bleb fibrosis and lack of adequate pressure lower-
ing remains the most important problem associ-
ated with glaucoma implants (see 11.1.2). Very
low pressures remain difficult to obtain due to
this bleb fibrosis. Methods adopted to overcome
bleb fibrosis include:

1. The use of systemic antibiotic medication
   (Molteno), with good reported results
2. The use of topical antimetabolites (mitomy-
cin C), not very effective
3. The use of supra-tenon’s placement of the im-
   plant with encouraging early results

Eliminating bleb fibrosis will require further
research to include implant design and tissue-
healing properties.
Summary for the Clinician

- Tube or plate exposure may lead to endophthalmitis.
- Motility problems and diplopia are more common with the Baerveldt implant, and with inferior placement of any implant.
- The hypertensive phase is more common with the inflexible Teflon Ahmed implant.

11.7 New Glaucoma Implants

11.7.1 The Ex-Press Glaucoma Shunt

Within the past few years, a new mini-glaucoma shunt, the Ex-Press mini shunt, has been introduced. The device is made of stainless steel, with a 3-mm-long tube with an external diameter of 400 μm and a 50 μm inner diameter. The tube is attached to a disc-like flange at its proximal end to prevent it from being implanted too deeply. The device has a penetrating tip that is inserted into the anterior chamber. Behind the tip is a spur to prevent extrusion of the device. The Ex-Press is used both as a primary procedure and when conventional surgical treatments have failed. Although originally designed to be used subconjunctivally, because of associated complications with this method of implantation, the device is now used predominantly under a scleral flap.

A standard trabeculectomy flap is made and, instead of removing corneal tissue, the Ex-Press shunt is inserted beneath the flap into the anterior chamber, without a peripheral iridectomy. Early results with the shunt placed under a flap have been encouraging. The present author has found the device to be particularly effective in patients with small orbits, where standard implants would be difficult to use. In a recently published report, the Ex-Press was placed into 24 eyes with open-angle glaucoma, 16 with previously failed glaucoma surgery and 8 defined as high risk for failure. The device was placed under a scleral flap. The IOP was significantly reduced from 27.2 mmHg pre-operatively to 14.5 mmHg at 12 months and 14.2 mmHg at 24 months [10]. Future studies, comparing the device to standard trabeculectomy, are required.

11.8 The Future for Glaucoma Implants

The traditional criteria for "successful" IOP control, as reported in the majority of studies, is 21 mmHg, which in advanced glaucoma is currently recognized as too high; thus, a more standardized definition of success with lower IOP and perhaps protection of the visual field needs to be developed.

Will glaucoma implants become the procedure of choice in patients requiring filtering surgery? This question hopefully will be determined by an ongoing study comparing trabeculectomy surgery to glaucoma implants as related to success and complications.

The long tube implant design has stood the test of time for 30 years; nevertheless, changes in implant material, implant size, and methods for reducing fibrosis remain challenges for ongoing research.

References