This article presents a system of glaucoma surgery known as the Safe Surgery System that has evolved at Moorfields Eye Hospital in London. The system’s development is based on a need to improve the consistency of the surgery and its outcome, particularly from the patient’s point of view.

The use of strong antimetabolites such as mitomycin C (MMC) during trabeculectomy increases the risk of potential complications, including hypotony with visual loss and leaking as well as uncomfortable blebs that may lead to endophthalmitis. The Safe Surgery System is designed to preserve visual acuity by minimizing hypotony and bleb-related complications while achieving a desirable postoperative IOP. Table 1 highlights several ways in which the system prevents complications.

**POSITION OF FILTRATION AREA**

Our first step is carefully to assess and draw the lid’s position in relation to the superior limbus. We ensure that the bleb is ultimately located under the upper lid. Otherwise, the chance of discomfort to the patient and of bleb-related complications such as leak and infection is markedly higher. If it is not possible to place the bleb under the patient’s upper lid, then we perform tube-drainage surgery instead.

**TRACTION SUTURE**

We always use a corneal traction suture to avoid a superior rectus hematoma and to achieve maximal traction. Our preference is a 7–0 black silk suture on a semicircular needle (Figure 1).

**CONJUNCTIVAL INCISION**

We now only use fornix-based flaps, mainly because of the scleral exposure and controlled surgery they afford. This type of flap also eliminates the posterior incision of limbus-based surgery that often results in a posterior restricting scar. We avoid radial, side-relaxing incisions. We dissect backward with Westcott scissors to make a pocket approximately 10 to
15 mm posteriorly and sufficiently wide to accommodate the antimetabolite sponges. When dissecting over the superior rectus tendon, we lift the conjunctiva to cut attachments while avoiding the tendon itself (Figure 2).

In the past, we relied on a limbus-based incision and an antimetabolite due to our concern about postoperative leaks. Dr. Khaw’s clinical observation of all cystic blebs, however, led to his hypothesis that they had two things in common. The first was restricted posterior flow due to a ring of scar tissue, which he called the ring of steel. The second was a source of limbal drainage (Figure 3). The restricted flow from the posterior incision resulted in more focal, cystic blebs, a finding that led us to convert to fornix-based flaps.

With limbus-based flaps, the effects of treatment were focal. Moreover, although their growth halted,1,2 the cells at the edge of the treatment area could produce scar tissue and encapsulate the area, both of which resulted in a thin, cystic bleb. A fornix-based incision, by contrast, allowed a larger area of antimetabolite treatment, without a posteriorly placed restricting scar. Similar blebs can be achieved with a limbus-based flap, but the incision must be located quite posteriorly. Results are less consistent with this method, and we find it more difficult subsequently to create the scleral flap and place sutures, particularly in repeat trabeculectomies.

**SCLERAL FLAP**

Our next step is to create an incision and a scleral pocket (similar to a phacoemulsification pocket), after which we cut the two side incisions (Figure 4). We do not cut the side incisions right to the limbus in order to encourage posterior flow and reduce the incidence of cystic blebs. We cut the scleral flap before applying an antimetabolite.

We try to make the largest flap possible. Leaving the side cuts at the limbus incomplete (1 to 2 mm from the limbus) (Figure 5) forces the aqueous backward over a wide area to achieve a diffuse bleb. An aqueous jet at the limbus encour-

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**TABLE 1. FEATURES OF THE SAFE SURGERY SYSTEM TO MINIMIZE COMPLICATIONS**

<table>
<thead>
<tr>
<th>Prevent Hypotony</th>
<th>Prevent Thin, Uncomfortable, Cystic Blebs</th>
<th>Prevent Limbal Leaks of Aqueous</th>
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<tr>
<td>New adjustable sutures for the scleral flap that can be gently titrated downward</td>
<td>Large area of antimetabolite treatment</td>
<td>Corneal groove-closure technique</td>
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<td>Continuous intraoperative infusion to prevent intraoperative hypotony and achieve accurate pressure titration</td>
<td>Posterior diversion of aqueous by altering scleral flap’s construction</td>
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<tr>
<td>Small sclerostomy punch</td>
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<td>Fornix-based conjunctival flap to optimize construction of the scleral flap</td>
<td>Bleb’s location under eyelid confirmed</td>
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ages the formation of an anterior, focal cystic bleb. In contrast, a posteriorly directed, diffuse flow of aqueous from the incompletely cut sides of a large scleral flap results in a more diffuse, noncystic bleb. We preplace sutures in the scleral flap while the eye is still firm, because suturing is more difficult after the eye has been entered and is hypotonous.

**ANTIMETABOLITES**

**Intraoperative Use**

Our earlier article for *Glaucoma Today* covered patient risk factors for scarring, the risks of antimetabolite-related complications, and our regimen with these agents. If intraoperative antimetabolites are indicated, we now use them after cutting the half-thickness scleral flap but before entering the eye, because we have often found scar tissue in the sub scleral space upon re-exploration. The other advantage of cutting the flap first is that we can withhold antimetabolites if there is any problem with the scleral flap or scleral integrity or any sign of aqueous leaking through the flap.

** Conjunctival Clamp**

We use a special conjunctival T clamp (Khaw Small Conjunctival Clamp, No. 2-686; Duckworth & Kent Ltd., Hertfordshire, England) designed to hold back the conjunctiva and to prevent exposing the cut edge of the conjunctiva to the antimetabolite. This clamp maintains a pocket for antimetabolite treatment. Because our experiments have shown that the agent affects mainly the area it touches, protecting the conjunctiva’s edge prevents wound leaks and dehiscence (Figure 6).

**Type of Sponge**

We use circular, medical grade, polyvinyl alcohol sponges that are commonly employed during LASIK; our preference is corneal shields rather than other sponges. Once cut in half and folded like a foldable lens (Figure 7A), the sponge fits through the entrance to the scleral pocket without touching the conjunctival edges. Each sponge is approximately 5 X 3 mm, and we insert about six of them into the pocket (Figure 7B).

We treat as large an area as possible, including under the scleral flap. The polyvinyl alcohol sponges maintain their integrity. In contrast, methylcellulose sponges fragment relatively easily, which increases the chance that small pieces of sponge will remain in the wound. Enlarging the surface area of treatment results in a more diffuse, noncystic area clinically. It also prevents the development of the ring of steel, which would otherwise restrict aqueous flow and promote the development of a raised, cystic, avascular bleb.

**Duration and Washout of Antimetabolite Treatment**

We apply the antimetabolite for 3 minutes based on our pharmacokinetic studies. If we need to vary the effect of MMC, we change its concentration but only use either 0.2 or 0.5 mg/mL. Alternatively, we apply 50 mg/mL of 5-fluorouracil intraoperatively and wash it out with 20 mL of BSS. Our pharmacokinetic experiments have shown a rapid uptake of the drug by the conjunctiva for 3 minutes during the application, after which the ocular tissue absorbs relatively little additional antimetabolite. In the period from 1 to 3 minutes, the dose delivered varies considerably, and small, unavoidable inconsistencies in the time of delivery cause a great variation in drug delivery.

**Complication Rate**

An altered area of treatment (described earlier), our aforementioned construction of conjunctival and scleral flaps, and our use of adjustable sutures (described later) have dramatically reduced our incidence of short- and
long-term complications. For example, the cystic areas within the bleb have decreased from 90% to 29% (Figure 8). The rate of blebitis and endophthalmitis over 3 to 5 years was 20% for older limbus-based techniques with a smaller treatment area versus none during the same period for the current technique. In 2004, Paul Palmberg, MD, of Miami told Dr. Khaw that his complication rate also decreased in low-risk populations from approximately 6% to 0.5%. If Dr. Palmberg’s and our statistics were extrapolated to an approximate figure of 50,000 trabeculectomies with antimetabolites per year in the US, it is possible that bleb-related complications could be avoided in thousands of patients.

PARACENTESIS

Next, we create a paracentesis to allow us fine control of the anterior chamber. The paracentesis is made obliquely (Figure 9), parallel to the limbus, so that the blade remains in the peripheral region of the anterior chamber with a minimal chance of damaging the crystalline lens. Similarly, if we need to reform the anterior chamber intra- or postoperatively, we will introduce a cannula through an oblique paracentesis and thereby minimize the chance of lenticular trauma. An inferiorly placed entry site will allow us access to the anterior chamber, if necessary, in the outpatient clinic.

INFUSION

We use an anterior-segment infusion cannula (Lewicky; Visitec Company, Sarasota, FL) on a three-way tap through the paracentesis (Figure 10). This technique maintains the pressure and rigidity of the globe throughout the surgery. It also minimizes the occurrence of serious complications such as intraoperative choroidal effusions, particularly in high-risk patients (eg, high myopes, buphthalmics). We find that using the bottle’s height to control IOP increases the accuracy of the suture closure and nearly eliminates the incidence of significant hypotony and choroidals on the first postoperative day.
**SCLEROSTOMY**

We use a special punch to perform block removal of the cornea and sclera. An incision perpendicular to the surface at the sclerolimbal junction allows us to enter the anterior chamber through the anterior part of the trabecular meshwork. It is best to create the incision for filtration as anterior and corneal as possible in order to reduce bleeding and the chance of the ciliary body’s exposure or damage.

We prefer to use the punch, because it gives us anterior access to the potential sclerostomy area, even when the sides of the sclerostomy are not cut down fully. There is evidence that a small sclerostomy (0.5 mm) is adequate, may minimize astigmatism and the chance of limbal aqueous flow, and may maximize the chance of controlling outflow. We create an anterior incision that is slightly larger than the diameter of the punch’s head, insert the titanium Khaw Small Descemet Membrane Punch (No. 7-101; Duckworth & Kent Ltd.), and verify that a full thickness of limbus is engaged. The punch is aligned perpendicular to the eye to ensure a clean, nonshelved sclerostomy (Figure 11).

**PERIPHERAL IRIDECTOMY**

Next, we perform a peripheral iridectomy through the sclerostomy. The infusion acts like a third instrument. We can make the iris present to the wound without any intraocular manipulation by pressing gently on the posterior edge of the sclerostomy, a technique that minimizes trauma and the need for an assistant (Figure 12).

**SUTURING THE SCLERAL FLAP**

The sutures secure the scleral flap and provide adequate tension so that it can restrict the flow of aqueous. The ten-
sion provided by the flap and sutures is particularly important when antimetabolites are used in surgery, because it is the primary regulator of the IOP until significant healing occurs, which may be many months later if the surgery involved MMC. Tension is also important when particular ocular problems occur such as angle closure, which will likely produce a flat anterior chamber postoperatively in the absence of adequate resistance to aqueous outflow.

We routinely place a new type of adjustable suture designed by Dr. Khaw at each posterior corner of the scleral flap; we use a 10-0 nylon suture during trabeculectomy with MMC. Some sutures (eg, the 10-0 from Alcon Laboratories, Inc. [Fort Worth, TX]) are better suited for use as adjustable sutures, because they tend not to break under tension during their removal. After placing the initial two sutures, we can assess the need for additional sutures by

Figure 14. Transconjunctival loosening of adjustable sutures does not produce a sudden drop in IOP.

Figure 15. The authors create five corneal grooves for closure of the fornix-based conjunctival flap in order to minimize leakage and suture-related discomfort.
observing the amount of aqueous flowing through the flap.

We have used this new type of adjustable suture for more than 4 years. We adjust the sutures' tension postoperatively through the conjunctiva with a specially designed forceps that has very smooth edges (Khaw Transconjunctival Adjustable Suture Control Forceps, No. 2-502; Duckworth & Kent Ltd.) (Figure 13). The adjustable sutures allow a gradual titration of the IOP, more gradual than with suture removal or digital massage (Figure 14).8 In contrast, completely cutting or removing sutures in the early postoperative period can lead to insufficient flap resistance with aqueous overdrainage and hypotony, which is a particular problem when antimetabolite therapy is used.

CONJUNCTIVAL CLOSURE

We make a series of corneal grooves through which we place all closing sutures. We bury the knots in the cornea so that the patient experiences no suture-related discomfort (Figures 15 and 16). We first pass the suture through the corneal groove, create a purse string, exit through the corneal groove, and there tie off the suture. The procedure is repeated, except for the conjunctival purse string with the two to three middle sutures. This new technique has virtually eliminated central conjunctival retraction, leaks, and suture-related discomfort. To ensure a watertight wound, it is important to take secure bites of both Tenon's and conjunctiva if single closure is used.

POSTOPERATIVE MANAGEMENT

At the end of surgery, we administer a subconjunctival injection of steroid and antibiotic 180° away from the trabeculectomy site and ensure that it does not directly enter the eye through the sclerostomy. We no longer use mydriatics, because this trabeculectomy technique rarely results in ciliary muscle pain, a shallow anterior chamber, or the formation of central posterior synechiae. A mydriatic's disadvantages include a dilated pupil, which may increase the chance of lens-corneal touch if the anterior chamber is shallow, and a loss of accommodation with blurred vision.

If surgery involved MMC, we gradually lower the IOP over several weeks by means of the adjustable sutures. The period when adjustment is possible is much shorter (only a few weeks at most) if a weaker antimetabolite was used. We examine the topically anesthetized eye at the slit lamp. If there is significant inflammation, we blanch the conjunctiva with adrenaline 0.01% before adjusting the sutures. The stitch is identified by gently stroking and flattening the conjunctiva. We grasp the suture gently through the conjunctiva and push it in to bow and loosen it. If this technique does not work, then a sideways motion should loosen the suture. We cease loosening the sutures and check the IOP if we observe fluid flow. This process is repeated until the IOP falls a few millimeters of mercury, and we may use the process at subsequent visits until the target pressure is reached. In cases involving MMC, it is best not to loosen the suture too much at each adjustment, or the IOP may drop too low.

Videos of the Safe Surgery System are available at http://www.ucl.ac.uk/ioo/research/khawlibrary.htm.

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