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# Pediatric Trabeculectomy

Maria Papadopoulos and Peng Tee Khaw

## History

Trabeculectomy was first described by Cairns in 1968 in an attempt to replace full-thickness sclerostomy with a safer "guarded sclerostomy" associated with fewer complications [1]. With time trabeculectomy was to become, and still remains, the reference standard for filtering surgery worldwide. Following its introduction in adult glaucoma surgery, it was also adopted for use in children. Conventional techniques at the time such as Elliot trephining, iridencleisis, and cyclodialysis were associated with poor outcomes for refractory cases and significant complications in buphthalmic eyes, fuelling the search for alternative operations with better and safer outcomes [2, 3]. Furthermore, it gradually became evident that angle surgery even after multiple attempts was not always successful in primary congenital glaucoma (PCG), especially in older children [4], and even less so in secondary childhood glaucoma [5, 6].

Beauchamp and Park were the first in 1979 to publish trabeculectomy outcomes in children with advanced or refractory glaucoma. Most children in the series had previous surgery before trabeculectomy, and around 30% of eyes were aphakic at the time of surgery. Successful outcomes were low and complication rates high for which the authors cited numerous reasons, including "more rapid healing processes" [7]. Despite subsequent more encouraging reports of trabeculectomy in children without previous surgery (primary trabeculectomy) [8–10], excessive scarring in the region of the scleral flap remained a barrier to success in many cases. In the adult glaucoma literature, evidence was mounting that adjunctive therapy such as topical steroids [11] and 5-fluorouracil (5FU) [12] could improve outcomes by limiting the wound healing response and reducing fibrous tissue formation. However, the association of 5FU with complications such as corneal toxicity and the need for frequent postoperative subconjunctival injections made its use in children impractical. In 1991, Miller and Rice demonstrated the use of intraoperative beta radiation (750 cGy) to the surgical site improved trabeculectomy outcomes in children and was associated with diffuse elevated blebs with no increase in complications [13]. However, despite the simplicity of application, it never gained widespread use probably because of limited

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access to the strontium$^{90}$ probes. The introduction in the late 1990s of mitomycin C (MMC), a potent inhibitor of fibroblast function, which could be applied at varying potencies and required only intraoperative exposure, offered major advantages over 5FU as an adjunct to trabeculectomy surgery in children. Although MMC was generally thought to improve trabeculectomy success, its association with significant, potentially blinding complications such as bleb-related infection led over the years to trabeculectomy falling out of favor in children and to alternative techniques to replace it, such as glaucoma drainage devices (GDD) [14–16].

However, the limited surgical armamentarium for childhood glaucoma and the fact that trabeculectomy was able to achieve lower mean intraocular pressure (IOP) and be less dependent on medication for IOP control than GDDs, led to a reevaluation of the technique in the late 1990s [17]. The resulting simple modifications to the surgical and antiscarring application technique have shown trabeculectomy in the twenty-first century to be associated with satisfactory outcomes in appropriate cases in children of all ages and with reduced complications [18, 19]. This is of particular relevance and importance to the developing world, where often the need is great but access to GDDs limited.

## Indications and Contraindications

In PCG, the most common indication for trabeculectomy is failed angle surgery [20]. However, it can be considered as first-line surgery by surgeons unfamiliar with angle surgery, if angle surgery is not possible, or if the patient is unlikely to respond sufficiently to angle surgery (e.g., very early or late presentations). A further indication may be cases where very low target pressures are required (advanced optic disc damage or to improve corneal clarity) as the IOP can be potentially titrated. In juvenile open-angle glaucoma (JOAG), trabeculectomy is usually the procedure of choice [21], although 360° trabeculotomy may be effective in selected cases. For most phakic secondary glaucomas, trabeculectomy can be considered first-line due to the lower success rates of angle surgery compared to PCG. Possible exceptions include uveitic glaucoma [22], congenital rubella [5], and infantile presentations of Sturge-Weber syndrome (SWS) [23] when angle surgery may be attempted first.

Trabeculectomy is contraindicated in glaucoma secondary to malignant intraocular tumors to prevent the risk of tumor seeding. Relative contraindications to trabeculectomy surgery include aphakia or pseudophakia following congenital cataract surgery due to poor outcomes and Peters anomaly (moderate to severe forms) as it is our impression it's associated with an increased risk of trabeculectomy failure. The presence of a cataract requiring imminent surgery or corneal pathology that may require transplantation in the near future is also a relative contraindication because of the high risk of failure after pediatric anterior segment surgery. And, the inability to regularly review children in the postoperative period to assess bleb function and inflammation may compromise success.

## Risk Factors for Failure

There are numerous risk factors for failure of trabeculectomy in children, which include age, severity of disease, previous surgery involving the conjunctiva, absence of a natural lens, and lack of cooperation with examination and with the administration of drops in the postoperative period.

Children have lower trabeculectomy success rates compared to adults [24]. It has been suggested that a thicker Tenon capsule in children acting as an impediment to filtration and as a large reservoir of fibroblasts results in an enhanced inflammatory and healing response in pediatric eyes [7, 25]. Infancy, especially less than the age of 1 year [26–29], has often been cited as a risk factor for failure; however, contemporary trabeculectomy results in infants suggest satisfactory long-term outcomes [19].

Conjunctival scarring [13, 24, 29–31], a legacy of previous surgeries, increases the risk of failure as does aphakia or pseudophakia following congenital cataract surgery [28, 32–34] and long-term drop use particularly when associated with conjunctival redness and inflammation [13].

Glaucoma filtering surgery, such as trabeculectomy, is unique in that the actual technique contributes only partially to success, with bleb management in the postoperative period being just as important. Failure tends to occur early in children, and so frequent postoperative examinations to assess the bleb and the ability to perform postoperative manipulations, such as suture removal, are crucial to trabeculectomy success. Regular and sometimes intensive steroid topical therapy is also often required to avoid failure from excessive inflammation. However, both these factors can be challenging for clinicians and parents due to difficulties with cooperation in infants and young children. Examinations under anesthesia (EUA) may be required possibly on a repeated basis to adequately monitor IOP and bleb progress. Although there are concerns related to multiple general anesthetics in children affecting development, they should be considered within the context of the high risk of blindness from glaucoma inadequately assessed or managed surgically.

## Advantages and Disadvantages

For advantages and disadvantages of trabeculectomy with MMC, refer to Table 6.1 [20].

**Table 6.1** Advantages and disadvantages of trabeculectomy with mitomycin C

| | |
|---|---|
| Advantages | • Titration of postoperative IOP possible with corneal buried releasable sutures<br>• Lower IOP achievable compared to GDD and therefore indicated if low IOP required, e.g., to clear hazy cornea<br>• Less medication for IOP control compared to GDD<br>• Fewer postoperative surgical revisions compared to GDD<br>• No tube-related complications, e.g., corneal decompensation or tube retraction/exposure<br>• May significantly clear cloudy corneas and avoid potential corneal surgery<br>• Many surgeons worldwide have experience performing trabeculectomy |
| Disadvantages | • More invasive and higher complications than angle surgery<br>• Need regular postoperative follow-up which may include examinations under anesthesia<br>• Less likely to be successful if previous superior conjunctival surgery<br>• Poor results in aphakic and pseudophakic patients even with MMC<br>• Significant lifetime risk of endophthalmitis with thin, avascular bleb (more likely with small treatment areas of MMC and a limbal-based conjunctival flap) |

Adapted from Papadopoulos et al. [20] with permission
*IOP* intraocular pressure, *GDD* glaucoma drainage device, *MMC* mitomycin C

## Preoperative Considerations and Preparation

Once the decision is made that trabeculectomy is the best surgical option, it is vital to discuss the details of the surgery with the parents including likely success, the need for regular follow-up, and intensive postoperative drops along with the possibility of unplanned surgery should there be a complication. A “quiet eye” is necessary to maximize the chances of success, for example, in children with uveitic glaucoma who may need additional topical and/or systemic immunosuppression preoperatively.

Preoperatively it is important to also give consideration to the MMC dose, which depends on multiple factors such as the type of glaucoma, age, race, inflammatory state of the eye, previous surgical history, corneal clarity, severity of optic nerve damage, and the state of the fellow eye. For example, you are more likely to use a higher concentration of MMC if a combination of high-risk factors exists or if a low IOP is required to maximize corneal clarity or to preserve a very damaged optic nerve’s function in advanced glaucoma.

The surgical instruments required are as per trabeculectomy for adult glaucoma surgery.

**Table 6.2** Suggested instruments, suture, and consumables for pediatric trabeculectomy surgery

| |
|---|
| *Instruments and knives* |
| Eye speculum (e.g., Khaw pediatric or standard glaucoma speculum) |
| Needle holder |
| Fine, notched/grooved forceps |
| Tying forceps |
| Westcott scissors |
| Tooke knife |
| Calipers |
| 15° Feather® blade |
| Angled crescent blade |
| Descemet membrane punch (e.g., Khaw small Descemet membrane punch 0.5 mm) |
| Vannas scissors (straight or curved) |
| *Sutures and consumables* |
| 7/0 Mersilk for corneal traction suture |
| 10–0 Nylon on a spatulated needle |
| 23G needle on 3 ml syringe |
| Anterior chamber maintainer (e.g., Lewicky) |
| Bipolar diathermy |
| Mitomycin C |
| Merocel corneal shields |
| Balanced salt solution |
| 20 ml syringe with 20G Rycroft cannula |
| Sterile air |
| Apraclonidine 0.5% (for hemostasis) |
| ± Tear film strip |
| ± Viscoelastic (e.g., Provisc or similar) |

A small but adequate 500 μm sclerostomy can be created quickly with a Khaw Descemet membrane punch 7–101 (Duckworth & Kent, UK) and can be considered. An anterior chamber (AC) maintainer is mandatory for all cases. For MMC treatment, Merocel corneal shields (Beaver Visitec, UK) or pieces of a wick sponge can be used. In infants, consideration should be given to treating the undersurface of the scleral flap with a tear film strip (Clement Clarke, UK) soaked in MMC (Table 6.2).

## Operation

### Intraoperative Preparation

Following general anesthesia induction, a sterile field is prepared.

### Surgical Technique

The aim of trabeculectomy surgery is to create a pathway for external drainage of aqueous from the AC to the subconjunctival space. Although there are many ways to successfully perform trabeculectomy surgery in children, contemporary trabeculectomy techniques have evolved with the aim of encouraging posterior aqueous flow and the development of diffuse drainage blebs to minimize complications while achieving satisfactory outcomes (Fig. 6.1). One such technique is the Moorfields Safer Surgery System [35], which emphasizes posterior aqueous flow through a fornix-based conjunctival flap, a large area of treatment with antiscarring agents, and short scleral flap radial incisions which discourage direct flow near the limbus (Fig. 6.2). Titration of postoperative IOP is possible with releasable or adjustable sutures. Buphthalmic eyes are especially prone to hypotony, flat anterior chambers, choroidal effusions, and suprachoroidal hemorrhage due to low scleral rigidity if aqueous flow is not well controlled. The potential for these complications should never be underestimated. Measures to minimize hypotony are essential in trabeculectomy surgery especially in cases such as aniridia and (SWS). In cases of SWS, some surgeons have suggested prophylactic measures such as sclerotomies with glaucoma surgery [36] to prevent suprachoroidal

**Fig. 6.1** Diffuse, elevated bleb using contemporary trabeculectomy surgery. (Courtesy of Maria Papadopoulos, MBBS, FRCOphth)

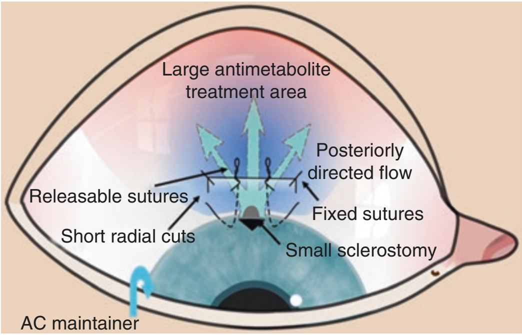


**Fig. 6.2** Moorfields Safer Surgery System: a contemporary pediatric trabeculectomy technique for infants and children. (Courtesy of Peng Tee Khaw, PhD, FRCP, FRCS, FRCOphth, FRCPath, CBiol and Maria Papadopoulos, MBBS, FRCOphth)

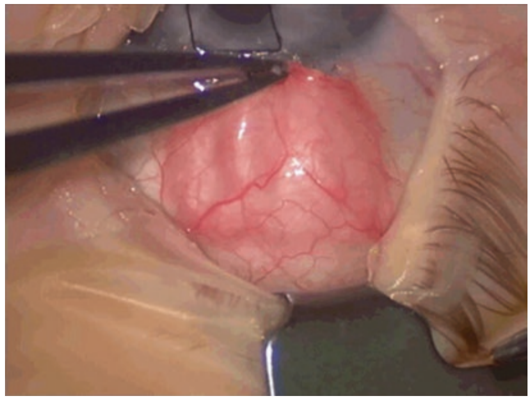

**Fig. 6.3** Large treatment area with mitomycin C-soaked Merocel corneal shields. (Courtesy of Maria Papadopoulos, MBBS, FRCOphth)

effusion and hemorrhage, but others have questioned the need [37]. We feel that the use of an AC maintainer and secure closure techniques significantly reduce the rate of choroidal effusions and the need for prophylactic sclerotomies in these cases.

## Moorfields Safer Surgery System

Adequate exposure of the superior fornix is necessary and can be achieved with a 7/0 Mersilk (Ethicon, US) corneal traction suture (see Table 6.2). Apraclonidine 0.5% drops are applied to the superior conjunctiva before the conjunctival incision to minimize intraoperative bleeding from the conjunctiva. We prefer this to adrenaline as it produces better blanching and less pupil dilatation. A superior fornix-based conjunctival flap is created by incising the conjunctiva and accessing the Tenon layer at the limbus with fine, notched forceps and Westcott scissors. The peritomy is extended to allow adequate access to the superior sclera to fashion the scleral flap. This is followed by posterior blunt dissection of the subconjunctival space, around 8 mm from the limbus, to create a space for antiscarring treatment. Any bleeding vessels are cauterized before a wide area of approximately 3 clock hours is treated with MMC-soaked Merocel corneal shields (Beaver Visitec, UK) (Fig. 6.3). In infants MMC treatment occurs after the scleral flap is fashioned so that the undersurface of the scleral flap can also be treated with a tear film strip (Clement Clarke, UK) cut to size and soaked in MMC. MMC is applied at concentrations varying between 0.2 and 0.5 mg/ml for 3 min before irrigation with 20 ml of balanced salt solution.

Diathermy is applied to blanch the area of incision, and loose episcleral tissue is cleared with a Tooke knife. At the 12 o'clock position, a 15° Feather® blade (PFM Medical, UK) is used to create a 5 mm partial thickness tangential incision which forms the posterior edge of the flap about 4 mm from the limbus. A rectangular (5 mm × 4 mm), lamellar scleral tunnel is then fashioned with an angled crescent blade beginning at the posterior incision and advancing anteriorly to the superficial limbus for the width of the initial incision with care not to enter the AC (Fig. 6.4). In infants with buphthalmic eyes, the wide limbus mandates the correct positioning of the scleral flap. The posterior edge of the flap should not be at the edge of the limbus but within more robust sclera to minimize cheesewiring of sutures. The sides of the scleral tunnel are then opened toward the limbus with the Feather® blade to create the scleral flap. Due to the elastic nature of sclera in children, these radial cuts should be short to enable tight closure without the need to suture the radial edge of the flap and to also encourage posterior aqueous flow and a diffuse bleb (Fig. 6.5).

A 10-0 nylon (Alcon, UK) is used to preplace intralamellar scleral sutures, with a fixed suture at each corner and two releasable sutures at the posterior edge of the scleral flap (Fig. 6.6). We avoid passing the needle full thickness through the sclera to avoid aqueous seepage around the needle track. Releasable sutures are preferable as they can be loosened or removed while under EUA in infants and young children and on the slit lamp in older children. The releasable loop is buried in a corneal slit parallel to the limbus, so it can be left indefinitely without the risk of infection. Preplacement of the sutures with a formed globe is easier than after the sclerostomy, and it also reduces the duration of intraoperative hypotony after the sclerostomy and peripheral iridectomy have been performed. The paracentesis for the AC maintainer (Lewicky, Beaver Visitec, UK) is then created with a Feather® blade and 21G green needle and the AC maintainer inserted in the AC. An AC maintainer is used in all cases to rapidly reform the AC, maintain the IOP intraoperatively, minimize intraoperative hypotony-related complications (choroidal effusions, suprachoroidal hemorrhage, vitreous prolapse with peripheral iridectomy), and facilitate the accurate judgment of flow through the scleral flap to ensure adequate flap closure.

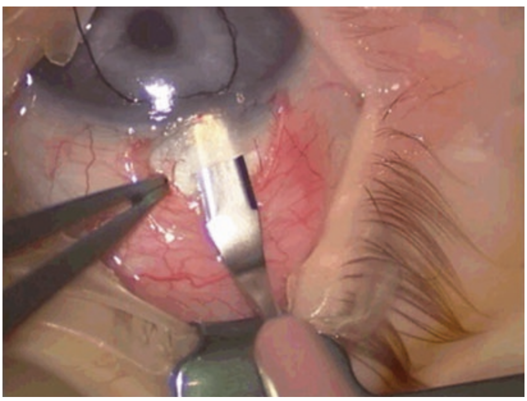

**Fig. 6.4** Lamellar scleral tunnel fashioned with an angled crescent blade. (Courtesy of Maria Papadopoulos, MBBS, FRCOphth)

The AC is entered at the anterior edge of the scleral bed, and a 500 µm sclerostomy is created with a Khaw Descemet membrane punch 7-101 (Duckworth & Kent, UK) followed by a surgical iridectomy. The scleral flap is then sutured closed by tying the preplaced releasables first (four throws), followed by the fixed sutures in infants and children. The AC maintainer must be temporally turned off to soften the eye when tightening the sutures to prevent them from tearing the scleral flap. Further sutures are placed in the scleral flap as required with the aim of achieving minimal or slow aqueous flow through the flap at the end of procedure, e.g., gradual hydration of a sponge swab. A tenonectomy is not performed to minimize the theoretical risk of a thin bleb developing. The removal of the AC maintainer

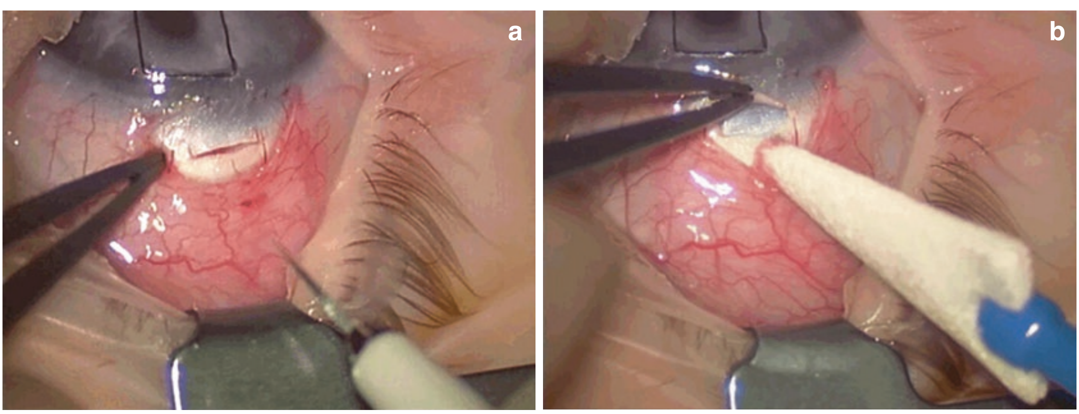



**Fig. 6.5** Short radial cuts to encourage posterior aqueous flow and a diffuse bleb. (Courtesy of Maria Papadopoulos, MBBS, FRCOphth)

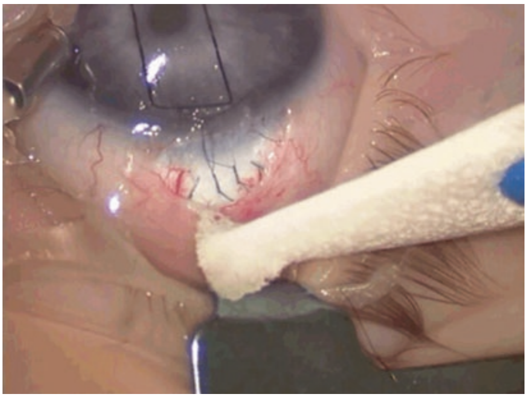

**Fig. 6.6** Two fixed 10-0 nylon sutures at the edge of flap and two releasables with four throws at posterior edge of flap allowing minimal flow. (Courtesy of Maria Papadopoulos, MBBS, FRCOphth)

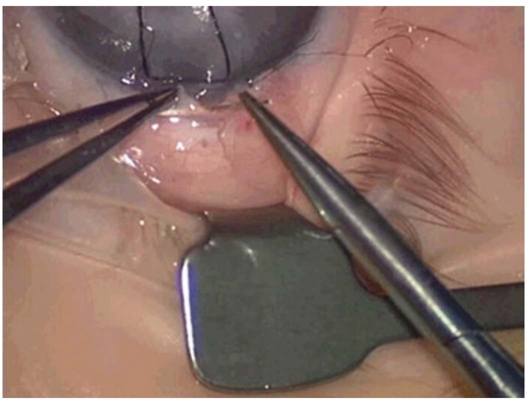

**Fig. 6.7** Horizontal mattress suture for conjunctival closure. (Courtesy of Maria Papadopoulos, MBBS, FRCOphth)

with suturing of the paracentesis (required in buphthalmic eyes, unlike adults) is followed by conjunctival closure with 10-0 nylon sutures, all the while intermittently judging the depth of the AC and IOP. Purse-string sutures are used at the edges of the peritomy with either horizontal mattress sutures along the limbus (Fig. 6.7) or corneal buried, conjunctival sutures. Nylon suture ends are trimmed short to disappear in the corneal slit with corneal conjunctival closure, or cut short and covered well by a conjunctival frill with horizontal mattress suture closure along the limbus. This is to avoid discomfort and excessive eye rubbing which may lead to conjunctival wound dehiscence.

Viscoelastic (usually Provisc®, Alcon, UK) and air are occasionally left in the AC if the scleral flap cannot be secured by multiple sutures. Subconjunctival injections of steroid (betamethasone), antibiotic (cefuroxime), and often local anesthetic (Marcaine) to minimize postoperative pain and possibly reduce scarring by suppression of fibroblast activity are given at the end of the case. All eyes are patched overnight (Table 6.3) [20] (Video 6.1).

## Antiscarring Agents

The main cause of filtration ceasing and trabeculectomy failure is fibrous tissue formation in the region of the scleral flap, which necessitates the use of an antiscarring agent in children. This is usually MMC due to its greater antiproliferative potency than 5FU and the need for only intraoperative exposure. In a small prospective series of 12 eyes of primary and secondary childhood glaucoma comparing the use of MMC (0.2 mg/ml, 88%) and perioperative 5FU to perioperative 5FU alone (maximum 6 injections), 7/8 eyes of the MMC and 5FU group were controlled off medications as opposed to 0/4 eyes in the 5FU group alone [38].

The greatest advance in MMC therapy has been the understanding that a wider application of MMC treatment is more likely to be associated with a diffuse elevated bleb as opposed to a focal avascular bleb and therefore associated with a significantly reduced risk of complications such as bleb-related infection [18, 19, 39] (Fig. 6.8). However, we suggest adjunctive MMC for those experienced in its use. The most appropriate MMC application method (i.e., whether to also treat under the scleral flap), concentration, and duration of exposure for children are unclear from the literature. The MMC dose is usually determined by the number of risk factors for scarring and the surgeon's familiarity with specific concentrations, but most surgeons use between 0.2 and 0.5 mg/ml. The duration of MMC exposure is best kept constant, and only the dose varied to establish consistency of use, with our preference being for 3 min [40]. An

**Table 6.3** Pediatric trabeculectomy technique aimed at encouraging posterior flow and formation of diffuse bleb: important surgical points

| Surgical steps | Surgical points/rationale |
|---|---|
| Corneal traction suture (7/0 Mersilk) | Allows adequate exposure<br>Avoids hemorrhage from superior rectus muscle suture |
| Fornix-based conjunctival flap | Less likely to form a scar limiting posterior flow<br>Allows better visualization of limbal anatomy |
| Wet field cautery | Hemostasis<br>Avoids scleral shrinkage (important in thin sclera) |
| Antiscarring agents | Diffuse, large treatment to minimize risk of a focal, avascular bleb |
| Scleral flap | Consider fashioning scleral flap first before antiscarring treatment in infants to enable treatment under scleral flap<br>Large scleral flap (4 × 5 mm) and as thick as possible<br>Sutures less likely to cheesewire<br>Greater resistance to aqueous outflow<br>Posterior edge must be well beyond limbus to prevent cheesewiring of flap<br>Dissection forward into cornea avoids iris, ciliary body, and vitreous incarceration<br>Short radial cuts enough to allow reflection of scleral flap for the sclerostomy<br>Greater the scleral elasticity (incision gap) the shorter the radial cuts<br>Directs aqueous flow posteriorly to prevent cystic blebs |
| Preplaced scleral flap sutures before sclerostomy | Easier to place with formed globe<br>Reduces duration of intraoperative hypotony after sclerostomy and PI performed<br>Releasable sutures through posterior edge of scleral flap and fixed sutures at corners if scleral flap gapes, e.g., in infants<br>Releasable loop buried in cornea so suture can be left indefinitely without risk of infection<br>Can be adjusted or removed under anesthetic or slit lamp without laser |
| Paracentesis for anterior chamber (AC) maintainer | Oblique, peripheral, long tunnel with a 21G needle minimizes risk of inadvertent lens damage, avoids wound leak, and stabilizes infusion cannula<br>Allows maintenance of intraoperative IOP preventing hypotony and potential choroidal effusions, suprachoroidal hemorrhage, and vitreous prolapse with PI<br>Allows AC reformation<br>Must turn off temporarily when tying scleral flap sutures tight to prevent cheesewiring<br>Used to gauge flow through sclera flap and ensure adequate flap closure |
| Sclerostomy | Small sclerostomy punch (500 μm diameter) allows increased control of aqueous outflow both intra- and postoperatively and is quick to perform<br>As anterior as possible prevents iris, ciliary body, and vitreous incarceration |
| Scleral flap closure | Tight closure vital with antiscarring agent use<br>Add additional sutures as required to reduce flow |
| Fornix-based conjunctival closure | 10–0 Nylon retains tension longer than dissolvable sutures with minimal inflammation<br>Purse-string sutures at peritomy edges<br>Corneal buried, conjunctival suture closure, or limbal horizontal mattress sutures |
| Prevention of postop hypotony | Appropriate concentration of MMC<br>Short radial cuts direct flow posteriorly and minimizes anterior flow from scleral flap sides<br>Tight scleral flap sutures with option to adjust or release at later stage<br>Watertight conjunctival closure<br>Suture paracentesis<br>May leave viscoelastic in AC if high flow rate through scleral flap despite maximal suturing or if ciliary body shut down anticipated (uveitic cases) |

Adapted from Papadopoulos et al. [20], with permission
*IOP* intraocular pressure, *AC* anterior chamber, *PI* peripheral iridotomy, *MMC* mitomycin C

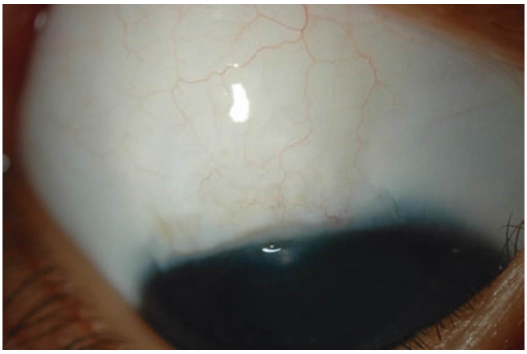

**Fig. 6.8** Elevated, diffuse bleb following Moorfields Safer Surgery System trabeculectomy with a large treatment area of mitomycin C

approach when using MMC in infants following failed angle surgery is to use a low dose, e.g., 0.2 mg/ml, at the time of surgery which minimizes the risk and duration of early complications such as hypotony but then to "top up" with subconjunctival 5FU injections at the time of postoperative EUA, as indicated [19].

## Potential Modifications

Trabeculectomy can be combined with trabeculotomy to theoretically provide two major outflow pathways and potentially better results than either operation performed alone, but there are no prospective comparisons of all three operations. Combined trabeculotomy-trabeculectomy (CTT) is advocated in some ethnic populations due to its higher incidence of successful IOP control retrospectively compared to these operations performed separately, for example, from the Middle East [41–43]. However, Dietlein et al. in a retrospective study comparing trabeculotomy, trabeculectomy, and CTT without antiscarring agents in PCG patients (Caucasian 71%, Turkish and Arabian 29%) demonstrated no statistical difference in success between the three operations after a median follow-up of 3 years [31]. The authors argued that success was determined more by the severity of the disease rather than the procedure. Conversely, Lawrence and Netland in a retrospective review of trabeculectomy versus CTT both with MMC (0.25 mg/ml, same average exposure time) in 40 eyes (mostly Caucasian and African-American) reported a lower success rate in the trabeculectomy group (70.6% versus 91.3%) at the last follow-up. Mean IOP was the same for both groups. Success was defined as IOP control (6–21 mm Hg) with or without glaucoma medications and without further glaucoma surgery or loss of light perception. However, there were significant differences between the two groups with regard to age (trabeculectomy group was older, 100 months versus 19 months), lens status (more aphakic/pseudophakic children in the trabeculectomy group), number of preoperative medications (higher in the trabeculectomy group), casemix (more PCG and anterior segment dysgenesis in the CTT group), and follow-up (longer for CTT group). Chronic hypotony was the cause of three of the five failures in the trabeculectomy group and one of the two in the CTT group [44].

With regard to CTT technique, once the trabeculotomy is performed, a block of sclera is removed at the limbus by scissors or punch by extending the initial Schlemm canal incision. As a result the sclerostomy is placed more posteriorly than is usual for trabeculectomy, which increases the likelihood of the iris incarceration. This can be avoided by making a separate more anterior incision under the hinge of the scleral flap for the sclerostomy. CTT is described in more detail in Chapter 5, Angle Surgery: Trabeculotomy.

## Postoperative Management

Postoperatively, children receive intensive steroid drops (dexamethasone 0.1%) every 2–3 h and ointment at night (e.g., betamethasone ointment). Topical steroids are gradually weaned over 3–4 months or sooner as dictated by the degree of conjunctival inflammation and the IOP. Antibiotic drops (e.g., chloramphenicol) four times a day are usually stopped once exposed sutures are removed. Cycloplegics are not routinely administered but necessary when the AC is significantly shallow and/or choroidal effusions are present. A plastic shield over the operated eye at night time for the first month after surgery is advised.

An important consideration in the planning of a trabeculectomy in children concerns postoperative management. Failure tends to occur early in children, and so frequent monitoring in the early postoperative period is vital. Children should be examined the first postoperative day followed in cooperative older children and teenagers by weekly monitoring for the first month, as with adults, to examine for the presence of a bleb and the degree of bleb inflammation. Subsequent outpatient visits occur at greater intervals depending on bleb appearance and IOP control (Fig. 6.9). In infants, at least one EUA is often needed within the first month after surgery, preferably within the first 2 weeks. Jayaram et al. reported close postoperative monitoring of infants with EUAs at 1 week, 3 weeks, and 6 weeks following trabeculectomy surgery and average duration of postoperative topical steroids of around 3 months achieved satisfactory long-term outcomes off medications [19]. While under anesthesia, sutures can be loosened or removed, and subconjunctival 5FU (0.2–.3 ml of 5FU 50 mg/ml), steroids such as betamethasone, and local anesthetic can be injected adjacent to the bleb depending on the characteristics of the bleb and the degree of bleb inflammation. Monitoring for complications in the postoperative period is also important, and B-scan can be useful in uncooperative children to exclude choroidal effusions.

**Fig. 6.9** A diffuse bleb with minimal inflammation 2 months post-trabeculectomy surgery. (Courtesy of Maria Papadopoulos, MBBS, FRCOphth)

## Complications

There are a many challenges to successful trabeculectomy surgery. These relate not only to surgical technique but also to anatomical factors of a buphthalmic eye, which must be respected to minimize complications. The potential for complications in children after trabeculectomy, especially with MMC, cannot be overstated. Trabeculectomy surgery in young children has been associated with significant surgical complications including early hypotony, flat anterior chambers, choroidal effusions, and suprachoroidal hemorrhage along with retinal detachments and phthisis [14, 26, 32]. Thin avascular, cystic blebs, which use to be common [26, 28], predispose to late complications of bleb-related infection such as endophthalmitis and chronic bleb leaks [14, 28, 32]. However, with contemporary pediatric trabeculectomy techniques, most of these are now avoidable and have significantly decreased [18, 19, 45]. The most common complications associated with trabeculectomy are discussed, along with management and prevention. It is worth emphasizing the point that the best way to manage complications is to avoid them.

### Hypotony

Hypotony is a potentially major sight-threatening complication of surgery due to the risk of suprachoroidal hemorrhage in buphthalmic eyes which can occur intra- or postoperatively. The risk is significantly higher in buphthalmic versus normal adult eyes, so careful attention to surgical technique is critical to avoid this potentially devastating complication. In addition to hemorrhage, hypotony can also result in a shallow or flat AC, which in phakic patients may precipitate or hasten cataract formation. Furthermore, lens-endothelial corneal touch can lead to endothelial decompensation and ultimately to corneal failure. Hypotony maculopathy and choroidal effusions can also develop.

Children with glaucoma are at high risk of hypotony with trabeculectomy surgery for many anatomical reasons. The thin sclera of buphthalmic eyes and the reduced scleral rigidity of pediatric eyes result in a tendency for the eye to collapse at low pressures. A sufficiently thick scleral flap is vital for the adequate closure of the flap to avoid hypotony and to prevent sutures cheesewiring the flap causing full-thickness holes and leaks. However, it is made challenging by the scleral thinness of buphthalmic eyes. Elastic sclera tends to gape when incised requiring increased suture tension to close the incision. Furthermore, if the sclera is very thin, other modalities such as GDD surgery might be more appropriate.

Children with SWS who have choroidal hemangiomas are especially prone to large serous choroidal effusions, even at relatively normal IOP, and also to suprachoroidal hemorrhage in the early postoperative period. In light of this, it could be argued that an alternative operation to trabeculectomy such as GDD (with the use of an AC maintainer, a tight tunnel with a 25 gauge needle, both an extraluminal ligature (6-0 Vicryl) and an intraluminal stent (3-0 Supramid) to restrict flow with a Baerveldt implant) should be considered in SWS patients with choroidal hemangiomas. Postoperative hypotony with this technique may be less likely compared to trabeculectomy in which early postoperative IOP may be less predictable despite efforts to avoid low IOP. Uveitic patients also carry an increased risk of hypotony and its consequences thought to be due to ciliary body shutdown from surgically induced inflammation, so inflammation must be suppressed pre- and postoperatively with topical and if necessary systemic immunosuppression. Children with aniridia are particularly vulnerable to lens-endothelial touch due to an absent iris to separate an anteriorly displaced lens and the cornea, and so hypotony should be avoided at all costs.

Early hypotony following trabeculectomy is potentially common and has been reported in almost 50% of cases [28]. However, more recent literature suggests a lower incidence of around 10% [19]. Choroidal effusions and flat anterior chambers associated with early hypotony following trabeculectomy surgery have been reported at a rate of 22% [32] and 10% [26], respectively, in the past. With recent modifications to the trabeculectomy technique, these complications have been significantly reduced to a choroidal effusion rate of 10% and no cases of flat anterior chambers [19]. Chronic hypotony associated with trabeculectomy can also occur but is much less common and has been reported at a rate of 0–8% [14, 15, 19].

The management of hypotony depends on the degree of hypotony and is targeted toward its cause. Buphthalmic eyes with significant hypotony should not be managed conservatively by observation for very long due to the real risk of suprachoroidal hemorrhage. Following trabeculectomy, early hypotony is often due to overfiltration rather than a limbal bleb leak with fornix-based conjunctival flaps, which is uncommon due to the new closure techniques. If the IOP is low but the AC is reasonably formed and there are no choroidal effusions, the patient can be observed with the frequency of topical steroids reduced to encourage healing and a cycloplegic, e.g., atropine, added. However, if the AC is very shallow or flat and/or there are significant choroidal effusions, it is appropriate to consider injecting viscoelastic into the AC with a reduction in the frequency of topical steroids, or further surgery if the cause is excessive filtration through the scleral flap which can be resolved with the addition of further sutures. Dealing with the consequences of hypotony alone such as drainage of choroidal effusions should be avoided as these resolve once the cause of hypotony is addressed and the IOP rises.

To prevent hypotony and suprachoroidal hemorrhage during surgery, the use of an AC maintainer is advised. Furthermore, incisions such as paracentesis should be adequately sutured as they may not remain watertight with stromal hydration as they do in adults, due to reduced pediatric corneal rigidity. Postoperative hypotony following trabeculectomy can be minimized by using an appropriate concentration of MMC at the time of surgery to minimize prolonged early hypotony, fashioning as thick a scleral flap as possible with short radial cuts to minimize leakage through the scleral flap sides, tight scleral flap lamellar sutures to avoid cheesewiring and watertight conjunctival closure. Occasionally the use of a small amount of cohesive viscoelastic can help maintain the AC and the IOP in the first 24–48 h after surgery if the flap allows slightly too much flow despite maximal suturing.

## Bleb-Related Infection

Infection can develop in a bleb usually as a late complication of trabeculectomy surgery and is very serious as it is potentially rapidly blinding. Bleb-related infection (BRI) refers to a spectrum of disease severity ranging from infection limited to the bleb (blebitis) to fulminant endophthalmitis (bleb-related endophthalmitis). Blebitis is generally regarded as an isolated bleb infection without clinically apparent vitreous involvement, whereas bleb-related endophthalmitis (BRE) is generally regarded as extension of the infection into the eye (in which case a vitreous biopsy and intraocular antibiotics are indicated) [46]. BRI can occur following any filtration surgery in which there is a bleb such as trabeculectomy and combined trabeculotomy-trabeculectomy. Studies from the adult literature report a more virulent spectrum of organisms responsible for BRI such as *Streptococcus* species, *Haemophilus influenzae*, and *Pseudomonas aeruginosa* [46, 47] than those causing acute post-cataract surgical endophthalmitis which are usually gram-positive organisms introduced at the time of surgery. In the pediatric literature, the pathogens are often not reported. When they are reported, the organisms are consistent with those found in adults [28]. Generally, visual acuity outcomes in BRE are worse than in acute onset endophthalmitis after cataract surgery, but most cases of blebitis achieve vision back to or within one line of preinfection visual acuity [14, 47].

Numerous risk factors for BRI exist but by far the most important relates to bleb morphology, that is, an avascular, thin-walled, cystic bleb which results in compromised physical and immunological defenses against organisms (Fig. 6.10). The use of MMC has long been thought to cause thin avascular blebs, and although it may play a role, these types of blebs have been associated with glaucoma surgery well before the introduction of antiscarring agents [48]. Recent publications suggest that the development of these blebs is more likely related to application and surgical technique rather than the use of MMC per se [18, 19, 39]. Other risk factors for infection include chronic bleb leak [14, 49], interpalpebral or inferior placement of the trabeculectomy [50], contact lens use [51, 52], and bacterial conjunctivitis [52, 53].

BRI is believed to occur more frequently in children compared to adults due to poor hygiene [54] with rates varying from none up to 17% in a study with a mean follow-up period of 28 months [14, 32]. Bleb-related endophthalmitis has been reported in up to 9% of pediatric MMC trabeculectomies [14, 32].

BRI is usually symptomatic and may present with foreign body sensation, photophobia, blurred vision, pain, conjunctival inflammation, or purulent discharge. A prodrome of a few days

**Fig. 6.10** An “at-risk” bleb: thin, avascular, cystic bleb at risk of infection. (Courtesy of Maria Papadopoulos, MBBS, FRCOphth)

is characteristic of blebitis, whereas sudden onset and rapid progression suggests endophthalmitis. Children who present with a short prodrome of 24–48 h should be closely observed for progression of signs. In early blebitis there is intense conjunctival inflammation limited to the area immediately around the bleb, which helps distinguish it from generalized conjunctivitis, and this relative disparity alerts the clinician to the bleb as the source of the symptoms. The thin, cystic, avascular bleb is white against the hyperemic surrounding conjunctiva and is known as the "white-on-red" appearance (Fig. 6.11). This can progress to a mucopurulent infiltrate of the bleb and a purulent discharge. A thin slit lamp beam through the bleb may show a hypopyon within it. There may be an associated bleb leak. AC activity is variable and vitritis may be present indicating endophthalmitis. A B-scan is indicated if the presence of vitritis cannot be clinically assessed. Typically ultrasound shows low- to medium-density vitreal echoes with endophthalmitis. Conjunctival and eyelid cultures from BRE have been found to correlate poorly with intraocular cultures [47, 52].

BRI should be treated early and aggressively to maximize visual function as long-term visual prognosis depends on the extent of the infection, the virulence of the organism, and the timing of therapy. Blebitis, being a precursor of endophthalmitis, is more effectively treated at an earlier stage resulting in a better prognosis [46, 53]. Acute management is determined by the stage of disease, whether it is blebitis or endophthalmitis. There are no randomized, controlled trials which have established the optimum antibiotic regimen for the treatment of BRI. However, topical and systemic broad-spectrum antibiotics are indicated to cover the diverse spectrum of pathogens which may be responsible. The quinolones have a good broad-spectrum cover for gram-positive and gram-negative organisms. The 4th-generation quinolones (e.g., moxifloxacin, gatifloxacin, and besifloxacin) have better gram-positive coverage including significant activity against *Strep. pneumoniae* and *Staphylococcus* species resistant to 2nd- and 3rd-generation quinolones. Systemic moxifloxacin is usually avoided in children because of the theoretical risk of arthropathy in weight-bearing joints, but ciprofloxacin and amoxicillin/clavulanic acid can be considered instead. Consideration should be given to the addition of polymyxin B for multidrug-resistant bacteria and gram-negative bacteria and vancomycin for methicillin-resistant *Staphylococcus aureus* (MRSA). Later the antibiotic regimen can be refined according to the child's response to treatment and to the culture and sensitivity results. Children with BRI require frequent topical antibiotics (e.g., moxifloxacin hourly day and night). Cases of blebitis should be reevaluated within 4–6 h to check for signs of progression such as increasing symptoms, deterioration of vision, and/or cellular activity in the aqueous or vitreous. Hospital admission should be considered for clinical or social reasons when there are concerns that adequate treatment cannot be administered at home. BRE must also be treated with intravitreal antibiotics once aqueous and vitreous samples have been taken.

The value of intravitreal steroids in the treatment of BRE has also not been established although it may be associated with better visual outcomes [55]. The rationale is that the inflammatory response compounds the tissue destruction caused by the inciting infection. Topical steroids are recommended (e.g., dexamethasone 0.1%).

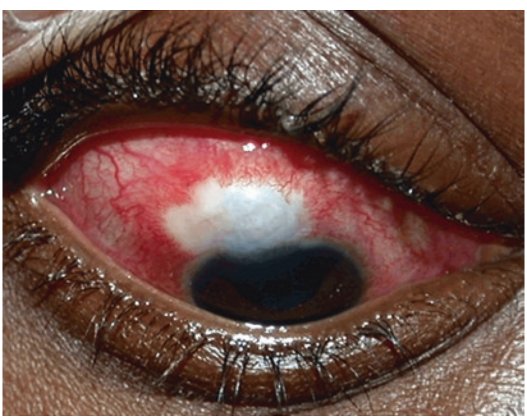

**Fig. 6.11** "White-on-red" bleb appearance associated with bleb-related infection. (Courtesy of Maria Papadopoulos, MBBS, FRCOphth)

Clear guidelines for the role of vitrectomy versus vitreous tap and intravitreal antibiotics alone in BRE are lacking. In theory, vitrectomy decreases the bacterial load and associated toxins, helping to preserve retinal function. It is advisable to consider a vitrectomy if there is significant vitreous involvement or in culture-positive patients showing no improvement after vitreous tap and injection. Furthermore, in children, vitrectomy may be the best way to obtain a satisfactory sample for culture and diagnostic purposes.

Late management of an episode of BRI usually involves a decision about whether surgical intervention is indicated to minimize the risk of further infection. Bleb filtration function is usually maintained after infection and often not an issue [14, 32]. Multiple factors must be considered such as a bleb which extends into the interpalpebral fissure, poor contralateral vision, poor hygiene, persistent bleb leak, ability of the patient to follow advice and act on the symptoms or signs of infection, and the accessibility to ophthalmic care. This last factor would definitely lower the threshold for surgical intervention. Bleb revision involving bleb excision and conjunctival advancement is the most definitive treatment. However, this alone will not prevent recurrence of a thin avascular bleb if scleral thinning or a full-thickness sclerostomy is evident at the time of the revision and is not also addressed with a simultaneous patch graft. Revising the bleb may lead to loss of IOP control. Bleb revision should be delayed until the infection has completely resolved which may be several weeks or months after the acute episode.

With regard to the prevention of infection of an “at-risk” bleb, the role of prophylactic antibiotics is controversial and has not been proven to decrease the incidence of infection. However, it may be appropriate in children with “at-risk” blebs who may be unable to reach an ophthalmologist urgently for assessment and treatment (e.g., while on vacation) to be given a broad-spectrum antibiotic to use if symptoms develop, until they can reach an ophthalmologist. If an avascular cystic bleb develops after surgery, parents should be informed about the risk and seriousness of bleb-related infection. They should be advised to report immediately to an ophthalmologist should symptoms or signs of bleb-related infection occur such as localized conjunctival injection, increasing pain, or an AC hypopyon. Children with filtering blebs, especially those which are “at risk,” experiencing bacterial conjunctivitis should be treated with a topical bactericidal antibiotic and closely observed during and after treatment for the development of intraocular inflammation. Furthermore, a history of prior bleb infection should prompt even greater vigilance as this has been calculated to increase the risk of developing endophthalmitis approximately 12-fold [52].

The prevention of a “bleb at risk” is vital as it puts the child at a lifetime risk of infection and potential blindness. Wells et al., in a retrospective comparative study undertaken in children and young adults, demonstrated a significant reduction in the incidence of a thin avascular bleb and serious bleb-related complications with modifications such as a large area of antiscarring treatment, fornix-based conjunctival flap, and fashioning a scleral flap which encourages posterior flow [18]. Furthermore, antiscarring agents should be cautiously and appropriately selected according to the patient’s risk factors for failure. Inferiorly placed blebs should be avoided, as should blebs with nasal and temporal extensions within the interpalpebral fissure. Releasable sutures should always be buried and antibiotics used when sutures are exposed.

## Chronic Bleb Leak

Chronic bleb leaks tend to occur late in thin, avascular blebs which are fragile and easily traumatized especially by children, and may be intermittent. A leak should always be excluded in such blebs with fluorescein 2%. Reported rates of late bleb leaks from older pediatric trabeculectomy literature range from 3 to 23% [14, 28, 32]. However, in recent studies using contemporary surgical techniques when performing MMC trabeculectomies in children, there were no early or late bleb leaks [19, 45].

Chronic, late leaks are usually refractory to conservative measures such as a bandage contact lens due to poor tissue integrity. Often surgical revision is necessary with excision of the unhealthy conjunctival tissue and advancement of healthy conjunctiva with well-vascularized edges. To prevent the recurrence of a thin, avascular, cystic bleb, any scleral defects must be addressed with a patch graft. Repairing the bleb leak may lead to loss of IOP control.

The prevention of chronic bleb leaks is best achieved with contemporary pediatric trabeculectomy techniques which minimize the risk of a thin, avascular bleb developing as discussed above (see Fig. 6.2).

## Outcomes

Criteria for success in published papers on trabeculectomy are largely based on IOP control either with (qualified success) or without (complete success) topical medications along with the absence of serious complications. Published studies of trabeculectomy for childhood glaucoma are all retrospective which makes comparison difficult as success is influenced potentially by a number of factors such as definition of success, patient's age and race, previous surgery, surgical technique, dose and duration of MMC, use of 5FU postoperatively, casemix (primary and secondary glaucomas), inclusion of non-phakic patients, and duration of follow-up. This makes the answering of questions regarding who are the best candidates for trabeculectomy and which is the most appropriate MMC dose or duration difficult to answer.

Early results of unenhanced trabeculectomy by Beauchamp and Parks in 25 eyes (44% PCG, 32% aphakic) were poor with only 50% success after a mean overall follow-up of 18 months and with a 20% complication rate. However, only 3 of the 25 eyes had a primary trabeculectomy (i.e., first operation on a virgin eye) [7]. Subsequent authors reported even lower success rates of 35% for trabeculectomy in childhood glaucoma after longer follow-up of around 3–5 years [24, 29]. These poor results were speculated to be due to multiple previous ocular surgery and age. In light of these findings, surgeons considered performing primary trabeculectomy. Fulcher et al. reported their findings in 20 Caucasian eyes (65% PCG) with primary, unenhanced trabeculectomy with a success rate (IOP of ≤ 18 mm Hg and clinical stability) of 92% in children with PCG and 86% in children with secondary childhood glaucoma (all phakic) and no serious complications, after a mean follow-up of almost 8 years [10]. These improved results likely reflected the fact that all patients were Caucasian and phakic and had no previous surgery. However, success of trabeculectomy as a primary procedure in certain populations was found to be lower at 54–72% [42, 56]. Elder reported results of unenhanced primary trabeculectomy in 44 eyes of Palestinian Arab children with PCG of 72% cumulative success (IOP of ≤ 21 mm Hg and no medication) with few complications, after a mean follow-up of only 2 years [42].

Despite encouraging reports of primary trabeculectomy in some groups, excessive scarring remained a barrier to success for many cases especially those cases refractory to previous glaucoma surgery. The introduction of MMC was thought to improve success in such cases [57]. Overall, the success of MMC trabeculectomy in children has been reported to be 59–95% with short follow-up of 2 years or less [14, 26, 27, 32, 57], reducing to 55–60% after 6–7 years mean follow-up [19, 58]. Publications suggest that the dose of MMC does not affect success or complication rates [27, 59]. Al Hazmi et al., in a large retrospective series of 150 PCG eyes undergoing trabeculectomy with variable MMC concentrations (0.2 or 0.4 mg/ml) and times of exposure (2–5 min), showed no significant difference in outcomes and complications [27].

Infancy (less than 2 years of age) has been reported to be a significant risk factor for MMC trabeculectomy failure. Outcomes in infants less than 1 year of age vary between 15 and 43% [26–28, 32] after less than 2 years of follow-up with the lower rates in series with aphakic patients [28, 32]. Beck et al. reported that being aged less than 1 year at the time of surgery was associated with almost a sixfold risk of failure [32]. For infants less than 2 years of age, Al Hazmi et al. described a success rate of 39% (IOP < 21 mmHg without topical medications) in 66 eyes (unreported follow-up) in a study population of PCG patients from the Middle East [27]. In a smaller series of 24 eyes with both primary and secondary childhood glaucoma (17% aphakic), Beck et al. reported a cumulative success rate of only 19% (IOP < 23 mmHg with topical medication) at 6 years in infants less than 2 years of age [15]. More recently, in a similar aged series of 40 eyes of phakic patients with primary and secondary childhood glaucoma, Jayaram et al. reported a cumulative probability of success of 60% at 7 years [19]. Almost all successful cases were not using topical IOP-lowering medications at final follow-up. For infants less than 1 year of age, 70% were successful at the end of follow-up.

A consistently reported risk factor for trabeculectomy failure, even with MMC, is glaucoma following congenital cataract surgery [28, 32–34]. In a study by Freedman et al. with a series of 21 eyes treated with MMC trabeculectomy (0.4 mg/ml, 3–5 min) and postoperative 5FU, the qualified success rates for phakic versus aphakic eyes ($n$ = 7) were 64% to 29%, respectively, after 23 months [28]. Azuara-Blanco et al. further highlighted this point in a series of 21 eyes treated with MMC trabeculectomy (0.4 mg/ml, 1–5 min) who found 0% complete success after 18 months in aphakic eyes ($n$ = 8) [33]. Beck et al. reported aphakia to carry an almost threefold risk of failure [32].

As the Tenon capsule is thought to be implicated in the higher failure rate of children, a recent 24-month prospective study by Awadein and El Sayed compared MMC trabeculectomy alone (0.4 mg/ml, 3 min) and MMC trabeculectomy with partial tenonectomy in 64 eyes of children with glaucoma [60]. A tenonectomy of about 8 mm in diameter to include the area over the scleral flap and expected bleb was performed from a fornix-based conjunctival flap leaving behind the “thinnest conjunctiva possible.” There was no significant difference between the two groups with regard to age, lens status, diagnosis, and prior glaucoma surgeries. The mean postoperative IOP was significantly lower in the group who underwent tenonectomy throughout follow-up as were the number of medications from the third postoperative month. Complete success (IOP 5–21 mm Hg without medications and signs of glaucoma progression) and qualified success (with medications) were the same in both groups. More failures (uncontrolled IOP despite maximum tolerated medical treatment, further glaucoma surgery, or devastating complication) occurred in the non-tenonectomy group (30%) compared to the tenonectomy group (55%), but this was not significant. After multivariate analysis, only the number of prior glaucoma surgeries was a predictor of failure. With regard to bleb morphology, the authors report that the tenonectomy group had blebs with “thinner walls” and that encapsulation occurred significantly less frequently in the tenonectomy group (3% versus 25%). There was only one case of endophthalmitis that occurred in a child who did not have a tenonectomy, and there were no cases of chronic bleb leak. Furthermore, less needling and 5FU injections were necessary in the tenonectomy group (3% versus 25%). Although this paper suggests a possible role for tenonectomy in pediatric trabeculectomy, the potential for the development of thin blebs at risk of infection and leaks in the longer term is a concern.

Another approach to improve trabeculectomy success was attempted by Mahdy et al., through the use of intraoperative subconjunctival bevacizumab (Avastin), a recombinant humanized monoclonal vascular endothelial growth factor (VEGF) antibody to modulate the wound healing effects of VEGF. In a prospective paired-eye study design, they compared MMC (0.4 mg/ml, 3 min) trabeculectomy alone in one eye and MMC trabeculectomy with bevacizumab (2.5 mg in 0.2 mls) in the fellow eye of 12 children with refractory glaucoma [61]. Following limbal-based conjunctival flap closure, bevacizumab was injected subconjunctivally over the scleral flap area. Sham injections were performed in the fellow MMC trabeculectomy alone group. There were no significant differences between the two groups with regard to preoperative IOP, lens status, and diagnosis. The mean postoperative IOP was significantly lower in the group who had subconjunctival bevacizumab at 1-year follow-up. Complete success (IOP 5–21 mm Hg without medications and no further glaucoma surgery or visually devastating complications) and qualified success (with medication) were significantly better in the subconjunctival bevacizumab group (complete success 75% versus 58% and qualified success 92% versus 75%, respectively). Shallow AC was the most common complication in each group (17%). One case in MMC trabeculectomy group alone developed late bleb-related endophthalmitis after 3 months and resulted in phthisis bulbi (8.33%). Although off-label use of drugs is common in pediatric ophthalmology and bevacizumab as an adjunct may improve MMC trabeculectomy results, further study of anti-VEGF agents to assess the safety and efficacy of these drugs in this population is needed [62].

Despite the fact that the aim of surgery is to preserve vision in children, visual outcomes are rarely reported in the literature. In Beauchamp and Park's paper, visual acuity was assessed in 18 of the 26 eyes, and the best acuity was 20/200. Where trabeculectomy visual outcomes in children are described, the majority of eyes maintain visual acuity within two Snellen lines; however, in a study by Beck et al. from 1998, 11% of eyes were reported to have lost more than 2 lines of vision or progressed to no light perception attributable to devastating surgical complications [32]. More recently, Jayaram et al. reported final overall visual acuity outcomes of 34.2% seeing 20/40 or better, 89.5% seeing 20/200 or better, and no cases of loss of light perception [19]. Hopefully future studies will evaluate success not only in terms of IOP control and visual acuity but also with regard to functional vision and quality of life measures.

## Comparison to Other Techniques

The accepted alternative to trabeculectomy following failed angle surgery is the insertion of a glaucoma drainage device (GDD). Success rates or success probabilities at last follow-up vary from 31 to 97% with variable follow-up from 1 to 7 years [63]. In infants, success of GDD at 1 year is reported at 74–87% [15, 64] with 53% survival at 6 years after surgery [15], comparable to the trabeculectomy outcomes of Jayaram et al. [19]. MMC trabeculectomy compared to GDDs may achieve lower mean IOP [32] and of significance be less dependent on medication for IOP control [19, 32, 63]. In one study, only 14% of infants undergoing GDD surgery achieved IOP control without topical medications [64] compared to 62.5% (25/40) trabeculectomy cases [19]. However a major difference between trabeculectomy and GDD surgery is the significant burden of associated complications in the latter group often requiring surgical revision. Beck et al. reported 46% of eyes with a GDD required one or more operations due to a complication related to the implant (most commonly tube corneal touch and exposure), in contrast to 12.5% of eyes in trabeculectomy group [15]. Tube malposition, erosion, and endophthalmitis are consistently reported with greater frequency in the pediatric compared to adult population [63]. Tube malposition requiring further surgery has been reported in 26–35% of cases [15, 64]. Of concern is particularly the rate of corneal decompensation in the longer term for these children following GDD surgery.

Trabeculectomy has also been compared to deep sclerectomy both with MMC (0.2 mg/ml, 1 min) in a small series of children with uveitis as primary procedures and found to be more successful with regard to IOP control off medications (88% versus 50%) with all failed cases of deep sclerectomy requiring further glaucoma surgery [65].

## Options After Failed Surgery

When trabeculectomy fails to control IOP, a popular option is to consider bleb needling with an antiscarring agent such as 5FU or MMC if the sclerostomy is patent. The MMC is best injected subconjunctivally posterior to the bleb and before needling while the intraocular pressure is still high, to prevent inadvertent intraocular entry after needling. Repeated needling may be necessary with early failure. Other options after failed trabeculectomy include repeating the trabeculectomy at an adjacent site with a higher dose of MMC or a GDD [20].

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