Atlas of Pediatric Ophthalmology and Strabismus Surgery

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Preface

Infants and children are not merely little adults. The presence of a developing visual system, both anatomically and functionally, necessitates specific modifications in surgical planning and technique. Therefore, optimal therapy for pediatric ophthalmology and strabismus patients requires a thorough understanding of the unique medical and surgical problems encountered in these patients. *Atlas of Pediatric Ophthalmology and Strabismus Surgery* is written as a simple, practical source of the latest information on diagnosis, surgical anatomy, surgical planning, and surgical technique. The information is presented in a concise, step-by-step "cookbook" format, as though we are assisting the reader at the time of surgery. It is not intended to be a comprehensive textbook of pediatric ophthalmology and strabismus; rather, based on our clinical experience, we have selected the specific surgical indications and techniques that we have found most useful, effective, and widely accepted. To promote success, we emphasize clinical pearls and pitfalls. Where different approaches are possible, thorough discussion of the advantages and disadvantages of each is included.

The text is accompanied by realistic, step-by-step illustrations—most drawn from actual surgical slides—to simplify, yet accurately portray, the appearance of the surgical field. Although some variation in surgical anatomy exists, these drawings will facilitate the learning process by assisting the reader in identifying important landmarks and structures at the time of surgery, helping to prevent complications and to improve success.

The atlas is the product of years of clinical experience by the members of the Pediatric Ophthalmology and Strabismus Service of the University of Michigan Department of Ophthalmology and the W.K. Kellogg Eye Center; experience that has been molded and refined by observing our colleagues, modifying our approaches and techniques where improvements are possible, and teaching our residents and fellows. It is written for beginning students, whether residents or fellows, as well as experienced, practicing general or subspecialty ophthalmologists, who see children or adult patients with strabismus. It will serve as an introduction to the field, or as a refresher when performing a particular uncommon procedure. The atlas can also help expand one's surgical repertoire, as well as promote a better understanding of the most current indications and techniques in pediatric ophthalmology and strabismus for those who see these patients and then refer them to others for care.

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We would like to thank and credit our teachers, especially Drs. Marshall M. Parks, David L. Guyton, Eugene M. Helveston, and Forrest D. Ellis. Many of the ideas and procedures presented here are our modifications of their pioneering work. Many other pediatric ophthalmology colleagues also have influenced this work through their presentations, research, and discussions. Especially important have been our associations with Drs. Gunter von Noorden, William E. Scott, and Kenneth W. Wright. We have attempted to credit these and other colleagues for their unique work and apologize for any omissions. We are also indebted to our orthoptists, Miss Ida L. Iacobucci, C.O. and Ms. Elnajean Martonyi, C.O., as well as to the many residents and fellows, who have asked questions, shared insights, and challenged traditional teachings, facilitating evolution of our approaches and techniques. We would also like to thank Jaye Schlesinger, M.F.A. for her outstanding illustrations, so accurate yet simple, and Ms. Terri Layher for her tireless typing, editing, revising, and re-revising of the manuscript. Finally, we would like to thank Dr. Paul R. Lichter for his leadership and the Skillman Foundation for its support during the preparation of the *Atlas of Pediatric Ophthalmology and Strabismus Surgery*.

Monte A. Del Monte, M.D. Steven M. Archer, M.D.

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1

Strabismus Surgery Planning

INTRODUCTION

Ideally, strabismus surgery should produce orthophoria in all gaze directions, provide a full field of single binocular vision, and eliminate any visual need for a compensatory head posture. It is possible to approach this ideal in some cases; however, more realistic goals need to be established for most patients. For patients who develop esotropia in early infancy, a small residual deviation with limited binocular cooperation is an optimal result. For a patient with sensory strabismus due to a blind eye, a cosmetically acceptable esotropia often provides the most stable results. Restoration of full motility may not be possible in patients with restrictive or paretic strabismus.

Fortunately, most patients do not demand complete correction of their motility disorder. They (or their parents) usually consult a strabismus surgeon seeking relief of one of the following specific problems: (1) an ocular deviation or head posture that they feel is disfiguring, (2) a functional problem, usually diplopia or asthenopia, or (3) fear that an observed motility abnormality, while not a problem in itself, may be an indication of serious underlying pathology. Proper management of the latter may involve further work-up or simply reassurance, but surgery is often required for the first two problems. In cases in which surgery is indicated, the surgeon's job is to establish realistic treatment goals that address the patient's chief complaint and to design a surgical procedure that comes closest to achieving these goals.

PREOPERATIVE EVALUATION OF STRABISMUS

Evaluation of the strabismus patient is aimed at establishing a diagnosis and delineating those features of the patient's ocular motility that need to be corrected. Often the diagnosis is clear. However, in cases of unusual or complicated strabismus, the surgeon may complete the evaluation and be left with no clear idea of the origins of the patient's problem. While this is intellectually unsatisfying, it should not prevent the surgeon from proceeding to design a surgical procedure to correct the pattern of strabismus that has been found.

Sensory evaluation of the patient begins with visual acuity testing by whatever technique is appropriate for the patient's age. If decreased vision is found, then, when possible, steps to optimize vision should be taken before surgery. This may include patching therapy for amblyopia or optical rehabilitation in the cases of media opacities, significant astigmatism, myopia, or extreme hyperopia. Lesser degrees of hyperopia also need to be corrected before final evaluation of horizontal strabismus to con-

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trol for the contribution of accommodative factors. In the context of esotropia, hyperopia in excess of +2.50 D should be considered significant (sometimes even less if the esodeviation is less than 20^{Δ}). Also in exotropia, hyperopia of more than +4.00 D may be a complicating factor.

Tests of retinal correspondence are of academic interest, but generally do not alter the treatment plan. In general, patients who acquire their strabismus as an adult have minimal sensory adaptations and complain of diplopia, the elimination of which is the primary objective of surgery. On the other hand, patients whose strabismus developed in childhood have a combination of anomalous retinal correspondence and suppression at times when there is a manifest deviation. In this latter group, some care must be exercised to avoid creating diplopia where none existed preoperatively. Children will usually adapt readily to a new postsurgical alignment, but older patients with a history of childhood strabismus will sometimes lose their sensory adaptations and develop diplopia if their strabismic angle is altered, particularly if overcorrection results in conversion of an esotropia to an exotropia or an exotropia to an esotropia. In these patients, a trial with a handheld prism in the office or a Fresnel prism worn at home to simulate the anticipated range of surgical correction is helpful. The presence of diplopia during this testing is not necessarily a strict contraindication for surgery. Even most adults adapt eventually, but the surgeon and the patient must be prepared for the possibility of a difficult period of postoperative diplopia or, in the worst case, if the patient does not adapt, a reoperation to move the eyes toward the original angle of deviation to place the image of regard back into the suppression scotoma.

Cyclotropia should be measured with double Maddox rods in patients with vertical deviations and in those with complaints of cyclotorsion. Symptomatic cyclo-

torsion is often worse in down gaze, and measurements can be obtained in this position by raising the bridge of the trial frames and sliding them down the patient's nose. As a sensory test, the double Maddox rods may reflect the result of sensory adaptations and not the true physical excyclotropia in cases of congenital cyclodeviations, such as superior oblique palsy. In these cases, objective diagnosis of cyclotorsion can be made with indirect ophthalmoscopy by looking for rotation of the fundus landmarks (fundus torsion test). The patient's localization of the cyclotorsion to one eye or the other is often unreliable and credence should only be given to the net torsion between the two eyes. Again, evaluating fundus torsion by indirect ophthalmoscopy can be helpful in determining which eye or whether both eyes are actually torted in situations in which this determination is important.

The motor evaluation of the strabismus patient begins by simply observing the patient's eyes under casual viewing conditions. In some patients, a 20^{Δ} esotropia can give a very acceptable appearance whereas in others only a 10^{Δ} deviation can be quite noticeable. It should be kept in mind that alternate cover testing will often identify a latent as well as the manifest component of the deviation, not necessarily reflecting the spontaneous deviation that a patient demonstrates during daily living. While the amount of surgery is based on numbers measured with the prism alternate cover test, the need for surgery is based on functional considerations as well as the appearance under casual viewing conditions. For the purpose of surgical decision making, the manifest deviation alone can be measured with simultaneous prism and cover testing. This test is performed by placing a prism in front of the deviating eye while simultaneously covering the fixating eye and adjusting the prism strength until no shift occurs when the prism and cover are simultaneously introduced.

Any abnormal head posture should be noted. Head posturing behavior that is intermittent can frequently be elicited when a patient is struggling to read the smallest line on a distance acuity chart. In conditions such as Duane syndrome, superior oblique palsy, congenital nystagmus, and A- or Vpattern strabismus, the abnormal head posture may not only be helpful diagnostically, but may also represent the major clinical manifestation of the motility problem that surgery must be designed to eliminate. The initial observation phase of the examination is also a good time to note which eve is preferred for fixation, a point that may become important in planning surgery for exotropia when a recess-resect procedure is planned, nonconcomitant strabismus, or esotropia with markedly unequal vision.

The next step is examination of ductions and versions. Careful attention should be paid to overaction, underaction, or restriction of specific muscles, which will direct the surgeon's surgical efforts toward these muscles. Because ductions and versions are routinely evaluated in more extreme gaze positions, one can often observe subtle limitations or overactions that escape detection on prism cover testing.

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Next, quantification of any deviation using prism cover and prism alternate cover measurements is done. Measurements should be taken with distance and near fixation as well as in up, down, and lateral gaze positions. For cyclovertical deviations, the oblique gaze positions as well as right and left head tilt are also needed. In nonconcomitant strabismus, a primary deviation will be measured when the prism is held over the restricted or paretic eye and a larger secondary deviation will be measured when the prism is held over the sound eye. Whether the primary or secondary deviation is most important in planning the surgery depends on whether the underlying paresis or restriction can be addressed directly and, if not, which eye is preferred for fixation.

In many cases, when limitation of eye movement is present, the cause is immediately obvious. However, in other cases, it is not clear whether the limitation is caused by paresis or restriction, and passive or forced duction testing, along with active force generation testing, is needed to distinguish between these possibilities (Fig. 1-1). Passive duction testing can be performed in the clinic with topical anesthesia. In this



Figure 1-1



Figure 1-2

setting, as illustrated in Figure 1-2, fixation of the eve with an OKMC Miller Forced Duction Cup corneal suction device (Ocular Instruments, Inc., Bellevue, WA) will avoid the problems with conjunctival tears and bleeding often associated with the use of forceps. Passive duction testing is accomplished by asking the patient to look into the limited field of gaze as the examiner manually attempts to move the eye further in that direction. Limited passive duction indicates mechanical restriction of the muscles or globe (Fig. 1-1A), whereas free passive duction to the full extent of normal globe excursion suggests a muscle palsy or paresis (Fig. 1-1B). When passive duction testing cannot be conducted in the office (with most children, for example) it can be deferred until the patient is under anesthesia in the operating room. In these cases, it is suggested that contingency plans be made in advance for what will be done if mechanical restriction is or is not found. In addition, Alan Scott's differential traction test (see also Ch. 8 for Guyton's elaboration on this test), useful in discriminating between oblique muscle and vertical rectus muscle restriction, is best performed in the operating room. In this test, the eye is grasped with two pairs of forceps and retropulsed to exaggerate restrictions of the

obliques or proptosed to exaggerate restrictions of the vertical recti.

With muscle palsy, the antagonist muscle often develops some degree of restriction and a combination of both paresis and restriction can be present. In cases in which a mild or moderate degree of restriction is found, it can be unclear whether the motility disturbance is due primarily to the restriction or to a paresis of the antagonist muscle, with the restriction being only a secondary manifestation. Active force generation testing is helpful in this situation and can be performed with the same instruments used for passive duction testing. Active force generation is judged by asking the patient to look into the limited field of gaze while the examiner manually attempts to move the eye in the opposite direction, thus feeling the force of contraction (Fig. 1-1C). Abnormal active force generation suggests muscle palsy (Fig. 1-1D). Surgical treatment for paresis will be different from that for a primarily restrictive problem; however, secondary restrictive problems may also need to be addressed.

Finally, the systemic status of a strabismus patient also needs to be considered. It may be important not only from the standpoint of anesthesia options and potential intraoperative bleeding problems, but in some

cases it is the key to the strabismus itself and to the way it will respond to surgical treatment. Patients with neurologic disease (such as cerebral palsy) may respond to surgery very differently from other patients. In patients with peculiar motility patterns, the diagnosis of myasthenia gravis, Graves' eye disease, and myopathic conditions such as chronic progressive external ophthalmoplegia or Kearns-Savre syndrome should be considered. In patients whose strabismus is caused by a cranial nerve palsy, any appropriate work-up (such as for intracranial mass) should be undertaken before surgery. It should be pointed out that once an intracranial lesion (most often a tumor) has been found and optimally treated (where effective treatment exists), it is not necessarily a contraindication to proceeding with strabismus surgery, although the patient must be warned that a recurrence or further exacerbation of the problem is possible. People with intracranial tumors are as entitled to freedom from diplopia as anyone else and, after successful strabismus surgery, are often some of the most appreciative patients the strabismologist will encounter.

DESIGNING A PROCEDURE TO MATCH THE PROBLEM

The strabismus surgeon has only a limited number of options in altering the influence of a given muscle on the ocular motility; however, these can be combined in a large number of permutations to provide a rich variety of surgical effects. The surgeon's task is to creatively combine the limited number of manipulations that can be performed on each muscle to produce a procedure that best addresses a specific patient's need for alignment, concomitance, and normal head posture. This process should include looking at the ductions, versions, and prism cover measurements in various gaze positions to direct surgical attention to the muscle(s) that will assist in the fields where it is needed most.

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For a given extraocular muscle, the surgeon can basically strengthen its action, weaken its action, or, to a certain degree, alter its direction of action. For both weakening and strengthening procedures, it must be remembered that an extraocular muscle effects the ocular motility in two ways: it moves the eye in its field of action by active contraction and it limits the excursion in the field opposite its field of action by its passive elastic or restrictive properties. Whether a strengthening or weakening procedure has its major effect in the field of action or opposite the field of action will depend on the relative balance of passive and active factors for a given muscle. Weakening of a muscle is usually accomplished by recession, tenotomy, or myotomy. Strengthening of a muscle is usually accomplished by resection, plication, or tucking. In addition, the weakening of a muscle can be exaggerated in its field of action by a posterior fixation (Faden) procedure. The direction of a muscle's action can also be somewhat altered by transposition of its insertion. Contracture or cicatrization of the conjunctiva, Tenon's capsule, adjacent orbital fat septae, or anomalous fibrotic bands can produce restrictive problems that are also, in many instances, amenable to surgical treatment. Restrictions caused by the conjunctiva or Tenon's capsule can usually be dealt with by recessing these structures. Lysis of anomalous fibrous bands can be very effective, but is often complicated by reattachment and contracture of these bands with recurrence of the restriction. This problem of recurrent restriction also pertains to lysis of fat adhesions.

Strabismus surgery should be designed to achieve the desired goals with a minimum number of operations (preferably only one). A secondary and somewhat conflicting principle is to minimize the number of muscles operated on to achieve these goals. Multiple muscles should not be operated on gratuitously, but enough surgery should be

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done to assure a reasonable likelihood of a satisfactory result after the initial procedure. With large deviations or complicated strabismus with combined horizontal and cyclovertical deviations there is a temptation to stage the surgery as a series of smaller, more familiar, procedures. Although complex surgery may have a lower success rate, the staged approach has little to recommend it. If an attempt is made to fully correct a problem with the initial procedure, the worst outcome, an unacceptable result requiring reoperation, equals the best outcome from the first in a series of deliberately staged procedures. Reoperation after an initial complex procedure is more likely to involve muscles affected by previous operations, but this should not be a serious problem if the initial surgery was technically well done (without inducing undue cicatrization) and involved no potentially irreversible procedures. Procedures that may be difficult to reverse should be undertaken with caution and include marginal myotomy, free tenotomy, and any procedure involving the superior oblique. Inferior oblique myectomy, myotomy, extirpation, and probably recession in most cases are also irreversible, but in practice there is seldom a need to do so.

SPECIFIC RECOMMENDATIONS

Strabismus is an extraordinarily diverse condition; even two seemingly identical cases may respond entirely differently to the same surgery. For this reason, it is not possible to devise a set of surgical instructions that will assure a successful outcome in all cases. The following specific recommendations for the muscles to be operated on and the type and amount of surgery to be performed on them should give a reasonable success rate, but they are intended only as a starting point. It is incumbent on the reader to modify the surgery to match the motility pattern of each specific patient in accordance with the principles detailed above. Just as the richness of the English

language permits many ways of expressing the same thought, the variety of combinations available to the strabismus surgeon may include several different solutions to a given strabismus problem, all of which are founded on sound treatment principles and give roughly equal chances of success. This section does not pretend to be an academic treatise on all possible or proposed treatment schemes. For the sake of simplicity, only a limited number of established treatment options are presented; these necessarily reflect the author's biases. There is generally an unwarranted preoccupation with the exact amount (millimeters) of surgery to perform. In cases of concomitant strabismus, the patient's neural response to the surgery is probably a much more important factor in determining the outcome. Nonetheless, for a given patient, some amount of surgery must be chosen and recommendations based on the size of the preoperative deviation are provided below. These numbers serve as a starting point, but are undergoing constant evolution.

Esotropia and Exotropia

Suggested amounts of surgery for concomitant esotropia and exotropia are given in Table 1-1. The primary numbers in the table are for two muscle procedures (those in parentheses are for four muscle procedures). If the procedure of choice is a bilateral recession, then the selected muscle in each eye is recessed by the amount shown in the table for the given preoperative deviation. Bilateral resection procedures may be done in the same way. For a recess-resect procedure, the numbers from the recess and resect columns are applied to the respective muscles. For example, a patient with 30^{Δ} of esotropia could be treated with 4.5-mm bilateral medial rectus recessions, a 4.5-mm medial rectus recession and a 7-mm lateral rectus resection on one eye, or 7-mm bilateral lateral rectus resections. While the numbers given are good general guidelines, there are a few condi-

	Esotropia			Exotropia		
Deviation (Δ)	Recess Medial Rectus OU (mm)	OR	Resect Lateral Rectus OU (mm)	Recess Lateral Rectus OU (mm)	OR	Resect Medial Rectus OU (mm)
15	3		4	4		3
20	3.5		5	5		4
25	4		6	6		5
30	4.5		7	7		6
35	5		8	7.5		6.5
40	5.5		9	8		7
50	6		10	9 (6)		7 (5)
60	7		10	10 (7)		8 (6)
70	7			11 (7.5)		9 (6.5)
80	7		_	12 (8)		10 (7)
	Recess Medial Rectus	AND	Resect Lateral Rectus	Recess Lateral Rectus	AND	Resect Medial Rectus

Table 1-1. Horizontal Strabismus Surgery^a

^{*a*} For bilateral symmetric procedures, follow the instructions at the top of the columns. For unilateral recessresect procedures, follow the instructions at the bottom of the columns. For large-angle exotropia, bilateral recess-resect procedures (four muscles) according to the numbers in parenthesis are preferable to a unilateral recess-resect procedure if there is no contraindication to operating on both eyes.

(Data from Parks MM, Mitchell PR: Concomitant exodeviation. p. 12. In Duane TD, Jaeger EA (eds): Clinical Ophthalmology. JB Lippincott, Philadelphia, 1991 and Parks MM, Wheeler MB: Concomitant esodeviation. p. 10. In Duane TD, Jaeger EA (eds): Clinical Ophthalmology. JB Lippincott, Philadelphia, 1991.)

tions in which they should be routinely modified. The most commonly encountered of these conditions is esotropia in patients with cerebral palsy and marked developmental delay, in whom the numbers in the table will produce an unacceptable number of overcorrections. Treating these patients as if they had 10 to 15^{Δ} less esotropia than actually measured is one way of reducing the overcorrection problem.

For concomitant horizontal deviations, the choice of procedure is relatively straightforward. Except for small deviations in which the need for surgery is borderline, at least two muscles must be operated on. To maintain concomitance, one of the selected muscles should have its field of action in right gaze and the other in left gaze. Appropriate pairs of muscles include the two medial recti, the two lateral recti,

or the medial rectus and lateral rectus of one eye. Symmetric procedures involving a recession of one muscle in each eye have a certain tissues-sparing aesthetic. Recessions are also technically easier than resections. In cases in which there is a greater deviation with distance or near fixation, bilateral recessions will often show a greater effect at the desired fixation distance (as in bilateral medial rectus recession for an esodeviation that is greater at near fixation or bilateral lateral rectus recession for an exodeviation that is greater at distance). Patients with esotropia at near up to 15^{Δ} more than at distance can have bilateral medial rectus recessions for the near deviation without running undue risk of overcorrection at distance. Exotropic patients with larger deviations at distance should always have bilateral rectus recessions for their distance deviation. An esotropia at near is unusual after such surgery, but can be managed with bifocals if it does occur. Paradoxically, bilateral recessions (of a reasonable size) do not usually produce a large difference between distance and near deviations in cases in which such a difference did not exist preoperatively.

One clear indication for a recess-resect procedure is one eye with significantly better acuity or potential acuity than the other, when both the surgeon and the patient will be more comfortable with surgery that is limited to the bad eye. In an adult patient undergoing surgery under local anesthesia, a recess-resect procedure also has the advantage of requiring a retrobulbar injection in only one eye. Like symmetric recessions, a recess-resect procedure can be made to have more effect at distance or near by emphasizing the amount of surgery performed on the lateral rectus or medial rectus muscle, respectively, although there is usually a price to be paid in terms of nonconcomitance in lateral gaze. A starting point for this type of unbalanced access-resect procedure can be reached by using the distance deviation to arrive at a number from Table 1-1 for the amount of surgery to be performed on the lateral rectus and the near deviation for the amount of surgery on the medial rectus. An unbalanced recess-resect procedure is also particularly well suited for correction of lateral gaze nonconcomitance. To accomplish this, each muscle is recessed or resected according to the amount in Table 1-1, based on the deviation measured in the lateral gaze position corresponding to its field of action. For example, if operating on the left eye of a patient with 15^{Δ} in left gaze and 25^{Δ} in right gaze, the left medial rectus is recessed for 25^{Δ} (4 mm) and the left lateral rectus is resected for 15^{Δ} (4 mm).

In children, esodeviations of 60^{Δ} and more can be treated with large bilateral medial rectus recessions with a reasonable chance of success, as indicated in Table 1-

1. Large esodeviations in adults are less likely to respond adequately and more likely to have limitation of adduction with medial rectus recessions in the 5- to 7-mm range. Therefore, in adults with esotropia of more than 45^{Δ} , smaller amounts of surgery on three or four muscles is preferable. In both children and adults, when surgery must be restricted to one eve, a recess-resect procedure can be done for esodeviations of this size but is less desirable than the options discussed above. Lateral rectus resections of greater than 8 to 9 mm may be more likely to result in restriction of adduction and, if combined with a 7-mm recession of the antagonist medial rectus, can lead to late overcorrection. Esotropia under 15^{Δ} can be satisfactorily treated with a single medial rectus recession of 3 to 5 mm. A single muscle procedure for small-angle esotropia has the advantage of a low incidence of overcorrection.

Exotropia of 50^{Δ} or more can also be treated with a two-muscle recess-resect procedure if one wishes to restrict surgery to one eye. However, the amounts of surgery listed in Table 1-1 for these deviations often result in significant limitation of movement and, if there is good vision in both eyes, a bilateral procedure with smaller amounts of surgery on three or four muscles is usually preferred. The numbers shown in parenthesis in Table 1-1 are for bilateral recess-resect (four muscle) procedures.

A- and V-Patterns

A- and V-patterns may be treated by oblique muscle weakening procedures or vertical displacement of horizontal recti. In general, if there is overaction of the appropriate oblique muscles (inferior obliques for V-pattern and superior obliques for A-pattern), then surgery is best directed toward weakening the offending muscles (see Chs. 7 and 8). The exception to this is the fusing patient with an A-pattern (usually exotropia) and superior oblique overaction, in whom superior oblique tenotomies can produce asymmetric weakening with a relative iatrogenic superior oblique palsy and a vertical deviation in primary position, which results in torticollis. In patients without oblique overaction or in whom superior oblique tenotomies are to be avoided, the A- or V-pattern is treated with vertical displacement of horizontal recti (see Ch. 10 for details, including the direction of displacement).

Displacement of a single muscle has little effect. This procedure is performed on pairs of muscles, either the medial rectus of each eve, the lateral rectus of each eye, or the medial and lateral recti of one eye. Avoid displacement of a medial rectus on one eye and a lateral rectus on the other eye; this combination may also correct A- or V-patterns, but that is little consolation for the peculiar pattern of nonconcomitance that results. When there is a horizontal deviation in primary position, as there usually is, displacement is combined with the appropriate recession or resection procedures without modification of the amount of recession or resection for the primary position deviation. When there is oblique muscle overaction, weakening procedures of the obliques tend to produce whatever amount of correction is needed in a particular patient. One-half tendon width displacement to two horizontal recti will correct approximately 15^{Δ} and full tendon width displacement will correct up to 30^{Δ} difference between up and down gaze.

Dissociated Vertical Deviation

Surgical treatment of dissociated vertical deviation (DVD) does not eliminate the problem, but it is usually possible to reduce the floating of the eye to an acceptably unobtrusive amount. DVD in combination with marked inferior oblique overaction can be treated with inferior oblique anteriorization (see Ch. 7). In most cases, though,

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Deviation (Δ)	Recess Superior Rectus OU (mm)		
<10	6		
10	8		
≥15	10		

Table 1-2. Dissociated Vertical Deviation

DVD is treated with bilateral hang-back recession of the superior recti (see Ch. 12) in the amounts shown in Table 1-2. DVD is a bilateral condition and bilateral surgery should be performed, even in cases in which the DVD is not easily demonstrated in one of the eyes preoperatively. If unilateral surgerv is performed, the DVD in the unoperated eve will usually become obvious postoperatively and require additional surgery. Unilateral surgery can be considered in patients with marked ocular preference as a result of permanently decreased vision in one eye in whom alternation of fixation is unlikely to ever occur. In unilateral surgery, smaller amounts of superior rectus recession (5 to 8 mm) should be used to avoid a postoperative hypotropia. The large superior rectus recessions performed for DVD do not produce significant limitation of elevation. However, significant limitation of elevation will occur if another cause of vertical deviation is mistaken for DVD and the superior recti are recessed according to Table 1-2.

Concomitant Vertical Deviation

Vertical deviations of 15^{Δ} or less can usually be managed by surgery on a single muscle. One can expect recession or resection of a single vertical rectus muscle to cause an alignment change in primary position of approximately 3^{Δ} /mm of surgery. The amount of recession or resection is usually kept to 5 mm or less, but this limit is routinely violated in the treatment of Graves' eye disease and DVD. A vertical recessresect procedure is more potent than would be expected from the sum of the effects from each muscle individually and should be used conservatively for vertical deviations greater than 20^{Δ} .

Duane Syndrome

Duane syndrome is classically divided into several types based on the pattern of aberrant innervation. Of more value in planning surgical treatment for Duane syndrome is simply the distinction of whether there is esotropia, exotropia, or no deviation in primary position. The most common indication for surgery in Duane syndrome is a deviation in primary position (usually esotropia) that necessitates a face turn to obtain fusion. Treatment is by recession of the appropriate muscle (medial rectus for esotropia or lateral rectus for exotropia). Resection of a muscle on the involved eye, especially the lateral rectus, should be avoided, as unexpected horizontal deviations and increased retraction result. In young patients with esotropic Duane syndrome, large recessions (8 to 12 mm) of the medial rectus are needed to produce adequate correction. In older patients with markedly positive passive ductions indicating medial rectus restriction, the medial rectus is more easily crippled and 5- to 8-mm recessions are more appropriate. The esotropia (and associated face turn) in Duane syndrome is typically worse with distance fixation than at near. An absent or negligible face turn at near should not dissuade the surgeon from performing surgery since adequate surgical treatment for the face turn at distance fixation does not generally produce an overcorrection at near.

There are two other surgically treatable problems that occur in Duane syndrome: marked retraction and upshoot or downshoot in adduction. Large recessions (10 mm) of both the medial and lateral recti can be used to improve the retraction and associated enophthalmos. This procedure will also generally correct the upshoot or downshoot in adduction. If the upshoot or downshoot in adduction is an isolated problem, then it can be corrected with a lateral rectus Y-splitting procedure (see Ch. 10).

Cranial Nerve Palsies

The treatment of lateral rectus palsy depends on whether there is any residual lateral rectus function. For the purposes of surgical decision making, abduction past the midline and active force generation testing are good practical indicators of significant residual lateral rectus function. Essentially complete lateral rectus palsy, as indicated by the inability to abduct past the midline and absent active force generation, is treated with total transposition of the superior and inferior recti or a Jensen procedure (see Ch. 10), combined with recession or botulinum injection of the ipsilateral medial rectus. A large recess-resect procedure produces only temporary improvement in cases of complete laterally rectus palsy; however, it is the procedure of choice in patients with some residual lateral rectus function. as demonstrated by abduction well past the midline or an active force generation testing. The recess-resect procedure in such cases must take into account that the deviation is worse in the field of action of the paretic lateral rectus muscle. Fairly good normalization of concomitance can be obtained by performing an unbalanced recess-resect procedure as described above for lateral nonconcomitance. Using a left lateral rectus palsy as an example, the left lateral rectus would be resected according to Table 1-1 based on the esotropia measured in left gaze and the medial rectus would be recessed based on the esotropia in right gaze. An alternative method of providing differentially more correction in the field of the paretic lateral rectus is to resect the ipsilateral lateral rectus and recess the contralateral medial rectus muscle, with or without a Faden procedure (see Ch. 10).

Third nerve palsy is one of the most difficult strabismus problems to treat. With complete third nerve palsy, a large (10 mm) resection of the medial rectus and a large (10 to 12 mm) recession of the lateral rectus may occasionally be effective but more often will yield only temporary correction of the exotropia. On the other hand, if the third nerve palsy is only partial, a horizontal recess-resect procedure can be very successful. The amount of surgery is planned from Table 1-1 based on the exotropia measured in right and left gaze, similar to the method described above for lateral rectus palsy. Depending on the balance of the residual strength of the inferior and superior recti, there may be a hypertropia or, more often, because of the continued function of the superior oblique, a hypotropia. These vertical deviations are usually small enough to be treated by vertical displacement of the horizontal recti (see Ch. 10), which can be done in conjunction with the recess-resect procedure for exotropia. A one-half tendon upshift of both horizontal recti will only correct approximately 5^{Δ} of hypotropia, but full tendon upshifts can correct 10 to 12^{Δ} . Some cases of partially recovered third nerve palsy with aberrant regeneration are amenable to correction of the blepharoptosis and exotropia with a recess-resect procedure on the opposite eye. Patients can be evaluated as to suitability for this procedure by placing a base-in prism over the sound eye. This causes abduction of the sound eye, synergistic contraction of the medial rectus with adduction of the palsied eye, and aberrant innervation of the levator of the palsied eye. If a prism is found that gives a good alignment and lid position, a recess-resect procedure on the sound eye for that amount of exotropia is appropriate.

Of the cranial nerve palsies, treatment of superior oblique palsy involves the greatest number of options and combinations of muscles that can be operated on. As in all strabismus surgery, treatment should adhere to the principle of operating on those muscles whose fields of action are in the gaze positions where the deviation is worst. Further details are given in Chapter 8.

Mechanical Restriction

Treatment of mechanical restriction is based on the principle of relieving the restriction. When restriction is caused by a rectus muscle, then that muscle should be recessed. It is not possible to give any specific recommendations for the amount of recession in restrictive disease. The muscle needs to be recessed far enough to relieve the restriction. This distance often can be judged intraoperatively by tugging on the muscle to feel at what point it becomes stiff or by repeating passive duction testing when the muscle has been reattached to the globe at what is deemed to be an appropriate position. An adjustable suture technique (see Ch. 9) can be helpful in arriving at the correct amount of recession, with adjustment done either postoperatively or intraoperatively on the basis of passive ductions. Unless it is combined with adequate recession of the restricted muscles or periocular structures, resection of the opposite muscle is ineffective and causes retraction of the globe. Particularly after lysis of restrictive cicatricial tissue or fibrous bands, resection of the opposite muscle can be helpful to mechanically splint the eve in an overcorrected position in the immediate postoperative period while the healing areas of lysed scar tissue heal, mature, and contract.

Recession of a restricted rectus muscle will sometimes create a secondary strabismus problem that, in as much as possible. should be anticipated by incorporating treatment for this secondary problem into the initial procedure. For example, a patient with no deviation in primary position with a left medial rectus restriction that causes diplopia in left gaze can be expected to develop exotropia after medial rectus recession. This problem is aggravated because a restrictive inelastic muscle that does not stretch well often does not contract well either. In the example, the expected exotropia would be worse in right gaze, so appropriate pre-emptive treatment would be to recess the right lateral rectus also at the time of the initial procedure.

Blowout fracture of the orbital floor is a common cause of restrictive strabismus in which there is a hypotropia of the affected eye caused by restriction of the inferior rectus. The restriction usually involves cicatricial changes in the adjacent fascia or fat septae rather than entrapment of the muscle itself and is located too far posteriorly for easy surgical access. For these reasons, attempts to free the inferior rectus are nonproductive and the inferior rectus should simply be recessed. An additional problem in blowout fractures is that the restriction frequently masks an associated inferior rectus palsy. Reversal of the hypotropia to a hypertropia in extreme down gaze or an abnormal inferior rectus active force generation test should alert the surgeon that there is likely to be a serious postoperative problem with diplopia in down gaze. Problems in down gaze can be limited (at some expense to up gaze) by moderately undercorrecting the strabismus in the primary position and performing a Faden procedure (see Ch. 10) on the contralateral inferior rectus.

Graves' eye disease most commonly produces restriction of the inferior and medial recti. With asymmetric inferior rectus involvement, the hypotropia of the more involved eye can be treated by recession of its inferior rectus. The weakening effect of inferior rectus recession often continues to progress for many weeks postoperatively, so the surgeon should aim for a moderate undercorrection in the immediate postoperative period. Adjustable suture techniques are helpful in obtaining this result and their use in Graves' eye disease is discussed in Chapter 9. The problem of postoperative progression of the recession effect is minimal for medial rectus recessions and for inferior rectus recession if the contralateral inferior rectus has been previously recessed. An additional problem in Graves' eye disease is the λ -pattern (marked exotropia in down gaze), which may exist before surgery but is exacerbated by inferior rectus recession. Nasal displacement of any inferior rectus and superior displacement of any medial rectus muscles that are operated on helps to minimize this problem.

Brown syndrome is a restrictive problem involving the superior oblique. Its management is discussed in Chapter 8.

Reoperation

Reoperations should be planned in much the same manner as other strabismus procedures. The muscles and procedures to be included in the reoperation should be based on evaluation of the ductions, versions, and measured deviations in the diagnostic gaze positions. In applying this principle to overcorrections, Cooper concluded that "undoing what was done" is often not the best approach. This statement has been enthusiastically (but mistakenly) embraced by many strabismus surgeons as a general mandate to avoid reoperating on the previously operated muscles. In assessing where a problem is most likely to be found (Sutton's law: go "where the money is"), it should be kept in mind that a surgically altered muscle almost certainly functions more anomalously than a normal unoperated muscle. Particularly in overcorrections, one must look carefully at ductions and versions for a subtle lag of a previously recessed muscle or a subtle restriction of a previously resected muscle which, if left uncorrected, will often lead to eventual recurrence of the deviation. Even seemingly obvious cases need to be analyzed carefully in the context of the previous surgery. For example, when bilateral medial rectus recession leads to a secondary exotropia that is greater at distance, it seems obvious that the lateral recti are overactive (divergence excess) and should be recessed. However, if one recalls that a muscle's passive properties may also play a major role in the field opposite its field of action, then this example could just as easily be interpreted as a problem of underchecking by the recessed medial recti. In practice, in this situation, either bilateral medial rectus advancement or bilateral lateral rectus recession may give the desired correction, which is greater at distance than at near.

Undercorrections more often necessitate operating on new muscles (e.g., bilateral lateral rectus resection following bilateral medial rectus recession), but here too it is well to regard the previously operated muscles with suspicion. Even on a recessed muscle, surgically induced scarring can produce a subtle restriction that leads to a residual deviation. Resected muscles may slip back to reduce the resection effect or even produce a recession effect. If a small bilateral recession results in a residual undercorrection that is greater at the fixation distance corresponding to the recessed muscles (e.g., exotropia greater at distance after bilateral lateral rectus recession or esotropia greater at near after bilateral medial rectus recession), then consideration should be given to re-recessing the previously recessed muscles.

Patients presenting for reoperation often come without any details of what the previous operations were. Even when records of the previous surgery are available, the actual location of the muscles is often not as reported. Some details of the previous surgery can be gleaned from careful preoperative inspection of the surface anatomy (see Ch. 3); however, the surgeon should not hesitate to explore any muscle whose behavior seems at all aberrant. Problems that clearly demand exploration are marked limitation of action suggesting a slipped or lost muscle and an unexplained vertical deviation after lateral rectus surgery, suggesting inadvertent inclusion of the inferior oblique.

It is difficult to give guidelines for the amount of surgery to be performed in reoperations. If reoperation involves previously unoperated muscles (e.g., recess-resect after a recess-resect on the other eve. bilateral lateral rectus resection after bilateral medial rectus recession), then the numbers from Table 1-1 can be used. However, the bilateral resection numbers will tend to produce a slightly greater effect than suggested in the table if the antagonist muscles have been previously recessed. The effect of operating on a previously operated muscle is more difficult to predict, and the use of an adjustable suture technique (see Ch. 9) in this situation is often helpful. Several guidelines may be useful. A small additional recession of a previously recessed muscle (e.g., 2 to 3 mm of additional recession of a medial rectus muscle) produces a fairly large effect. Advancement of a previously recessed muscle produces somewhat less effect than a comparable number of millimeters of resection. For this reason, a small resection is usually also done in combination with an advancement. Recession of a previously resected muscle is more potent than recession of an unoperated muscle. Resection of a previously resected muscle has slightly greater effect than on an unoperated muscle. When a large effect is needed, it is difficult to know how much additional resection can be performed safely. A sense for this can be obtained intraoperatively by pulling up on the muscle to the point at which the muscle becomes inelastic and the resistance increases rapidly; the maximal safe resection is just short of the length of muscle pulled up to reach this point.

Nystagmus

In congenital motor nystagmus with a null point, surgery is directed toward eliminating the associated face turn. In regarding the position of the eyes in a patient with a face turn, one can think of the adducted eye as being "esotropic" and the abducted eye as being "esotropic." In effect, surgery for this problem consists of performing a recess-resect procedure on each eye to cor-

	"Esotropic" Eye		"Exotropic" Eye		
Head Turn	Recess Medial Rectus (mm)	Resect Lateral Rectus (mm)	Recess Lateral Rectus (mm)	Resect Medial Rectus (mm)	
≤20°	5	8	7	6	
30°	6.5	10	9	8	
45°	7	11	10	8.5	
≥50°	8	12.5	11	9.5	

Table 1-3. Null Point Nystagmus

rect this respective "deviation." The amount of surgery is graded depending on the amount of face turn, as shown in Table 1-3. When the face turn is obvious at dis-

tance but not at near, full surgical correction of the face turn with distance fixation can be undertaken with little fear of producing a postoperative face turn in the opposite direction at near. The numbers in Table 1-3 need to be modified in cases in which both true strabismus and null point nystagmus coexist. A method for dealing with this situation is to place a prism over the fixating eve until the face turn is corrected. With this prism still in place over the fixating eye, a second prism is placed over the nonfixating eve until the deviation is neutralized. Recess-resect procedures can then be performed according to the amount of prism that was in front of each eye based on the numbers from Table 1-1.

General Surgical Considerations

INTRODUCTION

After devising a surgical procedure that is likely to benefit the patient, a sequence of events must occur in order to carry out this procedure. The anatomic basis (see Ch. 3) and the technical details of performing each specific procedure (see Chs. 4 to 13) are covered in the remainder of this book. However, many of the considerations leading up to the incision and subsequent to final wound closure and eye dressing are common to most procedures and are discussed in this chapter.

PREOPERATIVE DISCUSSION

As discussed in Chapter 1, it is rarely possible to achieve an ideal functional result with strabismus surgery. It is important for the patient to have a realistic understanding of the goals of surgery, what it is hoped that the surgery will accomplish, and, more importantly, what the surgery cannot accomplish. The need to discuss motility results (for example, that surgery for a complete abducens palsy will not restore full ocular rotations) is obvious; however, ancillary issues may also need clarification. Postoperative patching therapy and spectacle wear are common sources of patient misunderstanding. While amblyopia should, in general, be treated as completely as possible prior to surgery, it must be made clear to

the parents that the surgery will not necessarily obviate the need for future patching therapy if there is a recurrence of amblyopia. In most cases of partially accommodative esotropia, surgery is directed at the nonaccommodative component of the deviation and the patient must understand that surgery is unlikely to eliminate the need for spectacles. Obviously (to the surgeon but not necessarily to the patient's parents), if the spectacles were prescribed for myopia, astigmatism, or anisometropia, they will still be needed postoperatively.

Potential complications must be discussed preoperatively as part of the process of informed consent. These include anesthesia complications, standard surgical complications, such as localized hemorrhage or infection, and the possibility of perforation of the globe with its attendant risk of retinal detachment or endophthalmitis. It may be reasonable to discuss the possibility of anterior segment ischemia syndrome, particularly in elderly patients who will have surgery of multiple muscles in the same eye. However, by far the most common unfavorable outcome of strabismus surgery, and that requiring the most preoperative discussion, is simply a failure to achieve the desired ocular alignment. The possibility of undercorrection or overcorrection with an attendant need for a reoperation to fine-tune the result should always be discussed.

The patient should be appraised of what to expect in the postoperative course. There may be nausea and vomiting for several hours due to anesthesia. There will be ocular redness, most of which will fade by 2 weeks, but even 2 or 3 months may be required for the original whiteness of the eye to return. The alignment of the eyes may be quite variable in the immediate postoperative period, sometimes taking 6 to 8 weeks to stabilize. Depending on the circumstances, adults may have problems with diplopia in the postoperative period. Children, particularly those with the desired initial postoperative overcorrection after surgery for exotropia, will sometimes comment on but rarely complain about postoperative diplopia. The recovery period is of particular concern to parents who need to return their children to day-care or who do not wish them to miss school and to adult patients who need to return to work. As a rule, children are able to return to their normal activities in 1 to 2 days, whereas adults may not want to return to work for up to 1 week, depending on their motivation. If an adjustable suture procedure is planned, the routine for postoperative suture adjustment should be explained. An eve pad is generally not used, except briefly in adjustable cases; patients are often relieved to learn this, especially when bilateral surgery is planned. Postoperative discomfort is usually minimal in children but (although not usually a severe problem) is more variable in adults. The patient should know the postoperative follow-up schedule and who will be seeing them (the surgeon, an assistant, or an orthoptist) at each clinic visit.

ANESTHESIA

A brief history to identify specific anesthesia risk factors should be taken, concentrating primarily on cardiac and respiratory disease. Malignant hyperthermia has a higher incidence in strabismus patients, and a past history or family history of an unusual anesthesia reaction should be sought. Patients with potentially difficult airways include adults with extreme obesity or significant cervical degenerative changes, infants with a history of ventilator support, and children with congenital facial abnormalities, especially those associated with micrognathia.

General anesthesia is used for children. Strabismus surgery in adults may be performed with local anesthesia, although general anesthesia is still preferred for bilateral cases. Young adults are often nervous about a local and may prefer general anesthesia, but true claustrophobia is the only common absolute contraindication to local anesthesia. Strabismus surgery can be performed under topical anesthesia in selected adults, but offers no particular advantage over local anesthesia and is associated with considerably more discomfort in most cases.

While the anesthetic agent will be selected by the anesthesiologist in general anesthesia cases, some knowledge of the peculiarities of certain agents will be useful to the ophthalmologist. Succinylcholine causes contraction of extraocular muscles. Therefore, if passive duction testing is crucial, at least 20 minutes should be allowed to pass before passive duction testing is performed; alternatively, the ophthalmologist can request that a different paralytic agent be used. Strabismus surgery is often associated with postanesthetic nausea and vomiting. Intraoperative administration of droperidol and metoclopramide, used prophylactically for their antiemetic properties, has been helpful in reducing postoperative nausea and vomiting. Propofol anesthesia has shown promise in reducing postoperative nausea and vomiting in adult patients, but has not been approved for use in children.

For local anesthesia, the injections are better tolerated after a brief induction with fentanyl, midazolam, and methohexital administered intravenously by an anesthesiologist. Many patients who would otherwise not consider local anesthesia are willing to forego general anesthesia if they know they will be asleep for a brief period during the actual injections. Local anesthesia is obtained by retrobulbar injection of a 1:1 mixture of 2% lidocaine (with or without epinephrine) and 0.5% bupivacaine with 150 units of hyaluronidase per 10 ml. When rapid recovery of extraocular muscle function is required for same-day suture adjustment, the bupivacaine should be omitted. Passive duction testing can be compromised by retrobulbar injection, which should be limited to 4 ml when the results of passive duction testing are critical. Supplementation with subconjunctival or perimuscular injections may be needed during the course of the procedure, especially in cases in which there has been significant cicatrization caused by trauma or previous ocular surgery. While not essential, a van Lint or O'Brien block can facilitate surgery by reducing squeezing of the lids. Even for local anesthesia, it is important to have an anesthesiologist monitoring the patient since severe bradycardia from the oculocardiac reflex can occur during retrobulbar injection and the course of the procedure. Some patients will also require further intravenous sedation during the procedure, which is best administered by the anesthesiologist.

PREOPERATIVE PREPARATION AND DRAPING

Each surgeon has a standard routine for skin preparation in ophthalmic procedures; in most cases, this will also be suitable for pediatric ocular surgery. One system that is suitable is to scrub with a 1:1 solution of providone-iodine scrub and water, wait 2 minutes, and remove the solution with water. Antimicrobial solutions that may have ocular or systemic toxicity, such as chlorhexidine (Hibiclens) and hexachloraphene (pHisoHex), should be avoided. Irrigation of the conjunctival fornices is not necessary. At the conclusion of the skin preparation, a drop of 2.5% phenylephrine can be instilled in the eye for its vasoconstrictive effect, which can improve visualization of the muscle through a intact conjunctiva and reduce bleeding from the conjunctival incision.

After the field has been draped with the usual cloth or paper drapes, a self-adhesive plastic drape is applied directly to the skin surrounding the eye or eyes that will undergo operation. For operations on a single eye, a 3M 1020 drape can be used; for bilateral cases, an Alcon 8065-102820 drape can be used; and for intraocular procedures, a 3M 1060 incise drape can be used.

POSITIONING

The patient should be positioned as shown in Figure 2-1, with the top of the head even with the end of the operating table. A foam donut under the head will help stabilize its position. The patient's neck should be slightly hyperextended; any flexion will make the procedure more difficult to perform. A rolled towel may be needed under the shoulders to achieve the proper degree of hyperextension. If an adequate degree of hyperextension cannot be achieved (for example, when there is cervical degenerative disease), the face can be positioned in the same plane by placing the operating table in Trendelenburg's position.

For most nonophthalmic procedures, the anesthesiologist will be positioned at the head of the patient; however, for strabismus procedures, the surgical team is often positioned on both sides of the head. For this reason, the endotracheal tube should be fitted with a straight connector (rather than the usual right angle connector) that will direct the anesthesiology tubing toward the patient's feet (Fig. 2-1), allowing the anesthesiology equipment to be positioned far



Figure 2-1

enough toward the foot of the table to permit the surgeon and assistant unobstructed access to both sides of the patient's head.

The positioning of the surgeon and assistant varies, depending on the muscle to undergo operation. For horizontal muscles, the surgeon and assistant are positioned on both sides of the patient's head, 180° from each other, as shown in Figure 2-2A. The view for dissection of a muscle and suture placement is best when the surgeon is positioned opposite the muscle (on left side of patient's head for surgery on left medial rectus and right lateral rectus and on right side of patient's head for right medial rectus and left lateral rectus). The assistant should be positioned on the same side as the muscle to provide the best retraction and globe positioning with minimal obstruction of the operative field. It is not possible for the surgeon and assistant to position themselves 180° from each other when operating on the cyclovertical muscles, as this would necessitate someone sitting on the patient's chest. Instead, the surgeon and assistant are positioned at roughly a right angle to each other, one at the top of the patient's head and the other at the side of the patient's head, as shown in Figure 2-2B. The pre-

 Table 2-1. Positioning for Extraocular Muscle

 Surgery^a

Muscle	Surgeon	Assistant	
Medial rectus	Ι	II	
Lateral rectus	II	I	
Superior rectus	III	IV	
1	Shift toward		
	patient's feet		
Inferior rectus	IV	III	
Superior oblique	III	IV	
Inferior oblique	II	Ι	
	Shift toward top of patient's head		

^{*a*} Positions (as labeled in Fig. 2-2) are shown for operation on the left eye.



Figure 2-2A



Figure 2-2B

ferred positions for the surgeon and assistant when operating on a given extraocular muscle are detailed in Table 2-1.

It is apparent from Figure 2-2 that the operative field becomes quite crowded when four hands are present. Proper hand positioning is important to minimize obstruction. Instruments, particularly muscle hooks, should be held close to their distal ends to get the holding hand as far out of the operative field as possible. When traction is needed toward the side opposite where the assistant is seated, the assistant should not reach over the patient's chest, but rather should reach around the top of the patient's head with the hand nearest the head of the table, as shown in Figure 2-2A. This allows the assistant's arm to be kept below the plane of the operative field, where it will not block the surgeon's access. For the same reason, the assistant's hand position should not be any further above the plane of the operative field than necessary for any particular maneuver. In some circumstances, splaying the fingers out to get the hand flat on the patient's forehead or face is a good way of accomplishing this. This is particularly helpful in the initial stages of a fornix incision when the assistant is grasping the limbus with a pair of forceps to position the eye, as shown in Figure 2-2B.

EQUIPMENT, INSTRUMENTS, AND SUTURES

Pediatric ocular surgery is facilitated by magnification. An operating microscope is mandatory for the intraocular procedures described in Chapters 14 and 15, but it is cumbersome for strabismus surgery, which is best performed with the aid of magnifying loupes. In selecting operating loupes, there is always a trade-off between magnification on the one hand and field of view and depth of field on the other. For loupes that are constructed as a Galilean telescope (e.g., Oculus, Designs for Vision, and most Keller loupes), magnification of $\times 1.5$ to $\times 2.0$ provides a good compromise between magnification and field of view. With loupes constructed as an astronomic telescope (e.g., Zeiss and Keller Panoramic loupes), it is possible to provide greater magnification, up to $\times 3.5$, while still maintaining a satisfactory field of view. The working distance of a pair of loupes is also an important parameter to consider. The optimal working distance will vary from surgeon to surgeon and should be long enough to allow the surgeon to operate comfortably with the body erect and with 90° flexion at the clows (approximately 45 cm for a 6-ft tall surgeon). Too short a working distance will force the surgeon to hunch over the operating field, resulting in rapid fatigue as well as obstruction of the lighting and the assistant's view of the field. Loupes that function as simple magnifiers should be avoided as they provide magnification only by unacceptably shortening the working distance. When evaluating loupes for purchase, it is important to personally test them for magnification, field of view, depth of field, and working distance under mock operating conditions.

Lighting can be provided by standard overhead operating lamps, preferably with an adjustable focus. The lamps should be positioned fairly close to straight over the patient's eye and directed over the surgeon's shoulder. For procedures requiring far posterior dissection and exploration, such as cyclovertical muscle surgery or a search for a lost muscle, a fiberoptic headlamp worn by the surgeon can be helpful.

The instruments and their use in the context of each specific procedure are detailed in Chapters 4 to 12. The instruments that should be included on a standard strabismus

Table 2-2. Muscle Instrument Set^a

_		
2	Jameson muscle hooks	E0586
2	Stevens tenotomy hooks	E0600
2	Green strabismus hooks	E0588
3	0.5-mm Castroviejo forceps	E1798
1	0.3-mm Castroviejo forceps	E1797
2	0.5-mm locking Castroviejo forceps	E1798 S
1	Westcott scissors	E3322
2	Castroviejo needle holders	E3861 WHMC
1	Castroviejo caliper	E2404
2	Hartman curved mosquito forceps	E3916
2	Hartman straight mosquito forceps	E3915
1	Kirby lens loop	E1216
1	Bishop tendon tucker	E2304
1	Desmarres retractor	E0980
1	Conway retractor	E0985
1	Thin malleable ribbon retractor	G5820
2	Storz tying forceps	E1887
2	Storz serrefine	E3900
1	Lancaster eye speculum	E4056
1	Cook eye speculum, pediatric	E4082
1	Cook eye speculum, infant	E4080
1	Alfonso eye speculum	E4112
2	Small towel clips	
1	Bishop-Harmon irrigating cannula	E4922
1	Irrigator adaptor	E4942
1	Silicone bulb	E4944

^{*a*} Right column lists appropriate Storz Instrument catalog numbers.

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	Table 2-3. Intraocular Instrument Set ^a					
1	0.5-mm Castroviejo forceps	E1798				
1	Elschnig forceps	E1684				
1	0.12-mm Colibri forceps	E3199				
1	0.12-mm Castroviejo forceps	E1796				
1	Fine jeweler's forceps	E1947 5				
2	McPherson straight tying forceps	E1815 S				
2	McPherson angled tying forceps	E1815 A				
1	Bracken fixation forceps	E1670				
1	Curved iris scissors	E3344				
1	Westcott scissors	E3322				
1	Castroviejo corneal scissors, right	E3304 X				
1	Castroviejo corneal scissors, left	E3305 X				
1	Vannas angled scissors	E3388				
1	Vannas straight scissors	E3386				
1	Storz straight iris scissors	E3404				
1	Castroviejo needle holder	E3861 WHMC				
1	Cohan mini curved needle holder	E3836 C				
1	Castroviejo caliper	E2404				
1	Barraquer iris spatula	E0485				
1	Harms trabeculotomes, right and left	E0421				
1	Kelly Descemet's membrane punch	E2798				
1	Swan knife needle	E0161				
2	O'Connor-Elschnig forceps	E2256				
3	Beaver knife handles					
3	Hartman curved mosquito forceps	E3916				
1	Hartman straight mosquito forceps	E3915				
1	Lancaster eye speculum	E4056				
1	Cook eye speculum, pediatric	E4082				
1	Cook eye speculum, infant	E4080				
1	Alfonso eye speculum	E4112				
1	McPherson angled bipolar forceps	S2050 10A				
2	Small towel clips					
2	#27 GA blunt angled cannula	E0499 27				
1	Bishop-Harmon irrigating cannula	E4922				
1	Irrigator adaptor	E4942				
1	Silicone bulb	E4944				

^{*a*} Right column lists appropriate Storz Instrument catalog numbers.

procedure tray are listed in Table 2-2, along with appropriate Storz Instrument catalog numbers; most are also available from other manufacturers. Instruments used for intraocular procedures (Chs. 14 and 15) are listed in Table 2-3. Instruments used for nasolarcrimal duct procedures (Ch. 16) are shown in Table 2-4. Selection of the appropriate lid speculum is a consideration common to all procedures described in this text. Each tray should have specula in a range of sizes, as shown in Figure 2-3. The Alfonso speculum (Fig. 2-3A) or Infant Cook speculum (Fig. 2-3B) is used in newborn and premature infants and in patients with very narrow palpebral fissures. The Pediatric Cook speculum (Fig. 2-3C) is suitable for most infants. The Lancaster speculum (Fig. 2-3D) is used most frequently, especially for strabismus surgery, and is appropriate for many children under 1 year of age, most children over 1 year of age, and all adults.

Vicryl (polygalactin) has become the

Table 2-4. Nasolacrimal Duct Instrument Set^a

1 Castroviejo lacrimal dilator	E4340
1 Large safety pin	
1 Bowman lacrimal probe, size 0000–000	E4200
1 Bowman lacrimal probe, size 00-0	E4201
1 Bowman lacrimal probe, size 1-2	E4202
1 Bowman lacrimal probe, size 5-6	E4204
1 Crawford hook	
1 McIntyre straight lacrimal cannula	E4395 8
1 Lacrimal cannula	E4404
1 Tenzel periosteal elevator	E4595
1 Kennerdell bayonet forceps	E8164
2 Castroviejo needle holders	E3861 WHMC
1 Fine suction tip	
1 Stitch scissors	E3340 WH
1 Nasal speculum #1	N2101

^{*a*} Right column lists Storz Instrument catalog numbers.



standard absorbable suture material for strabismus surgery and is typically used in the 6-0 size. The needle should be spatulated to avoid the problems of perforation associated with a reverse cutting needle or unroofing of the scleral tunnel associated with a cutting needle. The S-29 needle has proven to be most useful for strabismus surgery, although the shorter curvature of the S-28 needle is helpful when working far posteriorly, in tight spaces, or with poor exposure. Mersilene or Dacron in size 5-0 or 6-0 is used for those strabismus procedures that require a nonabsorbable suture (Faden procedure, superior oblique tuck, or rectus or superior oblique plication).

POSTOPERATIVE MANAGEMENT

Strabismus surgery is usually performed on an outpatient basis, and the patient can be discharged without eye patches after recovery from anesthesia. It is traditional to place patients on a 1- to 2-week course of an antibiotic/steroid combination ointment; however, it is unclear how much this benefits the patient's recovery and it may be omitted when application of the ointment will be unnecessarily difficult or when complications from the ointment might be anticipated, such as in a patient with glaucoma who is suspected to be a steroid responder. Analgesics are rarely necessary in children, but may be helpful in some adults, especially when exposed conjunctival sutures are present. When needed, acetaminophen is usually sufficient for children, but an acetaminophen/codeine combination is often more satisfactory for adults. Activities should be limited only to the extent necessary to keep irritating and potentially infectious agents from entering the eyes. Swimming is the most common such activity and should be avoided for at least 1 week postoperatively; however, play causing children to get dirty hands (for example, making mud pies) is often followed by eye rubbing and should also be discouraged. Most other activities, including lifting, climbing, bending, running, or returning to work, can be resumed as soon as the patient feels able.

The first postoperative examination should be scheduled for 1 to 3 weeks after the surgery. Little is to be gained by examining the patient on the first postoperative day. It may permit early detection of a lost muscle, but this is often best treated by reoperation several weeks later, after the muscle has had an opportunity to reattach at some point posterior on the globe. Examination is facilitated by waiting 1 to 3 weeks postoperatively in that much of the postoperative edema, hemorrhage, and discomfort will have resolved. If the alignment does not appear to be progressing toward the desired endpoint, this is also an excellent time for orthoptic intervention, before the final alignment has stabilized. Cases that would have been overcorrected or undercorrected can often be salvaged during this early postoperative period by appropriate use of plus lenses, minus lenses, patching, Fresnel prisms, or orthoptic exercises. The second postoperative visit should be scheduled for 6 to 8 weeks postoperatively. At this point, a good idea of the final alignment can be obtained, and decisions regarding any possible need for additional surgery can be made.

Surgical Anatomy

INTRODUCTION

In strabismus surgery, as in most surgery, each step builds on the last; small errors in the early steps compound in subsequent steps, making the procedure much more difficult than it should have been. An understanding of the normal anatomy of the extraocular muscles and their associated fascial and vascular structures contributes to the smooth progression of the surgery and avoidance of unnecessary complications. In difficult cases in which the anatomy is abnormal or has been altered, such as reoperations or congenital anomalies, meticulous identification of relevant anatomic landmarks at each step of the procedure engenders an understanding of these unusual anatomic relationships, which enables the surgeon to successfully complete the procedure.

SURFACE ANATOMY

Attention to details of the surface anatomy can be important in getting a strabismus procedure off to a good start. The details discussed here are relevant to all strabismus surgery, but are particularly important in fornix-approach procedures in which errors in placement of the initial conjunctival incision can disproportionately affect the difficulty of the ensuing procedure.

In surgery of the medial rectus muscle, the plica semilunaris and caruncle are important landmarks. The plica semilunaris is a vestigial remnant of the nictitating membrane in other vertebrates; as such, it is a sensitive and vascular structure. Incisions that extend into the plica will cause bleeding at the time of surgery as well as excessive scarring postoperatively. The plica is often tucked far enough into the nasal corner of the palpebral fissure to stay out of harm's way. However, the plica may be dragged well into the palpebral fissure as the eve is rotated into an abducted position, as shown in Figure 3-1, making it important to identify the plica to avoid accidentally incising it. Children often have a follicular reaction that occasionally may extend up onto the bulbar conjunctiva and the plica. These follicles do not themselves pose any hazard for the incision site but, when they are numerous, may distort the anatomy and make identification of the inferior half of the plica difficult. The caruncle is located so far into the medial corner of the palpebral fissure that it is usually not at risk for injury during a strabismus procedure. However, it does have some attachment to the underlying tissue and may become recessed after a large recession of the underlying medial rectus muscle or advanced as a result of a resection or cicatrization of the medial conjunctiva.

The most important aspects of surface anatomy lie not in what can be seen on the surface, but rather in the identification of underlying structures, such as the extra-



ocular muscles and the extraconal fat pad. which can be seen through the intact conjunctiva. The extraconal fat pad (Fig. 3-1) can be seen as a vellowish bulge beneath the conjunctiva in the inferior fornix. It normally lies approximately 10 mm inferior to the limbus, but fat may be encountered more anteriorly in elderly patients and in those who have had previous ocular surgery. Fornix incisions and the relaxation incision in a limbal approach should be kept anterior to the fat pad. Incision into the fat pad can cause bleeding and prolapse of orbital fat into the surgical field during surgery and a restrictive adherence of fat septae to the sclera postoperatively.

All four of the rectus muscles can be seen beneath the conjunctiva. They appear as areas of pink subconjunctival tissue. The anterior ciliary arteries that are associated with the rectus muscles are often easier to identify than the muscles themselves. They can be recognized as large subconjunctival vessels that do not move with the overlying conjunctiva as the eye is rolled gently back and forth. Blanching of the conjunctival vessels by preoperative installation of a drop of 2.5% phenylephrine can facilitate identification of the rectus muscles and their associated anterior ciliary arteries. Localization of the rectus muscles before incising the conjunctiva helps to keep the surgeon from becoming disoriented and inadvertently operating on the wrong muscle. Knowing the initial location of the muscle (along with the intended manipulationrecession, resection, transposition) is helpful in placing the initial conjunctival incision with a fornix approach, in which subtle variation in the relationship between the muscle and the incision site can greatly facilitate or hinder the remainder of the procedure. Regardless of the surgical approach to the muscle, initially engaging it on a muscle hook is easier if its insertion can be seen beforehand. This eliminates the urge to perform large sweeping motions with the muscle hook with excursions far posterior into the orbit, which risks inadvertently engaging undesired tissue, such as oblique muscles or orbital fat, on the hook. In cases in which the muscle may not be in the ex-



Figure 3-2

Tenon's Capsule

pected position, such as craniofacial syndromes or previous surgery, early identification of the muscle is of obvious benefit. In reoperations in which old records are not available, knowing the current anatomy is helpful in planning the subsequent procedure. Horizontal recti that have been previously operated on can usually be identified by the presence of scarring in the overlying conjunctiva. However, by looking closely through the intact conjunctiva in the clinic or before making an incision in the operating room, it is often possible to determine whether a muscle was resected or recessed: sometimes, even the amount of recession can be determined.

FASCIA

There are four fascial structures that the strabismus surgeon will encounter: the Tenon's capsule, muscle capsule or sheath, intermuscular septum, and check ligaments.

Tenon's capsule is a layer of elastic connective tissue that overlies the entire scleral surface of the globe from the limbus to the optic nerve. The extraocular muscles originate outside of Tenon's capsule and must penetrate it to reach their insertion sites on the sclera. Tenon's capsule is divided into an anterior portion that lies between the limbus and the penetration sites of the rectus muscles, and a posterior portion that runs from the penetration sites of the rectus muscle back to the optic nerve (Fig. 3-2). The anterior Tenon's capsule fuses with the conjunctiva and sclera 1 to 2 mm from the limbus. With a limbal incision, the Tenon's capsule and conjunctiva are reflected away from the globe simultaneously (Fig. 3-3). However, the conjunctiva and Tenon's capsule are easily separated a few millimeters posterior to the limbus and are routinely incised separately for a fornix incision. At



Figure 3-3

points more posterior than 10 mm behind the limbus, Tenon's capsule serves to separate extraconal fat from the sclera. At points where there is underlying fat, penetration of the Tenon's capsule will cause fat prolapse, which can lead to cicatrization and restricted motility of the globe or even a fibro-fatty infiltration of the extraocular muscles themselves. The site at which a rectus muscle penetrates Tenon's capsule provides an important constraint on the course of the muscle through the orbit. When the anterior portion of the muscle is transposed to a different location on the sclera, it must still pass through the same opening in Tenon's capsule, which has a relatively fixed location; the muscle pivots around its penetration site in Tenon's capsule, leaving the posterior course of the muscle relatively unchanged.

Muscle Capsule (Sheath)

As the extraocular muscles course anteriorly to penetrate Tenon's capsule, they carry with them a sleeve of the posterior Tenon's capsule. This muscle sheath is sometimes referred to as the muscle capsule. While histologically there may be no true extraocular muscle capsule, from the standpoint of surgical dissection, the muscle sheath certainly behaves as such. The muscle sheath is quite vascular where it overlies the rectus muscles and will bleed if incised. Anteriorly, the muscle sheath inserts into the sclera separately from the rectus muscle tendon. This surgical plane between the insertion of the head of the muscle sheath and the muscle tendon (Fig. 3-3) is usually easy to demonstrate and facilitates separate disinsertion of the muscle sheath, providing clean exposure of the tendinous insertion for secure placement of sutures. Placement of sutures predominantly in the muscle sheath may allow the muscle to retract within its sheath rather than become firmly attached to the sclera, the socalled slipped muscle. When a hemorrhage occurs within the muscle sheath (most often during the course of a resection procedure). the hematoma is constrained to stay within the muscle sheath, giving the entire muscle a blue-black appearance.

Intermuscular Septum

The intermuscular septum is an extension of the rectus muscle sheath that extends between the rectus muscles. Posterior to the insertion of the rectus muscles, the intermuscular septum separates the anterior Tenon's capsule from sclera. Its loose adherence to the sclera in the space between the rectus muscle can be easily broken by blunt dissection in the oblique quadrants. The intermuscular septum is best demonstrated as wing-like extensions from both sides of a rectus muscle after it has been engaged on a muscle hook (Fig. 3-3). The intermuscular septum also splits to ensheathe the oblique muscles after they penetrate Tenon's capsule. When viewed from the scleral side, the oblique muscles can be seen coursing within the intermuscular septum.

Check Ligaments

The check ligaments form attachments between the rectus muscle sheaths and an-

terior Tenon's capsule (Fig. 3-3). On the inferior and superior rectus muscles, the check ligaments constitute a broad band of attachment over the entire width of the muscle. On the medial and lateral rectus muscles, these attachments take the form of several falciform folds. Particularly over the medial rectus muscle, the remainder of the space between the muscle sheath and anterior Tenon's capsule is bridged by loose areolar tissue, an excellent landmark indicating the correct plane of surgical dissection. Sometimes, particularly over the lateral rectus muscle, there are small bridging vessels between the muscle sheath and anterior Tenon's capsule that will cause troublesome bleeding when cut.

EXTRAOCULAR MUSCLES

In humans, there are typically seven extraocular muscles associated with each eye (Table 3-1). The levator palpebrae superioris plays no role in moving the eye. The two obliques and the four recti constitute the remainder of the extraocular muscles. From the medial rectus to the inferior, lateral, and superior rectus, the recti insert at progressively greater distances from the

Muscle	Insertion (mm From Limbus)	Total Length (mm)	Tendon Length (mm)	Arc of Contact With Globe (mm)	Action in Primary Position
Medial rectus	5.5	40	4	6	Adduction
Lateral rectus	7	40	8	10	Abduction
Superior rectus	8	40	6	6.5	Elevation Intorsion Adduction
Inferior rectus	6.5	40	7	7	Depression Extorsion Adduction
Superior oblique	12	60	28	12	Intorsion Depression Abduction
Inferior oblique	14	37	<1	15	Extorsion Elevation Abduction

Table 3-1. The Extraocular Muscles



limbus, a relationship known as the spiral of Tillaux (Fig. 3-4). The insertions of the recti are all roughly 10 mm wide with a curvature that brings the insertion closest to the limbus centrally with the ends curving back posteriorly away from the limbus, as shown in Figure 3-4. When engaging a rectus muscle on a muscle hook, this curvature of the insertion must be kept in mind to avoid prematurely directing the tip of the muscle hook anteriorly and failing to capture the entire far pole of the muscle on the hook. There frequently are also small attachments of the underside of the rectus muscle to the sclera lying slightly posterior to the true insertion. These attachments are known as foot plates. The distance between the adjacent poles of the recti averages only approximately 7 mm. Because of this close relationship of the muscle insertions, it is relatively easy to place the conjuctival incision over an adjacent muscle, resulting in hemorrhage when an attempt is made to incise down to bare sclera. Occasionally, an additional slip of muscle tissue is found inserting into the sclera between the positions of the recti. This may represent a vestigial remnant of the retractor bulbi, an additional extraocular muscle that is commonly found in other vertebrates. Even more rarely, one of the usual rectus or oblique muscles may have an anomalous insertion or even be entirely absent.

Horizontal Recti Muscles

The functional anatomy of the horizontal recti is relatively simple. The medial rectus functions as an adductor and the lateral rectus functions as an abductor. Because of the wide insertions of the rectus muscles, these actions remain relatively pure even when the eye is in an elevated or depressed position. As an example of why this is so, consider what happens to the medial rectus as the eye is elevated. The superior pole of the muscle will roll back into the orbit, slackening the superior muscle fibers, whereas


the inferior pole rotates more anteriorly, increasing the tension on the inferior muscle fibers. Thus, while the muscle insertion has moved superiorly, the effective point of insertion has shifted toward the inferior pole, keeping the line of action for the muscle relatively straight back into the orbit. The muscle therefore remains an adductor and does not become an elevator when the eye is elevated. Strabismus surgery should maintain the width of the muscle insertion to preserve this functional state.

Vertical Recti and Oblique Muscles

The functional anatomy of the vertical recti and oblique muscles is more complicated. In many vertebrates with laterally directed eyes, the vertical recti act only vertically and the obliques have a pure cyclorotary action. In humans, however, the development of frontally directed eyes has been accompanied by only partial migration of the orbits from a lateral to a frontal position. This leaves the vertical recti and obliques with lines of action that are oblique to the visual axis when the eye is in primary position, as shown in Figure 3-5. Thus, in

primary position, the vertical recti and obliques have both vertical and cyclorotary actions as well as some adduction or abduction effect, as listed in Table 3-1. Contraction of a vertical rectus muscle and an oblique muscle as a pair tends to cancel unwanted secondary vertical, cyclorotary, or horizontal effects to produce relatively pure vertical or torsional eye movements. For example, cocontraction of the inferior rectus and superior oblique produces depression of the eye, with the extorsion and adduction effects of the inferior rectus being balanced by the intorsion and abduction effects of the superior oblique. Similarly, cocontraction of the superior oblique and superior rectus will produce relatively pure incyclotorsion with little vertical or horizontal action. An understanding of these functional relationships is particularly helpful in understanding the problems and planning the surgical correction of patients with superior oblique palsy.

INDIVIDUAL MUSCLES

Medial Rectus Muscle

The medial rectus muscle usually inserts approximately 5.5 mm from the limbus. The

medial is the one rectus muscle that does not pass in close proximity to an oblique muscle. If traumatically disinserted or accidentally released during surgery, the retraction of the other recti is usually limited by their attachments to an adjacent oblique muscle. On the other hand, the medial rectus is more likely to retract through its penetration site in Tenon's capsule to become irretrievably lost in the orbital fat.

Lateral Rectus Muscle

The lateral rectus muscle inserts approximately 7 mm from the limbus. The insertion of the inferior oblique lies beneath the inferior border of the lateral rectus muscle (Fig. 3-4) and is often inadvertently included in a lateral rectus procedure when an inexperienced surgeon sweeps far posteriorly with the muscle hook. If this occurs and is not recognized, the inferior oblique may be sewn into the lateral rectus insertion site. This can occur in both resection and recession procedures and may lead to unexpected amounts of horizontal correction, bizarre vertical deviations, or new cyclodeviations.

Superior Rectus Muscle

The superior rectus muscle inserts approximately 8 mm from the limbus. The superior oblique passes directly beneath (inferior to) the superior rectus (Fig. 3-5A) and is easily injured while dissecting the intermuscular septum during superior rectus surgery. Recession of the superior rectus often places at least one pole over the tendon of the superior oblique muscle. To avoid dealing with a scleral attachment when there is intervening superior oblique tendon, it is common practice to suture the superior rectus to its original insertion and allow it to "hang back" the desired amount of recession.

Inferior Rectus Muscle

The inferior rectus muscle inserts approximately 6.5 mm posterior to the limbus. There are fascial attachments between the inferior rectus and the lower eyelid that must be dissected free from the surface of the inferior rectus for a distance of approximately 15 to 18 mm posterior to its insertion if retraction or advancement of the lower lid is to be avoided when the inferior rectus is recessed or resected. These fascial attachments to the inferior rectus are in part responsible for elevating the lower lid and contribute to the way it follows the limbus when the eye looks up. Thus, some retraction of the lower lid is expected just from dissection of these attachments, particularly in patients with Graves eye disease, even if the inferior rectus is not recessed. Posterior dissection of the inferior rectus becomes difficult where the inferior oblique crosses inferior to it. At their crossing, the muscle sheathes of these two muscles form a dense band of tissue known as Lockwood's ligament.

Inferior Oblique Muscle

The inferior oblique muscle is unique in that it originates in the anterior orbit rather than near the apex of the orbit, as do the other extraocular muscles. It courses inferior to the inferior rectus muscle to insert posteriorly on the globe near the inferior border of the lateral rectus muscle (Fig. 3-5B). The inferior oblique is rather firmly attached at Lockwood's ligament where it crosses the inferior rectus muscle. With most inferior oblique weakening procedures (recession, myectomy, or disinsertion), Lockwood's ligament probably becomes the effective insertion of the muscle. With anteriorization procedures of the inferior oblique, the inelastic neurovascular bundle that enters the muscle near the lateral border of the inferior rectus may become the effective insertion for the distal 15 mm of the muscle. This posterior tethering redirects the line of action and may actually convert the distal portion of the inferior oblique to a depressor, or at least provide a mechanical limitation to elevation of the eye.

Superior Oblique Muscle

The superior oblique muscle has a unique course. It originates near the apex of the orbit and runs anteriorly toward the anterior orbital rim, where it changes its line of action as it passes through the trochlea (Fig. 3-5A), which functions like a fairlead on a sailing craft. Because the tendinous portion of the muscle must pass from the insertion, through the trochlea, and back to the muscular portion of the muscle, which remains entirely behind the trochlea, the tendon of the superior oblique is the longest of any of the extraocular muscles, approximately 26 mm. In other nonmammalian vertebrates, the superior oblique originates in the anterior orbit, near the location of the trochlea, in a manner similar to the arrangement for the inferior oblique muscle. Perhaps because the course of the superior oblique is such a phylogenetically recent innovation, the superior oblique insertion is the most variable of all of the extraocular muscles and it is also the most frequently anomalous or absent muscle. The superior oblique tendon is chord-like as it passes beneath the nasal border of the superior rectus, but fans out into a 10- to 18-mm wide insertion that is oriented roughly parallel to the lateral border of the superior rectus. This broad insertion places the posterior fibers behind the center of rotation of the globe, making them function predominantly to depress the eye. On the other hand, the anterior fibers are oriented circumferentially with respect to the center of rotation of the eye and function predominantly to intort the eye. This functional segregation of the tendon can be exploited by limiting a procedure to the portion of the tendon whose function one wishes to affect, as in the Harada-Ito procedure.

VASCULAR STRUCTURES

Since the anterior ciliary arteries provide a significant portion of the blood supply to the anterior segment of the eye, consideration must be given to them when planning a strabismus procedure. There are usually seven anterior ciliary arteries for each eye, two associated with each of the rectus muscles except for the lateral rectus, which has only one (Fig. 3-4). The anterior ciliary arteries run within the muscle posteriorly and emerge at a point behind the transition to the tendinous portion of the muscle to run along the surface of the muscle, within the muscle sheath. Along the surface course, the vessels usually run near each border (peripheral one-third) of the tendon (most often the inferior border for the single lateral rectus vessel) and often break up into a cluster of vessels rather than running as a single discrete artery. At the insertion of the tendon, the vessels emerge near the poles of the muscles onto the sclera to form an episcleral plexus. The vessels are easily injured at this point when dissecting the extraneous connective tissue from the insertion. The associated anterior ciliary arteries are sacrificed in a routine recession or resection of a rectus muscle. This can rarely lead to a syndrome of anterior segment ischemia, consisting of conjunctival injection, corneal edema, iritis, iris atrophy, corectopia, posterior synechia, and even cataract. Risk factors for the development of anterior segment ischemia include systemic vasculopathic conditions (including old age), blood dyscrasias, and surgery on multiple rectus muscles (particularly the inferior and superior recti, which provide a disproportionate share of the blood flow to the anterior segment). Once disrupted, the anterior ciliary arteries only rarely recanalize; therefore, while a lapse of time between previous surgery and surgery on additional

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muscles may allow for development of collateral circulation, anterior segment ischemia may still occur. In addition to the anterior and long posterior ciliary arteries, the perilimbal conjunctiva may, under some conditions, contribute to the blood supply of the anterior segment. The conjunctiva is a vascular tissue with rich anastamoses through its insertion at the limbus, as can be readily appreciated from the bleeding encountered with a limbal incision. A fornix incision preserves these anastamoses, and it has been suggested that this approach may afford some protection against anterior segment ischemia.

The four vortex veins emerge from the sclera posteriorly, approximately 16 mm posterior to the limbus, as shown in Figure 3-6. They may be injured in strabismus procedures that require posterior dissection if

the surgeon does not maintain an awareness of their location and take measures to avoid them. The four vortex veins are not equidistant from the horizontal and vertical recti, but rather are closer to the borders of the vertical recti. This makes the vortex veins particularly susceptible to injury during far posterior dissection of the inferior and superior recti, which is often necessary. As shown in Figure 3-6, the inferotemporal vortex vein loops superotemporally in the sub-Tenon's space along the posterior border of the inferior oblique, making it susceptible to injury during inferior oblique procedures. Surgery involving the insertion of the superior oblique tendon may injure the superotemporal vortex vein, which is located near the posterior aspect of its insertion.

Conjunctival Incisions

INTRODUCTION

Selection of the ideal conjunctival incision method, as well as proper technique, is important to the overall cosmetic and functional success of strabismus surgery. At least three incision methods have been used in the past: the Swan or over the muscle incision, the limbal incision, and the fornix or cul-de-sac incision.

Swan Incision

The Swan incision, although very popular 20 years ago and still used by some general ophthalmologists, has relatively few advocates among subspecialty trained strabismologists today. While it would seem simpler to make the incision directly over the muscle of interest, two significant drawbacks make this technique less desirable. First, the Tenon's capsule and intermuscular septum near the muscle are quite vascular, and a conjunctival incision in this area frequently produces significant bleeding. In addition, when incising directly over a muscle, especially if any scarring is present from previous surgery, it is quite possible to unknowingly cut completely through the muscle, resulting in muscle loss. For this reason, as is discussed in greater detail later, it is important to have a muscle hook engaging the insertion of any muscle before attempting to dissect near it. Second, the placement of the conjunctival incision directly over the muscle creates a scar that obliterates the surgical plane between the conjunctiva and underlying muscle. This scarring makes reoperation, when necessary, extremely difficult. For these reasons, the Swan incision should not be recommended for general use since better, less risky techniques are available.

Limbal Incision

The limbal incision is probably the most widely used of the conjunctival incision techniques. The easiest of the currently popular techniques to learn, the limbal incision provides very broad exposure to the rectus muscles. The technique can be performed successfully either with or, more importantly, without a trained assistant for all except the most complex reoperation or trauma cases. This technique is especially recommended in patients over 50 or 60 years of age, whose conjunctiva tends to be extremely thin and easily torn or shredded by the stretching that is required for the fornix incision method.

Finally, limbal incision allows for the possibility of conjunctival recession during wound closure. In the past, this feature was emphasized by several prominent strabismus surgeons who suggested performing conjunctival recession with nearly all rectus muscle recessions, sometimes called "en bloc" recession. It was stated that conjunctival recession would augment muscle recession and therefore should be performed especially when correcting all large deviations. However, most strabismus sur-

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geons currently feel that conjunctival recession is effective and necessary only when conjunctival restriction is present, generally only in older patients with longstanding deviations or in patients with scarring from multiple reoperations, past ocular surgery, or trauma.

Unfortunately, limbal incisions require slightly more time to open and, because they require sutures, more time to close. Following healing, broad scarring of the conjunctiva and underlying Tenon's capsule to the anterior sclera between the limbus and the new muscle insertion make reoperation, if necessary, more difficult. Many patients, especially children because of their thicker conjunctiva and Tenon's capsule, are more uncomfortable during the first week following a surgical procedure using a limbal incision, in part because of the exposed suture knots required to close the wounds. Finally, the perilimbal conjunctival irregularity and thickening, especially in children, may lead to immediate postoperative complications, such as dellen formation, and to perilimbal conjunctival scarring and distortion with a poorer cosmetic result.

Fornix or Cul-De-Sac Incision

The fornix incision, although somewhat more difficult to learn initially, can provide excellent exposure as well as rapid access to any of the extraocular muscles. Incision and closure are quick since no suture is required with a properly performed two-plane fornix incision. One incision can be used to approach two to three extraocular muscles: a superonasal incision for the medial rectus, superior rectus, or nasal superior oblique tendon; a superotemporal incision for the superior rectus, lateral rectus, and temporal portion of the superior oblique tendon; an inferonasal incision for the medial rectus and inferior rectus; and an inferotemporal incision for the lateral rectus, inferior rectus, and inferior oblique insertion. In fact, exploration and surgery on all six extraocular muscles can be performed with only two incisions. Patients are very comfortable postoperatively since the relatively small incisions used are completely beneath the eyelids and require no exposed sutures for closure. This advantage is especially important in children, since it permits excellent eve and motility examination within hours of surgery. Two-plane fornix incisions close with little scarring to the underlying sclera, thereby allowing easy access to muscles for reoperation, the anterior conjunctiva and Tenon's capsule being completely free from underlying sclera. In addition, the fornix incision is especially helpful in patients who have previously undergone surgery using limbal incision since the more posterior fornix incision allows the surgeon to avoid the anterior scarring and to obtain direct access to the adjacent muscle. By leaving the limbal and intrapalpebral conjunctiva intact, dellen formation is avoided and better final cosmesis is possible.

The fornix incision, however, is not ideal for all surgeons or patients. Since "four hands" are required to obtain adequate exposure, it requires a trained, skilled assistant. In fact, by optimal positioning of the globe, wounds, and muscles, the assistant can be nearly as important as the surgeon in obtaining optimal results. Being more difficult to learn, the inexperienced or infrequent strabismus surgeon, especially if the assistant is also inexperienced, can easily get lost during the procedure, thereby approaching and operating on incorrect muscles, splitting muscles, and so forth. In addition, the fornix incision should be avoided in most elderly patients, who risk tearing of friable conjunctiva, and in situations in which conjunctival recession may be required for mechanical conjunctival restriction.

Summary

If a skilled and trained assistant is available on a regular basis, the fornix incision is preferred in most pediatric and young adult patients. Patients will be more comfortable and happier postoperatively, reoperation will be easier, and cosmetic results will generally be better. However, the limbal incision is probably better for patients over 50 to 60 years old and for patients with extensive scar tissue who have undergone previous retinal detachment or strabismus surgical procedures. In addition, the limbal incision is preferred for patients requiring complex muscle procedures, such as lost muscles, in whom anterior tissue distortion is present, major landmarks are gone, and broad exposure is required for optimal surgical success.

SURGICAL TECHNIQUES

Limbal Incision

The approach to the left lateral rectus is illustrated.

Step 1. A Lancaster lid speculum is placed between the lids, exposing the

globe. A 6–0 double-armed black silk suture with a spatulated S–14 needle is then placed through the perilimbal episclera at the 6- and 12-o'clock positions. These limbal traction sutures, when clipped to the drape with a small hemostat, maintain maximal adduction, abduction, elevation, or depression of the globe for approach to the horizontal and vertical rectus muscles.

Step 2. Using a fine-toothed Bishop-Harmon or 0.5-mm Castroviejo forceps, the conjunctiva and Tenon's capsule are grasped at the limbus anterior to the center of the muscle insertion and lifted slightly to tent the limbal conjunctiva. A blunttipped Westcott scissors held perpendicular to the limbus is used to make a small 2- to 3-mm incision immediately adjacent to the limbus (Fig. 4-1A). The conjunctiva and



Figure 4-1

Tenon's capsule are then separated from underlying sclera by spreading the blunt-tipped Westcott scissors in the small limbal incision (Fig. 4-1B). The conjunctiva and Tenon's capsule are adherent to sclera for 2 to 3 mm posterior to the limbus. Care is taken that the scissors dissect through this adhesion into the natural plane between Tenon's capsule and the scleral surface, and not into Tenon's capsule.

- Step 3. The Westcott scissors are then rotated parallel to the limbus and the posterior blade is inserted into the wound, which is opened with a fine-tooth forceps, allowing the conjunctiva and Tenon's capsule to be shaved cleanly away from the limbus for 2 clock hours in either direction from the original incision (Fig. 4-2).
- Step 4. Using a fine-tipped skin marker, two small reference marks are

made next to each other along the limbus at each end of the peritomy, as shown in Figure 4-3. These marks will be used later to facilitate wound closure by merely reapposing adjacent marks.

Step 5. Radial relaxing incisions are then made by elevating the wound and incising radially between adjacent skin marks using the Westcott scissors. Be certain the relaxing incisions are full thickness through the conjunctiva and Tenon's capsule down to the bare sclera, and extend in the oblique quadrants between the rectus muscles to avoid inadvertently cutting a rectus muscle. In some cases, particularly routine recessions and resections of horizontal recti not previously operated on, only a single relaxing incision is required (single-winged incision). However, two relaxing incisions (double-winged incision), as



Figure 4-2

shown in Figure 4-3, are generally required for vertical rectus muscle and more complicated surgical procedures (e.g., reoperations) in which anatomy is distorted and very wide exposure is required.

Step 6. Remembering that Tenon's capsule and intermuscular septum are loosely adherent to the sclera for

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approximately 8 to 10 mm posterior to the limbus, the approach to bare sclera posterior to the muscle insertion, for passage of a muscle hook, requires an opening made in each quadrant. With the conjunctiva and Tenon's capsule elevated, as shown in Figure 4-4, a Westcott scissors is used to bluntly dissect,



Figure 4-3



Figure 4-4

by widely spreading the blades, radially back into the quadrant on either side of the rectus muscle of interest. Care is taken that spreading occurs radially into the oblique quadrant and not toward either adjacent muscle, this will avoid trauma to the vascular muscle capsule, which would result in hemorrhage, making identification of the muscle more difficult. Also, dissection, either blunt or sharp, must never occur directly toward a rectus muscle insertion until the muscle has first been completely localized and securely hooked with a muscle hook. This will avoid inadvertent incision into the insertion, which would result in bleeding or possible inadvertent tenotomy. with uncontrolled release of the muscle from the globe.

Step 7. With bare sclera visible posteriorly on either side of the muscle insertion, it is now simple, with direct visualization, to pass first a small Stevens muscle hook and then a larger Jameson or Green muscle hook completely beneath the muscle insertion, as shown in Figure 4-5. In fact, the entire muscle insertion often will be visible as the assistant gently elevates the conjunctiva. Only when the muscle is secured on a muscle hook should cleaning of excess Tenon's capsule from the muscle insertion be attempted using a blunt Westcott scissors and dissecting perpendicularly toward the muscle insertion. The excess Tenon's capsule can be easily visualized by tenting it using forceps traction on the conjunctiva/ Tenon's capsule flap to produce radial Tenon's folds extending from the flap to the limbus. Be careful to avoid large vessels in the anterior muscle capsule if possible. If any



Figure 4-5

are incised, control hemorrhage with cautery before inserting sutures into the muscle insertion to avoid inadvertent melting of sutures once they have been placed.

Step 8. With the muscle insertion completely cleared of Tenon's capsule and intermuscular septum, and the muscle secured with a large muscle hook, temporal traction on the muscle hook, as shown in Figure 4-5B, produces excellent exposure of the entire fanned-out muscle for placement of sutures. No further posterior dissection of Tenon's capsule/intermuscular septum from the muscle capsule is required for routine muscle recession in a previously unoperated muscle.

> However, moderate to extensive posterior dissection is sometimes required depending on the type of procedure, the muscles involved, and the size of the recession. All

muscle resections require extensive posterior dissection of intermuscular septum and anterior Tenon's capsule to well behind the resection point to prevent anterior displacement of the conjunctiva and Tenon's capsule (Fig. 4-6). Both recession and resection of vertical rectus muscles require complete posterior isolation of the muscle capsule as far back as the point of penetration through Tenon's capsule (generally 15 to 20 mm posterior to the insertion) to prevent creation of upper or lower lid retraction or elevation. In addition, most reoperations require sufficient posterior dissection to completely isolate the muscle from surrounding scar tissue and adhesions to the sclera to eliminate any mechanical restriction.

Step 9. After successful completion of appropriate muscle surgery, the con-



Figure 4-6



Figure 4-7

junctiva/Tenon's flap can be returned to its original position by reapposing the perilimbal reference marks made prior to incision with two interrupted sutures, as shown in Figure 4-7. Any fine suture is appropriate; a 7-0 collagen or even a residual piece of 6-0 Vicryl left over from the muscle procedure works well. The blue skin marker reference marks allow for easy symmetric repositioning of tissues. The suture should be placed superficially through the conjunctiva alone at the edge of the flap and then passed through the episclera in the perilimbal area. For normal closure, sutures should be placed in such a way that the conjunctiva drapes smoothly across the limbus at the time of closure. However, this technique also allows for conjunctival recession, if necessary, by reapposing the edges of the flaps more posteriorly along the radial incision. In this way, restriction caused by tight conjunctiva can be

relieved. Uncovered bare sclera will re-epithelialize from adjacent conjunctiva within 2 to 3 weeks. To determine the amount of conjunctival recession necessary to relieve conjunctival restriction, it is helpful to move the globe manually into far duction away from the conjunctival incision (e.g., into maximum adduction for a lateral limbal incision) and to then close the conjunctiva such that no tightness is present even in this maximally rotated globe position.

Fornix or Cul-De-Sac Incision

The inferonasal approach to the left medial rectus is illustrated.

Step 1. The assistant firmly grasps the conjunctiva/Tenon's capsule at the 7:30-o'clock position and rotates the eye maximally upward and outward while lifting the eye anteriorly into the palpebral fissure. The conjunctiva is then examined carefully to visualize the



Figure 4-8

underlying rectus muscles, identified by their radial long anterior ciliary vessels (Fig. 4-8), which generally can be seen easily beneath the conjunctiva, especially if a drop of 2.5% phenylephrine is instilled into the eye before surgery to blanch more superficial conjunctival vessels. Sometimes movement of the globe into positions of greater abduction or elevation will accentuate these vessels and the deep reddish hue of the underlying rectus muscles. With the location of the muscles identified, the relatively avascular zone of conjunctiva in the quadrant between the muscles is then selected for conjunctival incision. The bulbar conjunctiva is incised 6 to 8 mm posterior to the limbus by placing the widely spread blades of the blunt Westcott scissors horizontally on a line parallel

with the lid margin and, with moderate pressure on the globe, squeezing the scissors as shown in Figure 4-8. This technique will produce an incision through the conjunctiva only. Extend the conjunctival incision from a point 2 or 3 mm nasal to the inferior rectus to a point 2 mm from the plica. Be careful not to cut across the plica as this will produce a cosmetically unsatisfactory closure. Be certain that the conjunctival incision remains parallel to the lid margins and does not curve up into the normal palpebral fissure area when the lower lid is returned to its normal position. Also, take care not to place the conjunctival incision too far posteriorly into the true fornix, where superficial orbital fat can be incised, making the surgery much more difficult.

Step 2. With the eye still rotated up and

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Figure 4-9



Figure 4-10

out, Tenon's capsule is securely grasped with two 0.3-mm Castroviejo forceps, one held by the surgeon and one by the assistant, to form a tent or ridge parallel to the conjunctival incision. This ridge is then incised with a perpendicularly positioned blunt Westcott scissors, pressing firmly on the globe so that a full-thickness incision down to bare sclera will be accomplished with a single snip, as shown in Figure 4-9A.

- Step 3. After confirming that the Tenon's capsule incision extends to bare sclera, exposure can be enhanced by enlarging the Tenon's capsule incision posteriorly in a second plane perpendicular to the conjunctival incision using the blunt Westcott scissors, as shown in Figure 4-9B, again taking care not to extend the incision so far posteriorly as to incise the anterior orbital fat. Generally, an extension of 5 to 6 mm is all that is required.
- Step 4. With the two-plane incision now complete, the muscle insertion is approached, identified, and initially secured using a small Stevens muscle hook. While the assistant continues to position the globe, the surgeon positions the Stevens hook, as shown in Figure 4-10, inserting the tip into the wound, rotating it posteriorly toward the sclera, and then sweeping superiorly to engage the inferior border of the medial rectus insertion. If the conjunctival incision has been properly placed, as illustrated in Figure 4-10, the inferior border of the insertion will be very near the incision, simplifying this part of the procedure. In addition, keeping in mind a mental

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picture of the anatomy of the muscle insertions will simplify this step. The goal of this step is to merely secure the inferior pole of the muscle, not to attempt to hook the entire muscle insertion. Remember, the insertion is the only structure in this location 5 to 7 mm from the limbus that the hook can engage. Do not sweep the hook far posteriorly, as this will increase the risk of inadvertently hooking the wrong structure, especially in the inferotemporal quadrant where the inferior oblique may be hooked or the superotemporal quadrant where the superior oblique insertion may be engaged.

Step 5. Once the muscle incision has been engaged with the Stevens hook, the limbal forceps can be released, and the small hook replaced with a large Jameson or Green hook. The heel of the Stevens hook is elevated slightly away from the sclera to form a pocket or tunnel beneath the rectus muscle. The large muscle hook is then positioned as shown in Figure 4-11A; its tip is inserted into the wound, depressed to indent the sclera, and gently passed perpendicular to the muscle fibers beneath the entire muscle insertion. Verification that the entire muscle has been hooked is accomplished by rotating the large hook further clockwise until its tip approaches the limbus, as shown in Figure 4-11B. If the large hook has not captured the entire insertion, it will not be possible to rotate the tip to the limbal area; instead, the tip will hang up behind the muscle insertion at a point 5 or 6 mm from the limbus. In this case, move the



Figure 4-11

tip of the hook posteriorly, again rotate it toward the sclera, and sweep beneath the muscle. Repeat this step until there is evidence that the entire muscle insertion is secure, as shown in Figure 4-11B. After the large hook is passed, the Stevens hook is removed.

Step 6. Once the muscle has been secured, the overlying conjunctiva and as much of Tenon's capsule as possible is reflected over the tip of the large hook to expose the muscle insertion. Place a small Stevens hook anteriorly beneath the conjunctiva and, using anterior and posterior sweeping movements to bluntly dissect the conjunctiva from the underlying muscle capsule, sweep the conjunctiva superonasally over the tip of the large muscle hook. This technique is facilitated by simultaneously moving the large hook inferonasally, bringing the muscle

insertion down into the conjunctival incision while keeping the tip of the large hook elevated and angled toward the limbus to prevent the insertion from slipping off. This step is illustrated before (Fig. 4-12A) and after (Fig. 4-12B) conjunctival reflection. Be certain the conjunctiva is fully reflected, without a residual fold over the tip of the large hook, before incising the intermuscular septum as described in Step 7. If a fold remains over the tip, a superior conjunctival buttonhole will be created.

Step 7. The superior intermuscular septum is grasped with a 0.5-mm Castroviejo forceps adjacent to the tip of the large muscle hook and incised with a blunt Westcott scissors between the forceps and tip of the large hook, as shown in Figure 4-13. The small muscle hook is then removed from beneath the conjunctiva and inserted through





Figure 4-13



Figure 4-14

this newly created hole in the intermuscular septum to reflect the remnant of intermuscular septum over the tip of the hook, exposing its bare end.

Step 8. With the large hook and the preplaced Stevens hook viously (from Step 7) held by the assistant, a second Stevens hook is inserted into the hole in the intermuscular septum down to the bare sclera posterior to the muscle insertion, with its tip pressed firmly against the sclera as illustrated by the shaded hook in Figure 4-14. This hook is then swept superiorly and anteriorly around the presumed superior pole of the muscle in what is called the *pole test*. If the entire muscle insertion has been secured on the large hook, then the second Stevens hook will sweep smoothly, its tip constantly

against the sclera, from posterior to anterior to the superior pole of the insertion. In fact, with the Stevens hook in the anterior position tenting the intermuscular septum and Tenon's capsule, the entire superior pole of the muscle can be clearly visualized, further documenting that the muscle has not been split (Fig. 4-14). However, if the muscle is inadvertently split by the large muscle hook, the remaining unhooked superior muscle fibers will snag the small hook as it sweeps superiorly. Any restriction to smooth movement of the Stevens hook during the pole test indicates residual unhooked muscle and a split tendon. Should this occur, the surgeon can lift the residual fibers hooked with the Stevens hook onto the tip of the large muscle hook and Steps 7 and



Figure 4-15

8 can be repeated until there is evidence that the large muscle hook has secured the entire muscle insertion.

Step 9. At the successful completion of the pole test, the surgeon will have the anterior Tenon's capsule hooked securely and well separated from the rectus muscle insertion by the Stevens muscle hook (Fig. 4-14). This plane between the Tenon's capsule and muscle insertion is easily extended by blunt spreading with the Westcott scissors across the entire anterior surface of the muscle and then incised by placing the inferior blade of the Westcott scissors between the anterior Tenon's capsule and the rectus muscle tendon, as shown in Figure 4-15A. Be careful not to cut the conjunctiva inferiorly. It is desirable to incise as much of the anterior Tenon's capsule as possible with a single snip since re-engaging the diaphanous anterior Tenon's capsule may be difficult.

Step 10. Any residual anterior Tenon's capsule not removed in Step 9 can be removed by tenting it into narrow bands by dragging the side of a Stevens hook anteriorly, stretching any residual Tenon's capsule bands. These are then incised with the blunt Westcott scissors held perpendicular to the sclera, as shown in Figure 4-15B, being careful to avoid incising any long anterior ciliary vessels that may be present. This step results in a muscle insertion completely



Figure 4-16

cleared of fascial tissue so that sutures can be placed securely through the true muscle tendon. With the conjunctiva/Tenon's capsule retracted using two Stevens hooks, as shown in Figure 4-15B, easy access to the entire muscle insertion is possible for completion of any operative procedures.

Step 11. After completion of the muscle surgery, the fornix incision is closed by merely massaging the bulbar conjunctiva inferiorly to its original location with a moistened cotton-tipped swab or the side of a small Stevens hook. The lid speculum is then removed from the eye. A large muscle hook is used to gently elevate the lower lid while the bulbar conjunctiva is further massaged gently into its original position beneath the lower lid using the side of a Stevens hook, as shown in Figure 4-16. The lower lid is then lifted and elevated toward the upper lid, closing the posterior aspect of the wound. If the conjunctival incision has been placed properly, the entire wound will be hidden beneath the eyelid and the two-plane incision will be entirely self-closing without conjunctival sutures. However, if the wound has torn or widely stretched into the interpalpebral space, then one or two interrupted 7–0 collagen sutures can be placed.

Rectus Muscle Weakening Procedures

INTRODUCTION

Weakening of rectus muscles, either by recession or marginal myotomy, is among the most frequently performed strabismus procedure. A rectus recession is simple to learn, quick to perform, and significantly safer than a resection: therefore, one or more rectus muscle recessions are included in most initial strabismus surgeries. In addition, rectus muscle weakening procedures, especially large recessions, are significantly more "potent" than muscle strengthening procedures, yielding larger amounts of alignment change per millimeter of surgery. A recession alone may be performed unilaterally or bilaterally, or it may be combined with a resection of its antagonist in the same eye. See Chapter 1 for a thorough discussion of muscle selection and other aspects of surgical planning for stabismus surgery.

If both a resection and recession are to be performed on the same eye, it is generally advisable to perform the recession first. The initial recession is easier to perform and relieves significant tension from the globe, providing freer rotation for performance of the more complicated and riskier resection procedure. In addition, since a resection increases tension on a rectus muscle and its suture, excessive rotation of the globe after resection should be avoided to prevent the suture on the resected muscle from breaking or slipping, which will result in muscle loss. When multiple procedures are to be performed on a single eye, performing the procedures in the following order is helpful:

1. Tenotomy or myotomy of an oblique muscle

2. Recession of the inferior oblique

3. Large hang-back recessions, such as of the superior rectus for dissociated vertical deviation (DVD)

4. Standard recession of a horizontal or vertical rectus muscle

5. A superior oblique strengthening procedure such as a tuck or plication

6. Horizontal or vertical rectus resection

Adherence to this sequence will simplify the performance of each successive procedure and reduce the risk of complications.

SURGICAL TECHNIQUES

Double-Armed Suture Recession

A recession of the left medial rectus through a fornix incision is illustrated.

A double-armed (or crossed-swords) suture recession can be easily performed through either a limbal or fornix incision. See Chapter 4 for details concerning muscle isolation by either of these techniques.

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- Step 1. After the rectus muscle has been isolated and cleaned of anterior Tenon's capsule, it is splayed out widely by the assistant using a Green or Jameson muscle hook as shown in Figure 5-1A. The muscle insertion is then secured using a single double-armed 6-0 Vicryl suture with S-29 needles (Fig. 5-1A, B). One pole of the muscle is secured by introducing the S-29 needle near the center of the insertion, approximately 2 mm from the scleral insertion, and passing it half thickness through the muscle, exiting at the muscle border 1 mm posterior to the scleral insertion. The muscle pole is secured by a second full-thickness bite through the muscle tendon, which is then locked on itself, as shown in Figure 5-1B. The

identical procedure is performed with the other arm of the suture to secure the remaining pole of the muscle. As shown in Figure 5-1A, a small Stevens hook can be used to provide exposure to the superior muscle pole during suture placement. Attention to the details of suture placement is required to prevent later complications. No portion of the suture should pass through superficial sclera, as this will result in transection of the suture when the muscle is cut free from the sclera. In addition, the second locked bite at the muscle pole must be full thickness through the muscle since a partial-thickness locking bite may secure only the muscle capsule, resulting in a "slipped muscle" as described in



Figure 5-1





Chapter 13. The locked bite should include no more than 1 to 2 mm of the tendon margin because a larger bite may cause excessive bunching of the tendon and narrov/ing of the postoperative insertion width.

Step 2. The muscle is then excised cleanly from the sclera using either blunt Westcott scissors or Manson-Aebli corneal section scissors. The muscle insertion, globe position, and sutures must be controlled by the surgeon while the muscle is being disinserted from the globe. This is best accomplished by holding the Green hook between the first and second finger, with the pole sutures pulled taut between the thumb and first finger, as shown in Figure 5-2B. This maneuver allows proper positioning of the globe and muscle insertion for disinsertion and enables independent tension to be applied to the sutures. Placing slightly more tension on the sutures than on the muscle is helpful in pulling the suture away from the sclera and preventing it from being inadvertently cut. In addition, if a suture is cut during disinsertion, the problem will be immediately detected by a slackening of one of the pole sutures and the suture can be replaced before the muscle is completely disinserted and at risk of becoming lost. When performing a recession through a fornix incision, it is preferable to begin disinserting the muscle at the superior pole, opposite the inferonasal fornix incision, as shown in Figure 5-2A. Once the superior half of the insertion has been disinserted, the superior pole of the muscle stump is

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grasped by the assistant using a 0.5mm locking Castroviejo forceps to mark and stabilize its location before disinserting the remainder of the muscle insertion. Once secured at the superior pole of the original muscle insertion, this forceps serves as a retractor, replacing the Stevens muscle hook, and maintaining an adequate conjunctival opening. When the muscle has been completely disinserted, a second 0.5-mm locking Castroviejo forceps is used to secure the inferior pole of the muscle stump. These two locking forceps, held in one hand by the assistant as illustrated in Chapter 2, serve to stabilize and position the globe, identify the original insertion site, and help to retract the conjunctiva to provide adequate scleral exposure for suture placement.

Step 3. In preparation for scleral suturing, the assistant uses the two locking forceps to maximally lift the eye anteriorly while rotating it away from the operated muscle (into abduction in Fig. 5-3) to expose the sclera posterior to the original muscle insertion. The surgeon loads one needle, near its tip, into a curved micro-needle holder, which is placed on the adjacent drape or held nearby by the scrub nurse to speed needle placement after caliper measurement. Using a Stevens hook, held in the nonsuturing hand, the surgeon retracts the conjunctiva to expose the posterior sclera at the point at which the pole suture needle will be passed. The point of scleral penetration is then measured on a line perpendicular to the original muscle insertion, as shown in Figure 5-3, using a caliper. An



Figure 5-3



Figure 5-4

adequate scleral mark is created by moderate steady pressure on the posterior caliper tip for 5 to 10 seconds. This scleral entry site mark is then rotated by the assistant, using the preplaced locking forceps, into a centered location between the blades of the lid speculum and margins of the conjunctival wound; this allows easy needle access for initiation of the scleral pass.

Step 4. The scleral pass is initiated at the scleral mark, the needle passing shallowly (half depth) through the sclera. The direction of the pass angles superiorly and slightly toward the limbus from the inferior mark, and inferiorly and slightly toward the limbus from the superior mark so that the needles exit from the sclera in a "crossed-swords" fashion as shown in Figure 5-4A. Great care must be taken during placement of the scleral bites to prevent perforation of the thin sclera posterior to the muscle insertion. The

chance of perforation is minimized by approaching the sclera with the needle holder parallel to the sclera, its handle held anteriorly towards the cornea when operating on the medial, superior, and inferior rectus and either anteriorly or posteriorly for the lateral rectus. The needle should be grasped near its tip, and the needle holder rotated to keep the needle tip parallel to the surface of the sclera as the sclera is approached. The distal 2 to 3 mm of the needle tip is then advanced through superficial sclera to establish the half thickness sclera track. The needle is advanced carefully, 1 to 2 mm at a time, being certain that it is continuously visible through the sclera along its entire track. When performing a crossed swords scleral reattachment, it is advisable to leave the first needle in place in the sclera while the second pole suture needle is passed to exit the sclera near or just beyond the first needle track. This prevents inadvertent cutting of the initial suture by the second needle as it passes through the sclera nearby.

Step 5. After both scleral sutures have been placed, the second needle is pulled through the sclera first. Its entry site should be carefully exposed with a Stevens hook to prevent inadvertent entrapment of Tenon's capsule into the scleral tunnel as the suture is pulled through. Finally, the initial needle is pulled through the sclera, again keeping its entrance site exposed and free of Tenon's capsule, until the muscle stump is pulled up tight to its new insertion site. The new muscle insertion is now inspected to be certain that both poles are pulled up tight, that the new insertion is located directly posterior to the original insertion, that it is of approximately the same width, and that it does not have central sag (see Ch. 12). The exact amount of recession can also be verified at this time by caliper measurement at each pole, as well as at the center of the insertion. If the new insertion is acceptable, the sutures are tied off either by hand or instrument. The tie should consist of 2 throws pulled tight followed by 2 single throws squared on the first double throw. The new insertion is again inspected for signs of central muscle sag or a slipped pole suture (see Ch. 12 for identification and management of these problems). If the new insertion is acceptable, the suture ends are cut off leaving at least 2 to 3 mm, as illustrated in Figure 5-4B, to prevent the knot from untying spontaneously during the postoperative period. The conjunctiva is closed as described in Chapter 4 for either the limbal or fornix approach.

Single-Armed Suture Recession

A recession of the left medial rectus through a fornix incision is illustrated.

A single-armed suture technique may also be used in a recession procedure. It has several advantages over the double-armed technique:

1. The scleral passes can be made in any desired direction, so that a forehand pass with the dominant hand can be used for both scleral bites.

2. The short scleral bites employed are technically easier and possibly safer than the long scleral tunnels needed for the crossed-swords technique, particularly when exposure is difficult, as in a large recession.

3. Since the site of the second scleral bite can be determined after the first pole of the muscle has been secured to the eye, it is easy to select its site to stretch out the new insertion to the desired degree.

However, the single-armed technique also has several disadvantages, which include the following:

1. Additional sutures clutter the operating field and make the procedure more cumbersome at several points.

2. The length of the procedure is slightly increased by having to tie two knots instead of one.

3. Rather than tying a knot over bare sclera at a site remote from the muscle insertion, the knots are tied in close proximity to the muscle and extra care needs to be taken to keep stray bits of tendon or capsule from becoming engaged in the knots.

In addition, the single-armed technique is not appropriate for recession by adjustable suture (Ch. 9) or hang-back (Ch. 12) techniques.

Step 1. After the rectus muscle has been isolated and cleaned of anterior

Tenon's capsule, it is splayed out widely by the assistant using a Green or Jameson muscle hook. One pole of the muscle is secured using a single-armed 6-0 Vicryl suture with an S-29 needle (Fig. 5-5). The needle is passed, partial thickness, from the border of the muscle approximately 1 mm from the scleral insertion to exit from the surface of the muscle. This partial-thickness pass should include approximately one-third of the tendon width and any ciliary vessels that may be running on this side of the muscle. A second full-thickness bite is made that includes 1 to 2 mm of the lateral border of the muscle and the needle is brought back through the loop to form an overhand knot, which locks the bite.

The two suture ends are pulled to cinch down the tendon and then clamped together with a serrafine. This process is repeated for the remaining pole with a second singlearmed suture.

- Step 2. The muscle is disinserted from the sclera as described above (Step 2, Double-Armed Suture Recession).
- Step 3. The reattachment site for the pole of the muscle furthest from the incision (the superior pole in this example, in which the conjunctival incision is placed in the inferior fornix) is marked and optimally positioned as described above (Step 3).
- Step 4. A partial-thickness scleral bite is made at the site marked on the sclera (Fig. 5-6B). The direction of the scleral tunnel does not matter;



Figure 5-5



Figure 5-6

therefore, the pass may be made in the direction most comfortable for the surgeon. The scleral tunnel should be kept short, about 2 mm, because, when the sutures are tied together, the first throw of the knot tends to loosen if the tunnel is longer. Equal tension is applied to the two suture ends in a direction parallel to the scleral tunnel to pull the muscle up to the scleral entry site. Care should be taken not to allow any Tenon's capsule to be pulled into the suture track. The suture ends are tied together with tying forceps using a surgeon's square knot (a double throw followed by two single throws) (Fig. 5-6C). Care must be taken to keep any portion of the muscle from becoming caught in the knot. The ends of the suture are trimmed long to prevent the knot from untying spontaneously postoperatively.

Step 5. After one pole of the muscle has been sutured to the eye, the suture attached to the remaining pole is used to pull the muscle into position to judge where the second scleral bite should be placed to fully stretch out the new insertion (Fig. 5-6A, B). Calipers are used to mark this site at an appropriate distance posterior to the original insertion and the remaining pole of the muscle is attached at this site by repeating Step 4 (Fig. 5-6A, B). The new insertion is inspected and the conjunctiva is closed as described in Chapter 4 for either the limbal or fornix approach.

Marginal or Z Myotomy

A marginal myotomy of the right medial rectus through a fornix incision is illus-trated.

Recession is always the preferred technique for weakening a rectus muscle. However, occasionally a rectus muscle has been maximally recessed using standard tables, but additional weakening is necessary due to agonist muscle contracture or antagonist weakness. In this case, the surgeon must choose between "supra-maximal" recession, with the risk of limiting duction into the field of action of the recessed muscle, and marginal or Z myotomy. Marginal myotomy results in additional muscle weakening without further posterior movement of the muscle insertion. However, the procedure tends to be difficult to quantitate, is less predictable, and frequently is very difficult to perform. Remembering that the procedure generally is indicated only after a maximal recession, it is easy to understand the technical difficulty of crossclamping and performing a controlled partial myotomy of a rectus muscle so far posteriorly. Technical difficulties with instrument placement and exposure increase the risk of complete muscle transection, which results in secondary muscle loss.

A recent modification of the Z myotomy technique using marker sutures, as described below, can increase the ability to quantitate and control the weakening effect. In addition, careful attention to detail, such as clamp placement and myotomy length, also improves predictability and reduces the risk of complications. Interestingly, reoperation on a rectus muscle that has previously undergone Z myotomy sometimes reveals apparent muscle regeneration, with restoration of nearly normal muscle width and bulk at the myotomy sites, in spite of a persistent weakening effect.

Step 1. The rectus muscle is isolated through either a limbal or fornix incision as described in Chapter 4. Adherent Tenon's capsule, check ligaments, intermuscular septum, and frequently scar tissue (since this procedure is most often performed on previously recessed muscles) must be cleared from the 60 • Atlas of Pediatric Ophthalmology and Strabismus Surgery

distal 12 to 14 mm of the muscle, as described for rectus muscle resection in Chapter 6.

- Step 2. With the rectus muscle exposed and maximally splayed out on a Green muscle hook by the assistant, exposure of the distal muscle 12 to 15 mm is accomplished with Stevens hooks (Fig. 5-7) or a Conway retractor. Two Hartman or other small straight hemostats are applied across the rectus muscle from opposite sides, each crushing two-thirds of the width of the muscle, as shown in Figure 5-7. The anterior clamp is placed 2 to 5 mm posterior to the insertion and the posterior clamp is placed 5 mm posterior to the anterior clamp. The clamps are left in place for at least 15 to 20 seconds.
- Step 3. Before the clamps are removed, 2 marker sutures consisting of 6–0 or 7–0 Vicryl are placed superficially



Figure 5-7

in the central portion of the muscle, one just anterior to the anterior clamp and one just posterior to the posterior clamp. After tying the sutures tightly, the anterior suture can be cut short. However, it is helpful to leave the posterior suture full length to facilitate identification of the proximal muscle end should complete myotomy accidentally occur. Both Hartman clamps can then be removed.

- Step 4. Prior to marginal myotomy, tension on the Green muscle hook is reduced to prevent dehiscence of the weakened muscle after myotomy. In addition, the distance (a) between the 2 marker sutures (Fig. 5-8A) is measured and recorded as an indication of premyotomy muscle length. The posterior crushed muscle is then cut with Westcott scissors as illustrated. After the posterior cut has been completed, the anterior crushed muscle is cut from the opposite border in a similar fashion.
- Step 5. The resulting Z myotomy results in muscle elongation and weakening as shown in Figure 5-8B. The amount of elongation can be quantitated by remeasuring the distance (b) between the two marker sutures with a caliper. The difference between the postmyotomy intersuture distance (b) and premyotomy distance (a) approximates the amount of muscle elongation, which is related to the weakening effect. Following the procedure, the Green hook is very gently removed from beneath the rectus muscle and the conjunctiva closed as described in Chapter 4 for either the limbal or fornix approach.

In recent years, increases in the acceptable maximums for rectus muscle recession



Figure 5-8

have greatly reduced the need for Z myotomies. In addition, while overcorrections associated with crippling of the weakened muscle can occur with both procedures, one's ability to reverse an untoward result by reoperation is less certain after a Z myotomy than a large recession. Therefore, although the marginal or Z myotomy can be performed safely and effectively as described above, it is rarely performed today.

Rectus Muscle Strengthening Procedures

INTRODUCTION

A rectus muscle can be strengthened by shortening its length (resection), moving its insertion toward the limbus (advancement), or tightening its fibers (plication). These procedures increase active muscle force and passive muscle tension, as reflected in the length-tension curve. Strengthening procedures are best performed either with or following a muscle weakening procedure on the antagonist muscle of the ipsilateral eve, since resections are generally less effective and technically more difficult when performed alone. In addition, it is important to remember that small to moderate size muscle resections, like recessions, tend to have their greatest effect in the field of action of the resected muscle. This knowledge is helpful when planning surgery for noncomitant strabismus as discussed in Chapter 1 (e.g., emphasizing the resection of a right medial rectus for an exotropia greater in left gaze, or performing bilateral medial rectus resection rather than a recess/resect procedure for greater correction at near in convergence insufficiency).

Large strengthening procedures may also mechanically restrict rotation of an eye into the field opposite the field of action of the strengthened muscle. This secondary restriction is a major desired effect of the large resection performed as part of a Kestenbaum procedure, since the procedure is generally not effective unless the eyes are almost entirely restricted from moving into the field of action opposite the resected muscles.

Because of the increased tension on muscles and other tissues, strengthening procedures are more difficult, and therefore more dangerous to perform. Careful attention to detail is critical, especially in assuring firm suture bites into muscle and sclera, since the increased muscle tension quickly results in muscle loss if suture release occurs.

SURGICAL TECHNIQUES

Double-Armed (Crossed-Swords) Suture Resection

A resection of the left medial rectus through a fornix incision is illustrated.

Rectus muscle resection using a single double-armed suture is fast and easy to perform, using the same suturing techniques as used in a recession. In addition, it is easier to control the final muscle tension and position using this technique rather than other, more cumbersome techniques involving muscle clamps and mattress suturing. This technique can also be adapted for resection by adjustable suture, as described in Chapter 9.



Since only a single suture and suture knot is used, extra care is necessary to prevent muscle loss should suture breakage or release occur during or even after surgery. To reduce this risk, a modification of the muscle suturing technique used for recession is employed as described in Step 2. With this modification, there appears to be no greater risk of muscle loss using the double-armed suture technique.

Step 1. After the rectus muscle has been isolated through either a limbal or fornix incision, the insertion and adjacent sclera are cleaned of anterior Tenon's capsule, as described in Chapter 4. For resection, the muscle must be further prepared for suture placement by posterior dissection along its surface to remove intermuscular septum and check ligaments. With the muscle insertion controlled by the surgeon, using a Green or Jameson muscle hook, the intermuscular septum is lifted off the sclera and stretched out by the assistant using two small Stevens hooks, as illustrated in Figure 6-1. The "tented up" intermuscular septum is then cleanly dissected posteriorly by cutting as close to the muscle as possible using blunt Westcott scissors. This technique also exposes the check ligaments, which are seen as whitish, foamy or fibrous tissue connecting the surface of the muscle to surrounding Tenon's capsule. This tissue is incised using a combination of blunt and sharp dissection to separate it from the surface of the muscle.

Step 2. When the distal rectus muscle has been cleaned of intermuscular sep-





tum and check ligaments for several millimeters more than the planned muscle resection, a second Green muscle hook is placed beneath the muscle belly in the op-

posite direction to optimally expose the segment of muscle to be resected (Fig. 6-2A). These two hooks are then passed to the assistant to maintain proper exposure

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during suture placement. Using a caliper, the desired length of distal muscle to be resected is measured posteriorly from the muscle insertion as shown (Fig. 6-2A). A small bite of rectus muscle is taken centrally, approximately 1 mm posterior to the desired resection site using a double armed 6-0 Vicrvl suture with S-29 needles. With the suture pulled half way through, so that each arm is of approximately equal length, the suture is secured to the muscle with a square knot. This knot will secure each arm of the suture separately to the new muscle insertion, further protecting against muscle loss should one arm of the suture inadvertently break during the procedure.

Step 3. The new muscle insertion is created by passing one of the needles half thickness through the muscle belly. The needle enters the muscle at a point just anterior to the knot and exits at the muscle edge at the point measured with a caliper that has been set to the desired resection amount. It is very important to accurately measure the point of suture exit from the muscle edge, since this point will determine the actual amount of muscle shortening (Fig. 6-2B). A full-thickness locking bite is then placed just proximal to the half-thickness bite to incorporate 2 to 2.5 mm of peripheral muscle tissue, as illustrated in Fig. 6-3A). The identical procedure is performed with the other arm of the suture to secure the remaining pole of the new muscle insertion.

- Step 4. The muscle is cross-clamped with a Hartman clamp just distal to the muscle suture, being careful not to include any of the suture track within the clamped tissue. The clamp is left in place for 15 to 20 seconds to provide hemostasis. The muscle is then incised distal to the new insertion site by cutting through the center of the crushed tissue, as illustrated in Figure 6-3B. It is important to maintain tension on the two Vicrvl sutures while incising the muscle to prevent inadvertent transection of the intermuscular or extramuscular portion of the suture.
- Step 5. The remaining muscle stump is



Figure 6-3
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Figure 6-4

then removed by incising it cleanly from its original scleral insertion using blunt Westcott scissors (Fig. 6-4). Be careful not to leave any residual muscle stump, which would be cosmetically disfiguring and make resuturing to the sclera more difficult, since sutures passed through residual tendon fibers are much less secure than those passed through sclera.

Step 6. The original scleral insertion is secured by placing a 0.5-mm locking Castroviejo forceps just beyond each end of the original insertion, as shown in Figure 6-5. The muscle is then secured to the original insertion in a crossed sword fashion by deep scleral bites (Fig. 6-5). Remember that the sclera anterior to the muscle insertion is formed by the combination of the collagenous muscle tendon with the thinner posterior sclera. This thicker anterior sclera forms a distinct ridge anterior to the site of the original insertion. Therefore, each pole suture needle should enter the sclera at the base of this ridge, as shown in Figure 6-5B, to ensure at least half scleral depth throughout the entire suture track. In addition, to maintain full muscle width, and thereby avoid central muscle sag (see Ch. 12), each pole suture must enter the sclera at the far end of the original insertion, and then angle anteriorly to cross the opposite needle approximately 1 to 2 mm anterior to the original insertion, as shown in Figure 6-5A. If the two sutures exit from the sclera at nearly the same point, it is much easier to hold the muscle insertion tight against the original insertion as the sutures are being tied.

Step 7. The shortened muscle is advanced to the original insertion by sym-



Figure 6-5

metric firm traction on each pole suture as the globe is rotated by the assistant toward the advancing distal end of the muscle. Traction on each pole suture should initially be parallel to the scleral tunnel until the muscle has reached its new insertion, to prevent "cheese wiring" of the sutures through the sclera, which will separate the suture scleral exit sites. For very large resections, in addition to maximally rotating the eye towards the upcoming muscle, bringing the muscle up to the insertion may be assisted by gentle traction on the muscle with forceps, elevating first one pole and then the other. The two arms of the suture are then tied together with a double throw overhand knot advanced to 1 to 2 cm from the sclera. The muscle insertion is again inspected, and if either pole has slipped, gentle upward traction on the sutures, along with rotation of the globe should advance both poles fully. The double overhand knot is then tightened to hold the muscle in place (Fig. 6-6). If both sutures exit from the sclera close together, this knot will be self locking, and can then be completed with three single throws, squared on each other. If, however, the two scleral bites exit somewhat apart. the knot can be temporarily secured by the assistant temporally grasping the knot with a needle holder until the next single throw is tied down. It is important to use a Stevens hook to keep the scleral suture exit site clear of conjunctiva and Tenon's capsule during the tying process to prevent either



Figure 6-6

from becoming caught in the suture knot, thus making it less secure.

Single-Armed Suture Resection

A resection of the left medial rectus through a fornix incision is illustrated.

A single-armed suture technique may also be used in a resection procedure. It has several advantages over the double-armed technique:

1. The scleral suture passes can be made in any desired direction so that a forehand pass with the dominant hand can be used for both scleral bites.

2. Since the site of the second scleral bite can be determined after the first pole of the muscle has been secured to the eye, it is easy to select the second site to stretch out the new insertion to the desired degree. This makes it less likely that the central portion of the muscle will sag, a relatively common problem with resections. Selecting the suture placement site in this manner is particularly helpful when the muscle insertion is also being shifted and there are not good landmarks for where the scleral bites should be placed.

However, the single-armed technique also has several disadvantages, which include the following:

1. Additional sutures clutter the operating field and make the procedure more cumbersome at several points.

2. The length of the procedure is slightly increased by having to tie two knots instead of one.

3. Rather than tying a knot over bare sclera at a site remote from the muscle insertion, the knots are tied in close proximity to the muscle, so that extra care must be taken to keep stray bits of muscle or capsule from becoming engaged in the knots.

In addition, the single-armed technique cannot be readily adapted to resection using an adjustable suture technique (Ch. 9).

- Step 1. Through a limbal or fornix incision, the rectus muscle is isolated and cleaned well posterior to its insertion and two Green muscle hooks are used to expose the segment to be resected, as described above (Steps 1 and 2, Double-Armed Suture Resection).
- Step 2. Using a caliper, the desired length of distal muscle to be resected is measured posteriorly from the muscle insertion (Fig. 6-7). The needle of one-half of an 18 in. 6–0 double-armed Vicryl suture is passed at this point, partial thickness, from the border of the muscle



Figure 6-7

to exit from the surface at almost the middle of the muscle. A second full-thickness bite is made that includes 2.5 mm of lateral border of the muscle and the needle is brought back through the loop to form an overhand knot, which locks the bite. The two suture ends are pulled to cinch down the tendon and then clamped together with a serrafine clamp. This process is repeated with a second single-armed suture on the opposite side of the muscle.

- Step 3. The muscle is cross-clamped, incised, and the remaining stump removed from the sclera as described above (Steps 4 and 5, Double-Armed Suture Resection).
- Step 4. The original scleral insertion is secured by placing 0.5-mm locking Castroviejo forceps just beyond each end of the original insertion, as shown in Figure 6-8. The muscle is then advanced and reattached to

the original insertion with scleral bites passed at the correct depth, as shown in Figure 5-6B. The pole of the muscle furthest from the conjunctival incision (the superior pole in this example, in which the conjunctival incision is placed in the inferior fornix) is secured first as described in Chapter 5 (Step 4, Single-Armed Suture Recession). The remaining pole of the muscle is then pulled forward to find the point of attachment that will stretch and fan out the insertion adequately for the prevention of central sag (Fig. 6-8A).

Step 5. A scleral bite is taken at the insertion with the needle from this second suture (Fig. 6-8B) and secured in the same manner as the first suture with a surgeon's square knot consisting of the double throw followed by two single throws (Fig. 6-8C). The needle should be passed. more or less, from posterior toward the limbus to take advantage of the scleral step-off at the disinsertion site; however, it may be angled somewhat to either side to best accommodate comfortable passage with the dominant hand. The scleral tunnel should be kept short, about 2 mm, because, when the sutures are tied together, the first throw of the knot tends to loosen if the tunnel is longer. Before tightening down the first throw of the knot, the muscle is pulled all the way up to the insertion by applying equal tension to the two suture ends in a direction parallel to the scleral tunnel while rotating the eye toward the upcoming muscle. Care must be taken to keep any portion of the muscle or Tenon's capsule from becoming caught in the knot. The ends of the suture are trimmed



Figure 6-8

long to prevent the knot from untying spontaneously postoperatively.

For large resections, the sutures at each pole can be partially pulled up in alteration,

a bit at a time, after the first double throw has been tied in both sutures. When one pole has been partially pulled up and the first throw of the knot snugged to hold it in position, the tension on the second pole is less and that suture is then in turn easier to pull up. By working back and forth between the two sutures in this manner, even a muscle under considerable tension can be brought up to its insertion site with relative ease.

Strengthening by Advancement

A rectus muscle can be strengthened by advancing its insertion toward the limbus. Advancement is most often performed when a muscle has been previously recessed. In this situation, a small resection is usually combined with advancement of the muscle back to the vicinity of its original insertion. The sum of the number of millimeters of resection and the number of millimeters of advancement can be used to give some idea of the expected strengthening effect; this combined procedure is roughly equivalent to the total number of millimeters of resection alone. The technique for advancement of a muscle is identical to that for resection except that, after the stump has been excised from the sclera, the locking Castroviejo forceps are placed at the site of the intended new insertion rather than at the current insertion site. The resection performed in association with advancement may be smaller than that which is normally performed for resection alone. When the resection is less than 3 mm, the excess muscle will retract sufficiently that excision of the muscle distal to the sutures is optional; the muscle can simply be disinserted from the sclera in the same manner as for a recession.

Strengthening by Plication

Plication of the left medial rectus through a fornix incision is illustrated.

Muscle plication may be performed instead of resection to strengthen a rectus muscle. This procedure is especially valuable in complicated cases because it can be easily and fully reversed during the early postoperative period by merely cutting the muscle suture and allowing the muscle to return to its original location. In addition, in eyes which have already had operations on several rectus muscles, this procedure may allow strengthening of a rectus muscle while preserving anterior segment circula-



Figure 6-9

tion through the intact anterior ciliary vessels, and thereby possibly reducing the risk of anterior segment ischemia.

This older technique was largely abandoned in favor of muscle resection partly because it was thought that the plicated muscle would produce a bulky, cosmetically disfiguring lump at the muscle insertion. However, when properly performed using newer surgical techniques and suture materials, postoperative inflammation rapidly subsides, with thinning of the plicated muscle bulk, which results in an excellent cosmetic appearance.

- Step 1. The distal portion of the rectus muscle to be plicated is isolated, cleaned, exposed, and secured with a double-armed suture as described above (Steps 1 to 3, Double-Armed Suture Resection), except that a nonabsorbable 5-0 or 6-0 Mersilene suture, double-armed with spatulated needles, is substituted for the 6-0 Vicryl suture, since no cut muscle surface will be created to firmly fuse the plicated muscle in its new location. When placing the Mersilene suture, it is important to avoid the anterior ciliary arteries, which lie superficially on the muscle surface along the distal 5 to 10 mm posterior to the insertion, as shown in Figure 6-9. The arteries can generally be avoided by passing sutures beneath them through the muscle itself, and being careful to avoid including the arteries within the lock bites. If one of the arteries is near the edge of the muscle, it can be gently pushed centrally over the surface of the muscle with a blunt tipped instrument while the full-thickness locking muscle bite is completed.
- Step 2. After the Mersilene suture has been secured in the muscle at a distance from the insertion equal to the de-



Figure 6-10

sired plication or shortening, the needles are placed through the anterior sclera in crossed swords fashion, as illustrated in Figure 6-10. The suture needle must enter the sclera just adjacent or slightly anterior to the pole of the muscle insertion to obtain the correct tucking effect. Be careful to avoid the finer branching ciliary vessels during suture placement to preserve as much anterior segment circulation as possible. Again, it is extremely helpful for both suture needles to exit from the sclera at nearly the same point, since this will reduce the risk of damage to anterior ciliary vessels, as well as improve control of the plicated muscle during suture tie-down.



Figure 6-11

Step 3. The remaining Green muscle hook is now removed and the sclera grasped with toothed forceps adjacent to each pole of the muscle insertion, as shown in Figure 6-11A. Using these forceps to rotate the globe toward the muscle to be plicated, the posterior muscle is advanced and tucked by firm traction on the two pole sutures. The best cosmetic appearance is obtained when the tucked portion of the muscle is directed beneath rather than on top of the advancing proximal muscle (Fig. 6-11B). The muscle is then secured in the plicated position by placing a double-throw overhand knot 1 to 2 cm from the sclera, gently lifting on the suture until the muscle is fully tucked, and then sliding the knot down to the sclera. If the 2 suture tracks exit close together on the sclera, the knot will be self locking. If not, it is helpful to grasp the knot with a needle holder to secure it until the remaining three single overhand knots can be secured to permanently hold the plicated muscle in place.

Inferior Oblique Muscle Surgery

INTRODUCTION

Historically, many surgical procedures have been described for strengthening and weakening the inferior oblique muscle. Inferior oblique muscle strengthening procedures are difficult to perform and unpredictable in result, and therefore rarely used today. However, multiple weakening procedures have been described, and opinions vary as to which are most effective under varying clinical situations. These include

1. Denervation of the inferior oblique muscle

2. Disinsertion at the origin or insertion of the muscle

3. Recession of the inferior oblique muscle by disinserting it at its insertion and controlled reattachment closer to its origin, including techniques for a recession of 8.0 mm (directly measured), 10.0 mm (reattachment to a point 3 mm posterior and 2 mm lateral to the lateral border of the inferior rectus insertion) or 14 mm (reattachment adjacent to the inferotemporal vortex vein ampulla)

4. Myotomy of the muscle temporal to the inferior rectus muscle

5. Myectomy of the muscle temporal to the inferior rectus muscle

6. Anteriorization of the muscle with reattachment lateral to, or anterior and lateral to the inferior rectus insertion

7. Denervation and extirpation of the muscle by myectomy of the entire muscle distal to its penetration through Tenon's capsule, which also requires denervation

Of these procedures, denervation alone, and disinsertion at the origin or insertion, have largely been abandoned as ineffective because of a high rate of recurrence of overaction. In addition, the 8.0 mm recession has been shown by Parks to be less effective than the 10.0 mm or 14.0 mm recession, and therefore is rarely indicated. The remaining procedures, however, are all widely used, and each has proponents among experienced strabismus surgeons.

INDICATIONS

Weakening of the inferior oblique muscle is indicated whenever clinically significant overaction of the inferior oblique is present. Diagnosis is usually accomplished by careful evaluation of ocular versions, with special attention to over elevation of the adducted eye, especially in elevation. The severity of overaction can be clinically estimated for the purpose of surgical planning using a +1 through +5 scale, where +1 indicates only minimal over elevation in adduction and elevation and +5 indicates such marked over elevation that the cornea of the adducted eye is not visible.

In general, patients with idiopathic (primary) inferior oblique overaction of +1 or less present no clinical problem. However, patients with idiopathic overaction of +2 or more are candidates for inferior oblique weakening procedures. By contrast, some patients with even +1 (minimal) secondary inferior oblique overaction, such as in superior oblique palsy, will benefit from surgery. In addition, patients with significant overaction of the inferior oblique muscles frequently exhibit excessive divergence in up gaze (resulting in a V-pattern or Y-pattern) or even hyperdeviation in primary position and/or lateral gaze. Inferior oblique weakening is also effective in eliminating these problems.

Inferior oblique overaction is frequently associated with horizontal strabismus, resulting in nonconcomitant horizontal and vertical deviations, and commonly associated with V-pattern. In these cases, inferior oblique weakening can be performed at the same time as horizontal rectus surgery. Several studies have demonstrated that inferior oblique muscle weakening does not alter horizontal alignment in primary position. Therefore, the amount of horizontal muscle surgery should be planned to correct the horizontal deviation in primary position, without regard for the simultaneous inferior oblique muscle weakening.

SURGICAL PLANNING

Idiopathic or primary overaction of the inferior oblique is usually bilateral, although it may be quite asymmetric in its early stages. Before undertaking inferior oblique muscle weakening in patients with suspected unilateral overaction, a very careful search for even mild overaction on the contralateral side is necessary. If even +1 overaction is found, then bilateral surgery should be performed to prevent the postoperative appearance of overaction on the milder side. Some strabismus surgeons prefer to titrate the amount of weakening effect in asymmetric cases by performing a more potent procedure (see below) on the more markedly overacting side and a weaker procedure on the less overacting side. However, in our experience, most inferior oblique weakening procedures are self-adjusting over a moderate range of overaction; the same procedure will correct greater amounts of overaction on the more severely affected eye and lesser amounts of the milder eye, to produce a symmetric final result. In this case, the procedure indicated by the more severely overacting eye should be performed bilaterally.

In cases in which no evidence for bilateral involvement is found, even after a thorough search, the presence of secondary overaction of the inferior oblique muscle, such as in superior oblique palsy, must be suspected. The Bielshowski head tilt test and the presence or absence of subjective (measured by the double Maddox rod test) or objective (measured by the amount of fundus torsion on indirect ophthalmoscopy) torsion are useful in differentiating primary inferior oblique overaction from that secondary to superior oblique palsy. The differentiation is essential since, although idiopathic inferior oblique overaction frequently requires bilateral weakening, unilateral secondary overaction will be corrected by unilateral inferior oblique weakening, and may even be worsened by bilateral surgery.

As alluded to previously, some strabismus surgeons believe the amount of inferior oblique weakening can be titrated by the selection of surgical technique. Based on the literature, inferior oblique weakening procedures can be ordered from weakest (least effective) to strongest (most effective) as follows:

- 1. 8.0-mm recession
- 2. 10.0-mm recession
- 3. 14.0-mm recession
- 4. Denervation and extirpation
- 5. Anteriorization

Measured Overaction	Recommended Procedure
+ 1	10 mm recession or myotomy/ myectomy
+2	10 mm recession or myotomy/ myectomy
+ 3	10 mm recession or myotomy/ myectomy
+ 4	Anteriorization or myotomy/ myectomy
+5	Anteriorization or denervation and extirpation or myotomy/myectomy

 Table 7-1. Selection of Inferior Oblique Weakening

 Procedure

On the other hand, strabismus surgeons who favor inferior oblique myotomy or myectomy, generally use this procedure for all but the most marked overaction, and it is therefore difficult to compare inferior oblique myectomy to the procedures above. Based on the literature and our experience, Table 7-1 presents a scheme for surgical procedure selection according to the degree of inferior oblique overaction.

In bilateral surgeries, the surgery recommended in Table 7-1 for the most severely overacting eye should be performed bilaterally for the most symmetric result. Unilateral use of the full anteriorization procedure, except in cases with inferior oblique overaction associated with dissociated vertical deviation or secondary to superior oblique palsy, should be avoided, since unilateral anteriorization can limit elevation and induce a clinically significant postoperative hypotropia.

COMPLICATIONS

Although the inferior oblique muscle is located relatively anteriorly in the orbit, the major portion of surgical interest, the insertion, is its most posterior part, which makes surgical access more difficult. In addition, several important structures lie near the inferior oblique insertion and are vul-

nerable to damage if improper technique is used. The posterior end of the inferior oblique insertion overlies the macular area; therefore great care must be taken to prevent needle penetration during suture placement, or trauma to the adjacent sclera during muscle disinsertion. In addition, the inferotemporal vortex vein passes from the sclera into Tenon's capsule near the posterior border of the inferior oblique just temporal to the inferior rectus. Care must be taken not to damage this vessel while hooking or cleaning the inferior oblique insertion. Finally, the distal inferior oblique muscle courses through Tenon's capsule adjacent to the intraconal orbit fat pad, and penetration into this fat pad, either with a muscle hook or scissors, can result in fat prolapse and development of the fat adherence syndrome, with severe motility restriction.

Other significant complications frequently associated with inferior oblique muscle surgery include the following:

1. Isolation and transection of the wrong muscle (either inferior rectus or lateral rectus) because of poor exposure, incorrect technique, or inadequate understanding of the surgical anatomy

2. Secondary hypotropia, especially associated with unilateral use of the anteriorization procedure or development of the fat adherence syndrome

3. Damage to the ciliary ganglion secondary to excessive muscle trauma or traction during isolation, with secondary pupil dilation and loss or reduction in accommodative ability

4. Inadequate surgical effect or recurrence of inferior oblique overaction, frequently secondary to incomplete muscle isolation resulting in myectomy or recession of only a portion of the muscle

Only through thorough understanding of the important anatomic relationships, as discussed in Chapter 3, and careful adher-



ence to the surgical principles and techniques described below, can the risk of these complications be minimized.

SURGICAL TECHNIQUES

This section describes the surgical technique for the most commonly used inferior oblique weakening procedures: recession, myotomy/myectomy, anteriorization, and denervation and extirpation. All four procedures begin with isolation of the inferior oblique muscle insertion through an inferotemporal fornix incision. Because the fornix incision results in the best exposure, a limbal incision is not recommended for inferior oblique surgery. In addition, proper illumination is best provided by a fiber optic head lamp, since bright illumination is required to identify important posterior surgical landmarks deep in the surgical wound, where illumination provided by ceiling mounted lights is inadequate.

Surgical Approach to the Inferior Oblique Insertion

Isolation of the left inferior oblique through an inferotemporal fornix incision is illustrated.

Step 1. After creation of a standard twoplane inferotemporal fornix incision, as described in Chapter 4, the lateral rectus is isolated, first with a small Stevens hook and then with a large Green or Jameson hook, as illustrated in Figure 7-1. With the hook lifted away from the sclera to create a space between the lateral rectus and the sclera, a 4-0 silk suture on a large needle is passed beneath the entire lateral rectus muscle and out through the conjunctiva superiorly. Keep the tip of the needle elevated, sliding it along the side of the large muscle hook, to



prevent inadvertent puncture of the sclera. This 4-0 suture beneath the lateral rectus is used as a traction suture pulled tightly across the bridge of the nose and clamped to the head drape with a hemostat to maintain the eve in a position of maximum adduction and elevation.

Step 2. The inferior oblique muscle is exposed by placing a small Stevens hook into the wound laterally along the inferior border of the lateral rectus muscle, and a large von Graefe or Jameson hook inferiorly, just temporal to the inferior rectus, as illustrated in Figure 7-2. Both hooks are transferred to the assistant who exposes the anterior and posterior border of the inferior oblique muscle, embedded in Tenon's capsule, by lifting the hooks away from the sclera and towards the orbital rim. Improved exposure is provided by the surgeon using a lens loop to further elevate the posterior aspects of the inferior oblique muscle or to indent the sclera at the posterior border of the inferior oblique, thus allowing clear visualization of the "pink/white" junction between the posterior border of the muscle and Tenon's capsule. At this point, it is also important to identify the inferotemporal vortex vein (Fig. 7-2), which exits the sclera and passes just posterior to the inferior oblique muscle as it enters Tenon's capsule. Once the posterior border of the inferior oblique muscle and the inferotem-



Figure 7-3

poral vortex vein have been clearly identified by direct visualization, a Stevens hook is inserted posteriorly, parallel to the sclera, taking care to avoid damaging the vortex vein. Its tip is then rotated 90° to cleanly engage the posterior border of the inferior oblique. The tip of the Stevens hook is then moved towards the orbital rim to securely engage the entire muscle belly before delivering it into the wound anteriorly, being careful to keep the tip of the hook elevated to prevent any muscle fibers from slipping off.

Step 3. The inferior oblique muscle is elevated into the wound on the Stevens hook, along with adjacent Tenon's capsule and intermuscular septum. This additional tissue is gently "off-loaded" with a toothed forceps by grasping any whitish Tenon's capsule draped over the tip of the hook and gently lifting it up and off the hook while dropping the tip of the hook slightly. Be careful not to inadvertently off-load any muscle fibers, which can result in splitting of the insertion, leaving an unoperated posterior slip of muscle and residual inferior oblique overaction. Once all Tenon's capsule and intermuscular septum have been removed from the hook and the posterior border of the inferior oblique is clearly visible as a pink/ white junction at the tip of the Stevens hook, the intermuscular septum is incised at the border of the muscle with Westcott scissors, as shown in Figure 7-3A. When properly performed, after all thick Tenon's capsule and orbital fat have been removed from the hook, this



Figure 7-4

incision will penetrate the whispy, almost transparent, intermuscular septum alone, exposing the shiny tip of the muscle hook.

Step 4. The small Stevens hook is then replaced with a large Green hook to prevent inadvertent muscle loss. and the entire inferior oblique insertion is exposed by inserting a second Green hook through the same track beneath the inferior oblique near the lateral border of the inferior rectus muscle, as shown in Figure 7-3B. This hook is then pulled by the assistant towards the patient's ear to engage the intermuscular septum that connects the inferior oblique to the inferior rectus muscle. In addition, the assistant places a small Stevens hook along the inferior border of the lateral rectus muscle to isolate the intermuscular septum that connects the inferior oblique and lateral rectus muscles. The inferior oblique muscle is pulled nasally by the sur-

geon using the Green hook, while the assistant lifts the previously placed Green and Stevens hooks away from the sclera to tent up the intermuscular septum and expose the inferior oblique insertion as shown in Figure 7-4. The insertion is then carefully cleaned of intermuscular septum and adherent Tenon's capsule with blunt Westcott scissors, dissecting as close to the muscle as possible. At the completion of this step, the entire inferior oblique insertion is inspected and should be clearly visible, without any fascial attachments.

Step 5. At this point, if a recession of the inferior oblique is to be performed, some strabismus surgeons secure the insertion with a suture before excising it from the sclera. However, this step can be technically difficult without a very skilled assistant to aid in exposure, and carries a significant risk of inadvertent needle puncture of the sclera in the





macular area. Therefore, muscle suturing can be simplified by clamping the insertion and excising it from the sclera prior to further surgical manipulation. To accomplish this, with the assistant continuing to provide exposure of the entire inferior oblique insertion, a small Hartman clamp is placed across the insertion adjacent to the sclera, as shown in Figure 7-5A. Both tips of the clamp must be clearly visualized before securing it to be certain that the entire muscle insertion and only the insertion is secured by the clamp. The large Green hook can then be removed from beneath the inferior oblique belly. With the clamp lifted away from the sclera, the inferior oblique insertion is shaved cleanly away

from the sclera with blunt, curved Westcott scissors, the curvature oriented to parallel the scleral curvature, as shown in Figure 7-5B. When the entire muscle insertion has been transected, the inferior oblique insertion can be lifted out from the wound (Fig. 7-5C) for further manipulation; either securing it with a suture for recession or anteriorization, or excision of part of the muscle for myectomy or denervation and extirpation.

Inferior Oblique Recession

A 10.0 mm recession of the left inferior oblique muscle is illustrated.

Step 1. With the muscle secured on a Hartman clamp after excision from the sclera, a double-armed 6–0 Vicryl



Figure 7-6

suture with S-28 needles is placed through the insertion, just posterior to the clamp, as described for rectus muscle recession. The suture is first passed half thickness across the entire muscle belly, either a half width at a time, or a full width depending on the width of the insertion. The suture is then secured with locking bites at each edge as shown in Figure 7-6. Keep track of the original posterior and anterior poles of the insertion by remembering that the *posterior* pole suture is locked at the edge of the muscle nearest the point of the Hartman clamp. This distinction is important in order to ensure that the posterior pole of the insertion is reattached to the sclera posteriorly. This will prevent twisting of the muscle belly, which might tighten it and reduce or eliminate the recession affect.

Step 2. The 4–0 silk suture is then removed from beneath the lateral rectus

muscle to release the globe from its adducted position. The inferior rectus muscle is secured through the wound, first with a Stevens hook and then a large Green hook, which is passed to the assistant to stabilize the eye in elevation for suture placement. The assistant also exposes the sclera just posterior and temporal to the inferior rectus insertion with a small Stevens hook, as shown in Figure 7-7A.

Several methods have been described to locate the point of scleral reattachment for various inferior oblique recession procedures. A 6mm or 8-mm recession can easily be measured with a caliper from the original insertion along the original muscle course. However, other landmarks are required to perform the larger 10-mm and 14-mm inferior oblique recessions, which are beyond the view of the original insertion provided by the incision. Standard localizations have there-



Figure 7-7

fore been determined. By convention, the new insertion for the classic 14-mm inferior oblique recession is located adjacent to the ampulla of the inferotemporal vortex vein. Similarly, the new insertion for a 10-mm recession has been defined as the point 3 mm posterior and 2 mm lateral to the temporal end of the inferior rectus muscle insertion.

Step 3. Figure 7-7B illustrates a schematic diagram to simplify and standardize placement of the new insertion for a 10-mm recession. In this case, the caliper is set on 3 mm and a scleral mark is made 3 mm posterior to the temporal end of the inferior rectus insertion as illustrated. The caliper is then rotated 90°, and a second scleral mark is made 3 mm temporal to the first

scleral mark. This second scleral mark will serve as the exit point for the suture tracks, as illustrated. Finally, a pair of scleral marks are created by setting the caliper at 5 mm, orienting the tips on a line perpendicular to that extending from the inferior oblique origin at the lacrimal crest (dashed line in Figure 7-7B), and moving the caliper 1 mm toward the first scleral mark at the lateral rectus border. The posterior pole suture is then passed half thickness through sclera from the posterior mark to the temporal mark, and the anterior pole suture is passed from the anterior mark to the temporal mark as shown in Figure 7-7B. When the sutures are pulled tight and tied off, the center of the new inferior oblique insertion is located 3 mm posterior and The classic 10-mm recession of the medial rectus is especially effective in weakening the inferior oblique muscle because it not only recesses it, but also significantly anteriorizes the insertion, which markedly reduces the elevating force while preserving the excyclorotatory force of the muscle.

Inferior Oblique Myectomy or Myotomy

Myotomy of the left inferior oblique through a fornix incision is illustrated.

Myectomy or myotomy is an effective procedure for weakening the inferior oblique muscle. It is functionally equivalent to recession of the inferior oblique without anteriorization; both procedures move the effective insertion of the muscle to its point of adherence at Lockwood's ligament. The advantages of myectomy or myotomy over recession of the inferior oblique are that it is a significantly shorter procedure and, since access to the posteriorly placed insertion is not required, the procedure is technically easier and without risk of perforation or other damage to the sclera underlying the macula. However, control of the inferior oblique insertion is lost after myectomy or myotomy, preventing reliable reoperation for anteriorization to treat DVD, if it develops (see Ch. 1).

Historically, inferior oblique myectomy developed a bad reputation for recurrence of inferior oblique overaction caused by presumed reattatchment of the muscle to the globe. Presumably to prevent recurrence, many authors recommend excision of as long a segment of inferior oblique as possible. However, because engagement of the inferior oblique for myectomy is often performed without direct visualization, most of these recurrences are probably due to incomplete myectomy, with a slip of uncut inferior oblique typically being found on re-exploration of these so-called recurrences. We have found that excision of inferior oblique tissue is superfluous and, when properly performed, a simple myotomy is equally effective.

- Step 1. Through an inferotemporal fornix incision, the inferior oblique is isolated under direct visualization (as described in Steps 1 to 3, Surgical Approach to the Inferior Oblique Insertion).
- Step 2. The Stevens hook is replaced by two Jameson or Green muscle hooks as shown in Figure 7-8A. These hooks are then rotated inferotemporally, as shown in Figure 7-8B, to expose the under surface of the inferior oblique. From this side, distinguishing between the pink muscle tissue and the white Tenon's capsule is easy. The posterior margin of the button hole in Tenon's capsule at the posterior edge of the inferior oblique is carefully inspected for any residual muscle fibers. If any are found, as shown in Figure 7-8C, they must be picked up with a Stevens hook and a new button hole made that includes these fibers on the Green hooks.
- Step 3. The muscle is cross-clamped with two Hartman hemostats introduced from the temporal side and the muscle hooks removed, as shown in Figure 7-9A. Care should be taken to slide the nasal hemostat as far toward the inferior rectus as possible before it is clamped. The muscle is then transected adjacent to the nasal hemostat with Westcott scissors. This keeps the proximal end of the muscle as short as possible and thereby encourages it to retract through its opening in Ten-



Figure 7-8

on's capsule. If a myectomy is desired, the muscle also can be cut adjacent to the temporal hemostat to completely excise the intervening muscle. Thermal cautery is then applied to the cut ends of the muscle (Fig. 7-9B).

Step 4. Both hemostats are then released and the muscle allowed to retract. The Stevens hook and the Green hook used in the initial exposure are replaced, and with the help of the lens loop and an additional Stevens hook if needed, the surgeon inspects the site at which the inferior oblique penetrates Tenon's capsule. The proximal end of the muscle should be noted to have retracted through this opening, as shown in Figure 7-10, with no residual fibers bridging the gap between the posterior edge of the opening and the distal cut end of the muscle. If any residual fibers are found, they must be cut by repeating the same steps as in the original myotomy. It is important to make certain that the proximal end of the muscle retracts through the opening in Tenon's capsule to prevent its reattaching to sclera. If it has not completely retracted through the



Figure 7-10

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opening in Tenon's capsule, this can be encouraged by gently pushing it through the opening with the tip of a Stevens hook or applying gentle traction to the edge of the opening with a toothed forceps. Forced retropulsion, depression, and intorsion of the eye can also be helpful in accomplishing this and, if an extra measure of security is desired, the opening in Tenon's capsule can be closed over the cut proximal end of the muscle with 6– 0 Vicryl suture.

Inferior Oblique Anteriorization

Recent studies by Elliot and Nankin (1981) and Elliot and Parks (1990) have demonstrated the anteriorization procedure to be among the most potent of inferior oblique weakening procedures, at least in terms of reducing overelevation in adduction and hypertropia in primary position. Figure 7-11 illustrates the important anatomic relationships, recently described by

David Stager, which make anteriorization so effective. Figure 7-11 shows a view of the left eye and nasal orbit from below, illustrating the anatomic relationships between the inferior oblique muscle attached to its original insertion posteriorly, as compared with its location after a 10 mm inferior oblique recession and after the anteriorization procedure. Especially notice the location of the neurovascular bundle that supplies innervation to the inferior oblique muscle, which acts as a fibrous tether stabilizing the anteroposterior location of that portion of the muscle adjacent to the temporal border of the inferior rectus muscle. This tether point becomes a secondary origin of the distal portion of the inferior oblique muscle when the distal portion of the muscle is relocated anteriorly during a recession or anteriorization procedure. Figure 7-11 illustrates how an overacting inferior oblique muscle is converted from a strong elevator at its original insertion, to a muscle having minimal vertical action (or possibly even a weak depressor) when its distal portion is slackened and anteriorized



Figure 7-11

during 10-mm recession. It also illustrates how the inferior oblique may even be converted to a significant depressor when the posterior pole fibers are fully anteriorized.

Step 1. To perform the anteriorization procedure, the inferior oblique insertion is isolated and secured with a double-armed 6-0 Vicrvl suture (Steps 1 to 5, Surgical Approach to the Inferior Oblique Insertion and Steps 1 to 3, Inferior Oblique Recession). However, to complete the procedure, both the anterior and posterior pole of the muscle are advanced fully and sutured adjacent to the temporal border of the inferior rectus muscle, as shown in Figure 7-11. For maximum effect, it is important that the posterior pole fibers, especially, are fully advanced. They should be maximally tightened to obtain the maximal active, as well as passive, depressing rather than elevating force. In fact, some surgeons further strengthen the procedure by advancing the posterior fibers further, even to a point 1 or 2 mm anterior to the inferior rectus insertion. However, this super-maximal anteriorization may increase the risk of the development of secondary postoperative hypotropia, with limited elevation, especially if the procedure is performed unilaterally.

Inferior Oblique Denervation and Extirpation

Denervation and extirpation of the left inferior oblique is illustrated.

The denervation and extirpation operation is the most drastic of the inferior oblique weakening procedures because fully 70 to 80 percent of the muscle (all inferior oblique muscle temporal to its penetration through Tenon's capsule) is removed and all innervation to the muscle is transected. This procedure should therefore be reserved only for the most severe, and/ or recurrent inferior oblique overactions. In addition, recent studies by Elliott and Parks have suggested that the full anteriorization procedure (which is fully reversible with reoperation) may be even more effective than denervation and extirpation in eliminating overelevation of the globe. For this reason, the denervation and extirpation procedure is rarely indicated today.

- Step 1. To perform the denervation and extirpation procedure, the inferior oblique insertion is isolated as described previously. After the inferior oblique insertion has been secured with the Hartman clamp and transected from the sclera, the 4-0silk traction suture under the lateral rectus is removed. To provide better exposure of the more proximal portion of the inferior oblique, the lid speculum is removed and replaced with a Desmarres lid retractor, and the inferior rectus is secured with a large muscle hook to elevate the globe, as shown in Figure 7-12. When the proximal inferior oblique has been exposed in this way, the residual intermuscular septum and check ligaments adherent to the proximal muscle are transected with blunt Westcott scissors.
- Step 2. The muscle is then pulled superiorly, anteriorly, and medially to demonstrate a fusiform expansion of the inferior oblique muscle at the point where the neurovascular bundle enters its posterior aspect as shown in Figure 7-13A. This bundle is hooked with a small Stevens hook to separate it from adjacent inferior oblique muscle and Tenon's capsule. The neurovascular bundle is easily identified as a



Figure 7-13

В



Figure 7-14

ported after this procedure, and are presumably secondary to traction on the ciliary ganglion.

Step 4. Once the neurovascular bundle has been transected, its firm tethering of the central portion of the inferior oblique muscle will disappear and an additional 10 to 15 mm of muscle will prolapse easily out of the wound. Additional sharp dissection with blunt Westcott scissors will remove any remaining intermuscular septum and check ligaments that are more proximal, which will completely expose the distal 70 to 80 percent of the inferior oblique muscle from insertion proximally until it enters Tenon's capsule. A 4-0 chromic or Vicryl ligature is placed tightly around the muscle belly as close to its origin as possible, as shown in Figure 7-14A, and secured tightly with several



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overhand knots. A Weck sponge is then placed behind the muscle to insulate surrounding tissue, and all muscle distal to the ligature is extirpated using hot cautery to transect and cauterize the muscle stump (Fig. 7-14B).

Step 5. The cauterized stump of the inferior oblique muscle sometimes retracts spontaneously through the opening of Tenon's capsule, or may be assisted by pushing it through the opening in Tenon's capsule with the blunt handle of a muscle hook. Finally, to eliminate any chance for readherence of the muscle stump to the sclera, Tenon's capsule can be closed over the muscle stump, if still exposed, with 2 or 3 interrupted 6–0 Vicryl sutures as shown in Figure 7-15.

Although this procedure is obviously irreversible, it interestingly has not resulted in significant long-term underaction of the inferior oblique when performed symmetrically on both eyes. Nevertheless, as stated previously, with the development of the reversible and equally effective anteriorization technique, the denervation and extirpation procedure is now rarely indicated.

Superior Oblique Muscle Surgery

INTRODUCTION

Strengthening or weakening of the superior oblique is frequently required in the treatment of strabismus. Unilateral overaction may result in vertical muscle imbalance, with incomitant hypotropia on the overacting side; the hypotropia will be larger with gaze toward the contralateral side and smaller with gaze toward the ipsilateral side. More commonly, however, bilateral overaction results in A-pattern strabismus, with relatively greater divergence in down gaze compared with up gaze. In addition, many patients with bilateral overaction demonstrate alternating hyperdeviations on side gaze, with a right hypertropia on right gaze and a left hypertropia on left gaze.

Superior oblique underaction, most commonly associated with superior oblique palsy, represents one of the more common cyclovertical muscle disorders seen in ocular motility practice. Patients with unilateral superior oblique palsy will demonstrate a variable hyperdeviation on the side of the palsy that is greater on gaze toward the contralateral side and on head tilt to the ipsilateral side (the Three-Step Test). A compensatory head tilt to the side opposite the palsied eye is frequently a helpful diagnostic sign. Patients with bilateral superior oblique palsy often have no significant vertical deviation in primary position and no head tilt; however, they can usually be diagnosed by the combination of chin down head posture and alternate hyperdeviation on side gaze, with right hypertropia on left gaze and left hypertropia on right gaze, and, most significantly, by symptoms and signs of marked excyclotorsion, usually greater than 10° on the double Maddox rod test.

INDICATIONS FOR SURGERY

Superior oblique weakening, generally performed by tenotomy of the superior oblique, may be required in the treatment of idiopathic primary overaction of the superior oblique or Brown syndrome. Indications for surgery in primary superior oblique overaction include (1) significant Apattern, especially in exotropia, but also in esotropia and orthophoria, (2) alternating hypertropia, (3) hyperdeviation in the primary position, and (4) head tilt.

It is important to remember that in primary superior oblique overaction, true hypercontraction of the superior oblique muscle occurs; therefore, unlike in Brown syndrome, tenotomy does not produce superior oblique palsy. In addition, special care must be taken when considering superior oblique tenotomy in patients capable of bifoveal fixation (normal binocular sensory status and

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at least 40 seconds of arc stereopsis). This situation occurs most commonly in patients with intermittent exotropia and superior oblique overaction, Brown syndrome, and A-pattern orthophoria. In these patients, any slight asymmetry in the weakening affect results in a relative unilateral superior oblique palsy with frequent secondary head tilt for fusion. Therefore, it is important to always check stereoacuity before planning superior oblique tenotomy and, if it is normal, to consider alternative therapy when possible.

In Brown syndrome, superior oblique tenotomy is indicated for patients with (1) abnormal head posture, (2) large hyperdeviation in the primary position, or (3) diplopia. Many patients with Brown syndrome have none of these indications, presenting only because of hyperdeviation or unusual ocular movements in up gaze. These patients require only close observation and careful follow-up for the later development of any of the above surgical indications.

Strengthening procedures of the superior oblique muscle are most often required in patients with unilateral or bilateral superior oblique palsy. Surgery is frequently indicated in these patients for a combination of one or more of the following: (1) vertical heterotropia with vertical diplopia, (2) compensatory head posture, either head tilt (unilateral) or chin depression (bilateral), and (3) torsional diplopia.

Many algorithms have been published to aid in treatment planning for patients with superior oblique palsy. In most cases, successful therapy can be accomplished by one or more of the following: (1) superior oblique tuck, (2) ipsilateral inferior oblique recession or myectomy, (3) contralateral inferior rectus recession, and (4) contralateral superior rectus resection.

All of these procedures, either singly or in combination, improve both the vertical deviation and the cyclotropia. Individual treatment planning is best accomplished by careful analysis of the ocular deviations in each of the nine cardinal gaze positions as well as quantitative analysis of torsion by double Maddox rod testing or fundus evaluation. In general, patients with less then 10 to 15Δ of vertical deviation in the primary position can be corrected by single muscle surgery, while those with greater than 15Δ will require surgery on two or more muscles. In addition, patients whose vertical deviation is greater in down gaze will benefit most from surgery on muscles whose primary field of action is in down gaze (the ipsilateral superior oblique and contralateral inferior rectus), and patients whose deviation is greatest in up gaze will benefit from procedures on muscles whose field of action is in up gaze (ipsilateral inferior oblique and contralateral superior rectus). Most patients with bilateral superior oblique palsy will demonstrate little or no vertical deviation in primary position but will be bothered by excyclotropia as well as significant esotropia in down gaze. These patients respond nicely to bilateral Harada-Ito procedures if the esotropia in down gaze is not too large, or to bilateral superior oblique tucks if marked esotropia in down gaze is present. In the minority of bilateral superior oblique palsy patients, those with asymmetric palsy and resulting vertical as well as torsional symptoms, the combination of superior oblique tuck on the more severely involved side associated with a Harada-Ito procedure on the milder side frequently gives an excellent result.

SURGICAL TECHNIQUES

Superior Oblique Forced Ductions

Evaluation of superior oblique tension by forced duction testing is important preoperatively, as well as intraoperatively, when performing superior oblique strengthening or weakening procedures. The technique described by Guyton, discussed here, requires some practice but is extremely sensitive in evaluating superior oblique overaction or underaction, especially when used to document the completeness of a superior oblique tenotomy.

Step 1. After a lid speculum is placed between the lids, the globe is grasped near the limbus at the 3-o'clock and 9-o'clock positions using 0.5-mm Castroviejo forceps. The globe is then retropulsed back into the orbit (Fig. 8-1a) to place the superior oblique tendon on maximum stretch. Its tension can then be determined or "felt" by (1) extorting the globe (Fig. 8-1b), followed by (2) further depressing the nasal forcep into the superonasal quadrant (Fig. 8-1c), and then (3) rocking the temporal forcep from inferonasally to superotemporally, as illustrated in Figure 8-2. As this maneuver is performed, the hand holding the temporal forceps will feel a tightening and loosening force as the tightening superior oblique tendon "flips" over the surface of the globe. With some practice, one can quantitate or grade the degree of tightness of the tendon both preoperatively and postoperatively. In addition, the complete absence of any "flip" tightening sensation after superior oblique tenotomy confirms a successful and complete procedure.

Superior Oblique Tenotomy

A right superior oblique tenotomy is illustrated.

Step 1. With the eye depressed and *adducted* by the assistant, a superotemporal fornix incision is made approximately 8 mm posterioir to the limbus in two planes, as described in Chapter 4 (fornix incision). Be certain to keep the incision parallel to the upper lid, so the closed wound will be entirely covered by the lid at the end of the procedure.



Figure 8-1



Figure 8-2

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Figure 8-3



Figure 8-4

- Step 2. The temporal border of the superior rectus is identified visually. It is hooked first with a small Stevens muscle hook and then with a larger Green or Jameson muscle hook to provide better control of the globe.
- Step 3. While applying traction on the superior rectus with the large muscle hook to stabilize the globe, a Stevens hook held in the other hand is used to expose the superior rectus insertion by reflecting the intermuscular septum, Tenon's capsule, and conjunctiva over the toe of the large hook, as shown in Figure 8-3A (before reflection) and Figure 8-3B (after reflection).
- Step 4. The eye is maximally depressed with the Green hook under the superior rectus and the superior surface of the superior rectus is exposed using two Stevens hooks, as shown in Figure 8-4. This exposes the broad sheet-like white check ligament that fuses to the superior surface of the superior rectus diagonally 8 to 12 mm posterior to its insertion, as shown in Figure 8-4. The ligament is opened centrally at its insertion on the surface of the superior rectus with a blunt Westcott scissors.
- Step 5. Two Stevens hooks are used to enlarge the opening in the check ligament and expose the bare superior surface of the superior rectus muscle posteriorly. A Desmarres retractor is inserted through this opening to further retract the Tenon's capsule and expose the nasal border of the superior rectus muscle. In some patients, exposure can be improved at this time by removing the lid speculum, allowing greater traction with the Desmarres retractor.

- Step 6. The Green muscle hook under the superior rectus is pulled temporally, and the Desmarres retractor is moved nasally to better expose the nasal border of the superior rectus muscle and the adjacent untouched nasal intermuscular septum (Fig. 8-5A). This maneuver will expose the parallel fibers of the superior oblique tendon, seen nasally through the wispy overlying intermuscular septum.
- Step 7. A Stevens muscle hook, with its tip pointing nasally, is moved posteriorly along the nasal border of the superior rectus muscle until the posterior margin of the superior oblique tendon is clearly identified. The tip of the hook is then rotated inferiorly behind the tendon and passed toward the sclera and anteriorly beneath the superior oblique tendon, pushing the intermuscular septum behind the tendon to completely surround it, as shown in Figure 8-5B.
- Step 8. The two layers of intermuscular septum on the toe of the Stevens hook are opened anterior to the tendon using a blunt Westcott scissors (Fig. 8-6A). A second Stevens hook is passed through the rent in the intermuscular septum and beneath the tendon from anterior to posterior. These two Stevens hooks, passing beneath the tendon in opposite directions, securely hold the tendon in place. The tenotomy is performed between them with a blunt Westcott scissors, as shown in Figure 8-6B, being careful not to damage the adjacent intermuscular septum.
- Step 9. The cut ends of the tendon are visible as they lie separated, exposed within the rent in the intermuscular septum nasal to the superior





Figure 8-5



rectus muscle (Fig. 8-6C). Some surgeons believe that the effect of the tenotomy can be graded, resulting in greater weakening effect, as is desired in more marked superior oblique overaction, if the tenotomy is performed more nasally, closer to the trochlea.

- Step 10. All instruments are removed from the incision, and the superotemporal conjunctival wound is massaged closed into the fornix.
- Step 11. Verification of complete tenotomy is accomplished by repeating the superior oblique forced duction test described above. In a complete tenotomy, no tightness or "flip" should be felt as the temporal forceps is rocked from the inferonasal to superotemporal position, as previously described. Any mild residual tension suggests incomplete tenotomy. In that case, the Green hook must be replaced beneath the superior rectus and the Desmarres retractor repositioned to again expose the nasal border of the superior rectus muscle. A thorough search for residual uncut posterior tendon fibers can then be made. Only when the forced ductions are completely negative can the surgeon be certain that a complete tenotomy has been performed. This is especially important since only a few remaining posterior fibers will completely eliminate any surgical weakening effect. In bilateral cases, uncut fibers on one side may result in a large unilateral hyperdeviation, which is very disconcerting to patient and surgeon alike.

Superior Oblique Tuck

A right superior oblique tuck is illus-trated.

- Step 1. Before performing a superior oblique tuck, it is important to determine the degree of preoperative superior oblique tightness for comparison postoperatively. This is best accomplished using the superior oblique forced duction technique of Guyton, as described above.
- Step 2. With the eye depressed and *adducted* by the assistant, a superotemporal fornix incision is made approximately 8 mm posterior to the limbus (as described in Steps 1 and 2, Superior Oblique Tenotomy). The superior rectus is identified visually and hooked with a Stevens hook and then with a large muscle hook.
- Step 3. Using traction on the superior rectus, the globe is maximally depressed and the wound is opened with two small muscle hooks to allow introduction of the Desmarres retractor (Fig. 8-7). The lid speculum can then be removed to allow more room in the orbit for better exposure with the Desmarres retractor.
- Step 4. The larger muscle hook beneath the superior rectus is pulled temporally while simultaneously moving the Desmarres retractor nasally. The temporal border of the superior rectus is moved nasally with a small muscle hook. This allows direct visualization of the parallel white fibers of the superior oblique tendon, the anterior border of which is gently identified with a small Stevens hook, as shown in Figure 8-8.
- Step 5. The Stevens muscle hook is passed beneath the superior oblique tendon until the posterior border can be identified by direct visualization and the full, fannedout insertion of the tendon picked



Figure 8-7



Figure 8-8



up on the muscle hook. It must be remembered that the superotemporal vortex vein (Fig. 8-9) generally penetrates the sclera near the junction of the posterior onethird and anterior two-thirds of the tendon insertion; it is therefore advisable that this vein be visually identified before the posterior aspect of the tendon is hooked to avoid inadvertent rupture. Intramuscular septum can then be incised anteriorly and posteriorly, clearing the distal portion of the tendon for tucking.

Step 6. The muscle hook holding the superior oblique tendon can be replaced with a tendon tucker (Fig. 8-10A) and the tucker tightened to take up the slack in the tendon for tucking (Fig. 8-10B, C). Many tendon tuckers are available for this purpose: the Green tucker is illustrated here. The total amount of tuck will vary from 8 mm to more than 20 mm, depending on the degree of tendon laxity. The correct amount of tuck will be verified by forced duction control later in the procedure.

- Step 7. The tucked tendon is secured using a double-armed, 5-0 Mersilene suture passed in a double mattress fashion and secured with a temporary half bow slip knot, as illustrated in Figure 8-11.
- Step 8. The tendon tucker and Desmarres retractor are removed, and forced duction testing is carried out by grasping the globe at the limbus in the inferotemporal quadrant (7:30o'clock position) and gently moving the eye into elevation and adduction (Fig. 8-12). Resistance, caused by tightening of the superior oblique tendon, should be felt as the inferior limbus reaches an imaginary line (dashed line in Fig.


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Figure 8-11

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Figure 8-12

8-12) drawn between the medial and lateral canthus (Saunders test). If significant resistance is noted while the inferior limbus is inferior to this line, the tuck is too tight and a significant iatrogenic Brown syndrome will result. If resistance is not felt until the inferior limbus is above this imaginary line, the tuck is not tight enough and inadequate correction will occur. It is important to maintain the globe in its proper anterior/ posterior position while performing this forced duction (i.e., do not depress the globe into the orbit or proptose it, as the forced duction testing will then be inaccurate).

Step 9. The large muscle hook is repositioned beneath the superior rectus to depress the globe and the surgical area is re-exposed by replacement of the Desmarres retractor. If the amount of tuck is incorrect, as determined by the forced duction test, then the tucker is replaced through the tucked portion of the tendon, and the temporary Mersilene slip knot is loosened and removed. The tucker can then be readjusted for either a larger or a smaller tuck, and the Mersilene suture is replaced as previously described. The instruments are then removed and the forced duction test is repeated.

Step 10. When forced duction testing verifies the correct degree of superior oblique tucking, the large muscle hook is replaced beneath the superior rectus to depress the globe and the Desmarres retractor is reinserted to expose the tucked tendon, which is picked up on a large muscle hook. The slip knot is taken down by cutting the loop of the bow and removing the loose end, resulting in a permanent knot. One end of the previously removed Mersilene suture is then through passed the tucked "knee" of tendon (Fig. 8-13A) and used to tack the tucked portion of the tendon to the sclera temporally, along the line of tendon action as illustrated in Figure 8-13B.

Step 11. The instruments are removed



Figure 8-13

from the eye and, using a large muscle hook to gently elevate the upper lid, the superotemporal conjunctival incision is massaged closed with a Stevens muscle hook. If the surgical wound is not exposed within the palpebral fissure, no conjunctival closure sutures will be required. A combination antibiotic/steroid ointment is applied. No eye patch is generally necessary.

Superior Oblique Plication

A right superior oblique plication is illustrated.

- Step 1. The superior oblique tendon is identified and isolated through a superotemporal fornix incision (as described in Steps 1 through 5, Superior Oblique Tuck).
- Step 2. Following isolation of the distal fanned-out portion of the superior oblique tendon by incising anterior



Figure 8-14

and posterior intermuscular septum, the Stevens hook is replaced with a large Green hook, and a 5-0 Mersilene suture on a doublearmed spatulate needle is secured at the desired tuck location. Generally, a plication of 8 to 12 mm from the insertion is a good initial estimate since the adequacy of the plication will be verified later by forced duction testing. The tendon is first secured with a small, central, full-thickness bite. Each arm is then passed one-half thickness through the tendon from center to edge, exiting the measured distance (X) from the insertion. The suture is then passed full thickness, one-third the width through the tendon, and locked securely at the edge. The needles are then passed just distal to the respective anterior and posterior margins of the superior oblique tendon insertion, with partial-thickness scleral bites as shown in Figure 8-14A.

Step 3. As the suture is pulled up, the tendon is plicated or folded, which shortens it by the measured amount (Fig. 8-14B). The sutures are then tied together in a temporary halfbow knot and forced duction testing (Step 8, Superior Oblique Tuck) is performed to evaluate for excessive shortening and secondary iatrogenic Brown syndrome or inadequate shortening and little or no surgical effect. If the tendon is too tight or too loose, the Mersilene suture is removed and replaced at a new location more proximal or distal in the tendon. When the appropriate forced duction is achieved, the sutures are tied down tightly, all instruments are removed, and the conjunctiva is massaged superiorly back into the fornix. Generally, no suture for conjunctival closure is required if none of the conjunctival incision is exposed between the palpebral fissures.

Harado-Ito Procedure With Fixed or Adjustable Suture

A right superior oblique procedure is illustrated.

The Harada-Ito procedure, as originally described by Harada and Ito in 1964, involves isolation of the anterior superior oblique tendon fibers and displacing them anteriorly and laterally, as shown in Figure 8-15.

A modification of this procedure by Fells in 1974 is used most widely today. In this procedure, the anterior fibers of the superior oblique tendon are disinserted and moved anteriorly and laterally to be sutured to the sclera at a point 8 mm posterior to the superior border of the lateral rectus insertion, as illustrated in Figure 8-16. This procedure can be modified, as will be shown, to an adjustable suture technique that allows postoperative adjustment of the quantity of cyclovertical deviation correction.

- Step 1. The superior oblique tendon is identified and isolated as previously described (Steps 1 through 5, Superior Oblique Tuck). With the tendon held on a muscle hook such that its insertion fans out completely, a second muscle hook is used to divide the tendon into anterior and posterior halves (Fig. 8-17A). The small hook can then, by merely pushing it through the tendon, be used to separate the anterior from the posterior half of the tendon (Fig. 8-17B). The posterior half can now be released without incising or further damaging the posterior intermuscular septum.
- Step 2. With the anterior half of the tendon elevated on a large muscle hook, a



Figure 8-15



Figure 8-16



Figure 8-17

6–0 double-armed Vicryl suture with S–29 spatulated needles is secured through the anterior half of the tendon, near its insertion, by passing it full width, half thickness, and then locking each arm of the suture at its respective edge of the tendon by twice passing it full thickness through one-third the width of the tendon and locking. The anterior half of the tendon can now be cut free from the sclera at its insertion using blunt Westcott scissors, as illustrated in Figure 8-18.

Step 3. The large muscle hook is then removed from beneath the superior rectus and the Desmarres retractor removed from the wound and replaced with a Lancaster lid speculum. The lateral rectus is secured first with a Stevens muscle hook, which is subsequently replaced by a larger Jameson or Green muscle hook to *adduct* the globe and expose the superior border of the in-



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sertion of the lateral rectus. Using a caliper, a new insertion site is measured along the superior border of the lateral rectus muscle 8 mm posterior to its insertion, as illustrated in Figure 8-19A.

Step 4. The anterior half of the tendon is then resutured to the sclera, centered at this point (Fig. 8-19B). For a nonadjustable technique, the tendon is pulled tight and the knot is tied securely. The conjunctival wound is then massaged closed in the superior temporal quadrant beneath the upper lid and antibiotic/ steroid ointment is applied.

> However, if an adjustable technique is preferred, the sutures are drawn up so that the tendon contacts the sclera at this new insertion site. A needle holder is clamped across the two sutures approximately 6 to 8 cm from the sclera,

and the two sutures are tied together using a square knot or figure-eight knot over the needle holder, as described in Chapter 9. One needle and its suture are then removed just distal to this knot, leaving the remaining needle connected to the tendon by equal length "pole sutures," as shown in Figure 8-19C.

Step 5. The conjunctiva is then massaged back into its original position and the area of conjunctiva overlying the exit point of the pole sutures from the sclera is identified. Using the remaining needle, the suture is passed from the scleral side of the Tenon's capsule out through the external surface of a conjunctiva at the point overlying the exit of the sutures from the sclera (Fig. 8-20). This suture is then pulled tight, pulling the two pole sutures and



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Figure 8-21

connecting pole knot up through the conjunctiva. An external sliding noose is tied around the two pole sutures using a separate piece of 6-0 coated Vicryl suture (Fig. 8-21), as described in Chapter 9. Finally, a traction suture of 6-0 black silk is placed through episclera near the limbus on a radial line from the pole suture through the center of the pupil. This will allow comfortable traction on the globe during suture adjustment.

Step 6. The adjustable suture is now set, stabilizing an initial tendon tightening, by pulling the pole sutures tight to move the tendon all the way to its new insertion. Using a caliper, the distance between the surface of conjunctiva and the slip noose is set at a distance of approximately 5 mm (Fig. 8-22). Then, as shown in Figure 8-23, the tendon is allowed to retract back until the slip noose knot makes contact with the conjunctiva. The tendon will then be recessed approximately 5 mm, generally yielding a slight undercorrection and requiring the easier pull-up rather than more difficult recession of the tendon during adjustment. The lid speculum is then removed and the conjunctiva massaged back beneath the upper lid closing the wound. Antibiotic/steroid ointment is applied and the pole sutures, traction suture, and noose suture are draped over the upper or lower lid. The eye is covered with a patch to prevent manipulation of the sutures before adjustment.



Figure 8-22



Figure 8-23

SUTURE ADJUSTMENT

Suture adjustment is accomplished between 4 and 24 hours postoperatively, as described in Chapter 9. Double Maddox rod testing and assessment of objective fundus torsion with indirect ophthalmoscopy are used to monitor ocular torsion during adjustment. The goal of adjustment is complete elimination of excyclotropia without inducing incyclotropia. Fortunately, there is tolerance in the human central nervous system to permit sensorial fusion of up to 6° to 8° of residual cyclotorsion postoperatively, so the overall success rate with the adjustable Harada-Ito procedure is quite high.

COMPLICATIONS

Because of the very posterior operative sites, difficult exposure, and great variability in anatomy, superior oblique surgery is among the most difficult of strabismus procedures. It is not surprising then, that complications occurring with these procedures are frequent and varied, especially in the hands of novice or infrequent strabismus surgeons.

Superior oblique weakening procedures can result in either undercorrection with residual superior oblique overaction or overcorrection with secondary superior oblique palsy. Residual overaction is not uncommon following superior oblique tenotomy and generally results from incomplete transection of the tendon with residual intact tendon fibers. This complication is best prevented by careful isolation of the tendon under direct observation prior to tenotomy and, more importantly, by verification of completeness of every tenotomy using the exaggerated forced duction test described by Guyton. This latter test has been especially valuable in detecting incomplete initial tenotomies in which residual overaction would have been present if additional exploration had not resulted in location of the residual uncut fibers.

Successful tenotomy in idiopathic superior oblique overaction rarely, if ever, results in secondary superior oblique palsy; however, secondary palsy is a frequent complication following superior oblique tenotomy for Brown syndrome. To prevent this complication, some strabismus surgeons are recommending simultaneous recession of the inferior oblique at the time of superior oblique tenotomy for documented Brown syndrome. Recently, however, Dr. Kenneth Wright has described an experimental superior oblique silicone tendon expansion procedure that he believes provides better control over the amount of superior oblique weakening and may reduce or eliminate secondary superior oblique palsy.

A third significant potential complication following any superior oblique procedure is the development of adherence syndrome. This devastating complication can occur whenever the orbital fat pad is entered during strabismus surgery. "Blind sweeping" with muscle hooks searching for the superior oblique tendon may result in rupture of the Tenon's capsule and entry into the fat pad. Therefore, all superior oblique procedures should be performed in a controlled fashion with direct observation, as described in this chapter.

Several complications also present problems in patients undergoing superior oblique strengthening procedures. Most prominent is the development of an iatrogenic Brown syndrome following superior oblique tucking. In fact, some limitation of elevation in adduction is almost universal if adequate superior oblique tucking is performed. Patients should be made aware of this potential "side effect" when superior oblique tuck is being considered. In addition, not so much a complication as an unexpected surgical result, reversal of hypertropia after unilateral surgery in patients with masked bilateral superior oblique palsy can be upsetting to patient and surgeon alike. This syndrome results from a markedly asymmetric superior oblique and palsy that initially presents with signs of pals only a unilateral palsy. After unilateral surgical correction, the patient develops what appears to be a marked overcorrection. On further testing, this is documented to be the result of contralateral superior oblique bila palsy. Only by maintaining a high index of that

suspicion can this problem be anticipated

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and prevented. Bilateral superior oblique palsy should be suspected in any patient who demonstrates greater than 12° to 15° of excyclotropia on double Maddox rod testing, alternating hypertropia in right and left gaze, significant esotropia in down gaze, or bilateral fundus torsion on indirect ophthalmoscopy.

Adjustable Suture Strabismus Techniques

INTRODUCTION

Unlike standard fixed suture techniques, in which new extraocular muscle positions and, therefore, forces are permanently set at the time of the surgery, adjustable suture techniques allow alteration in muscle position during the immediate postoperative period, after the patient has recovered from local or general anesthesia.

In the normal alert state, ocular alignment is determined by a combination of fixed mechanical forces and variable tonic forces on the globe. However, during strabismus surgery under either local or general anesthesia, the tonic forces on the globe are variably reduced or eliminated. During surgery using a standard fixed suture, an attempt is made to predict the change in tonic forces on the globe and, therefore, ocular alignment caused by changes in muscle length or position. Standard tables for amounts of recession or resection based on amount of deviation are available for this purpose. Unfortunately, however, the standard tables are devised and most useful for predicting the results in uncomplicated patients and, even in these patients, occasional surprises occur. The use of adjustable suture techniques in selected patients can help to reduce the number of unfavorable surgical results.

PREOPERATIVE EVALUATION

Indications

Adjustable suture techniques are most helpful in patients with good visual acuity in each eye, fusion capability, and complicated or unpredictable strabismus. In these patients, a very precise endpoint, elimination of diplopia, is required for successful results. This group includes patients with paralytic strabismus (e.g., 3rd, 4th, and 6th cranial nerve palsies), patients with mechanical or restrictive strabismus (e.g., thyroid or other myopathies, reoperations with variable amounts of scarring, and incomitance), and large-angle or longstanding strabismus with conjunctival and muscle contracture. In these situations, the standard tables for strabismus surgery do not apply, and the results of surgery using a standard fixed suture can be unpredictable. Adjustable suture techniques can also be extremely helpful in patients with fusion potential and combined vertical and horizontal deviation and in patients with small-angle strabismus with diplopia, in whom a precise postoperative alignment is required to eliminate symptoms. In addition to these more complicated cases, many strabismus surgeons routinely use adjustable suture techniques in all cooperative and consent-

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ing adults, even those undergoing routine strabismus surgery, to reduce the risk of the occasional unexpected postoperative "surprise." In general, adjustable suture techniques are not helpful and are technically difficult in children under 10 to 12 years of age, because of poor patient cooperation, and in most patients with dense amblyopia, macular scars, or eccentric fixation, in whom an exact endpoint for adjustment is not necessary or possible.

Patient Selection

As with any surgical technique, proper patient selection is essential for surgical success. Suture adjustment requires adequate patient cooperation in spite of some discomfort. In general, children under 10 to 12 years of age are not cooperative enough for consideration of this technique; however, occasional patients as young as 8 years of age who pass the Q-tip test, as described below, have been successfully treated. In addition, because of the anxiety and psychological effects produced by ocular manipulation, as well as oculocardiac reflexes, care must be exercised in using these techniques in frail elderly patients with significant cardiovascular disease.

Suture adjustment requires good patient cooperation (i.e., maintenance of a stable head position, controlled ocular rotations, and absence of excessive squeezing with secondary Bell's phenomenon). The Q-tip test has proved to be a simple and reliable patient screening technique. After a thorough explanation of the adjustable suture procedure, a drop of topical anesthetic is instilled into the eye being considered for adjustable suture surgery. With the patient reclining in the examination chair as during the actual adjustment procedure, the patient is then instructed to relax and the lids are gently opened manually by the examiner. A saline-moistened cotton-tipped swab is used to manually manipulate the conjunctiva overlying the muscle to be adjusted. If the patient is able to tolerate this manipulation without lid squeezing or excessive uncontrolled ocular movement, then successful suture adjustment should be possible. Consideration of this technique should be avoided in patients who become upset during a preoperative explanation or who fail the Q-tip test.

Anesthesia

Although adjustable suture surgery can be performed using general, local, or topical anesthesia, several issues must be kept in mind so that the patient will be properly prepared at adjustment time. Adjustable suture patients must be relatively comfortable, unsedated, and without severe nausea or vomiting, and must have had a return of normal ocular motility at the time of suture adjustment. If general anesthesia is used, any modification of the anesthesia that may reduce or eliminate severe postoperative nausea or vomiting, such as the administration of droperidol, should be discussed with the anesthesiologist. If local anesthesia is used, retrobulbar agents should be restricted to lidocaine (Xylocaine) or other short-acting agents alone and long-acting agents like bupivacaine (Marcaine) that can produce akinesia lasting more than 12 hours should be avoided. Retrobulbar injection of 3 to 5 ml of 2% lidocaine with epinephrine and hyaluronidase (Wydase) works well. Also, avoid the use of narcotics or sedatives for 4 to 6 hours before anticipated suture adjustment to eliminate any possible effect of these agents on patient alertness and extraocular muscle tone. If topical anesthesia is used, suture adjustment can actually be performed using these techniques at the time of initial surgery if no additional perimuscular local anesthesia is used.

SURGICAL TECHNIQUES

Adjustable suture surgery, like fixed suture surgery, can be performed using either a limbal or fornix approach. For advantages and disadvantages, as well as surgical techniques for each, see Chapter 4. A limbal incision, with its broad exposure and the possibility of conjunctival recession, is ideal for the surgeon who is a novice with the adjustable suture technique. Recession of the conjunctiva to the original muscle insertion allows for excellent exposure of the adjustable suture knot for adjustment. In addition, the limbal incision is the preferred technique for older patients, whose thin conjunctiva and Tenon's capsule are likely to tear with the stretching required for fornix surgery. However, for the surgeon experienced with the adjustable suture technique, the advantages of the fornix approach include improved patient comfort and cosmesis, since all incisions are hidden beneath the eyelids and no exposed superficial sutures are generally required.

Limbal Approach

A left lateral rectus recession is illustrated.

- Step 1. A limbal conjunctival incision is created as described in Chapter 4, extending over 4 to 5 clock hours directly in front of the muscle to be operated on.
- Step 2. For an adjustable recession procedure, the rectus muscle, either vertical or horizontal, is isolated, cleaned of adherent Tenon's capsule, secured with one 6-0 double-armed Vicrvl suture, and cut free from the sclera as described in Chapter 5 (double-armed suture recession), with the two following minor modifications. First, special care is taken to remove all Tenon's capsule anterior to the muscle insertion, leaving only bare sclera where the adjustable suture knot will lie. Second, in contrast to the fixed suture recession, some posterior dissection of the Tenon's capsule, intermuscular septum, and check ligaments is

required to allow for free, spontaneous movement of the muscle and to prevent these tissues from interfering with the sutures during adjustment. For an adjustable resection procedure, muscle isolation, cleaning, and suture placement can be performed exactly as described in Chapter 6 (doublearmed suture resection).

Step 3. Each pole of the original insertion is grasped with a 0.5-mm locking Castroviejo forceps to stabilize the globe. Each arm of the muscle suture is then secured to the original insertion site by half-thickness scleral passes, beginning approximately 1 mm from the pole and angling anteriorly and toward one another so their tips cross within the sclera, as shown in Figure 9-1 (the crossed-swords technique). The suture entry sites created in this way will keep the new muscle insertion nearly as wide as



Figure 9-1

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the original insertion, preventing bunching up of the muscle and central muscle sag, as described in Chapter 12. In addition, it is very important that both arms of the suture emerge from the sclera at nearly the same point or the sliding noose suture, described in Step 6, will not control both poles of the muscle symmetrically.

- Step 4. The muscle pole sutures are pulled up until both poles of the muscle are tight against the old insertion site (Fig. 9-2).
- Step 5. The two pole sutures are crossclamped with a needle holder 6 to 8 cm from the sclera and tied together at this point using a square knot (Fig. 9-2). This maneuver creates an equal length of suture from each muscle pole to the pole suture knot, allowing symmetric recession or advancement of the

entire muscle by tightening or loosening traction on the pole knot, as shown in Figure 9-3.

Step 6. The adjustable potential of this technique is provided by a sliding noose suture tied tightly around the pole sutures, which, when resting against the sclera, will stabilize the muscle at any desired location. This sliding noose is created by tying an 8- to 10-cm piece of 6-0 coated Vicryl suture (one of the cut ends from the original pole sutures with needle removed works well) very tightly around the two pole sutures, as shown in Figure 9-4. A knot consisting of three throws followed by a single throw, each tightened as tightly as possible using two needle holders, provides a noose tight enough to prevent slippage yet loose enough to allow sliding up and down the pole sutures with moderate force.









Figure 9-4



Test the tightness of the noose at this time by gently sliding it back and forth several times. If it slides too easily, it should be replaced. Creating a slip noose of the proper tension, tight enough to prevent inadvertent slippage between adjustments yet loose enough to be moved small amounts in a controlled fashion, is an important part of this procedure.

- Step 7. The ends of the noose suture are tied together with a square knot to create a *noose handle* (Fig. 9-5) approximately 2 to 3 cm in length. The noose handle and pole sutures must be of sufficiently different lengths to be easily differentiated at the time of adjustment.
- Step 8. To set the adjustable suture for any desired recession, the muscle is pulled tight against the original insertion and the sliding noose is moved to a point measured from

the anterior scleral exit of the pole sutures (X), as shown in Figure 9-5. The amount of initial recession (X) can be determined by reference to standard tables or by the assessment of muscle tension using forced ductions. This initial estimate need not be perfect, since postoperative adjustment will be possible. Nevertheless, if possible, the muscle should generally be recessed 2 to 3 mm more than the surgeon expects to need. since it is an easier and less painful adjustment to pull up an over-recessed muscle than to get a muscle to retract further. In addition, one of the amazing features of this procedure is that frequently, especially in complex cases, this presumably over-recessed muscle results in target alignment postoperatively without adjustment. These patients presumably would



Figure 9-6

have been under-recessed by fixed suture surgery.

- Step 9. The muscle is allowed to retract posteriorly by its own elasticity or, if necessary, it can be pushed posteriorly with a Stevens muscle hook, until the noose knot contacts the sclera, as shown in Figure 9-6. The amount of recession (X) can be verified, if cesired, by direct measurement using a caliper.
- Step 10. A single-armed 6–0 black silk traction suture is secured to superficial sclera near the limbus radially on a line from the noose knot to the center of the pupil. This suture will allow control of the globe during adjustment, without the painful use of forceps.
- Step 11. The conjunctival flap is recessed to drape across the original muscle insertion site with two interrupted 7–0 collagen sutures, as illustrated in Figure 9-6. This conjunctival position allows easy access to the traction suture, pole

sutures, and sliding noose during adjustment.

The eye speculum is then removed, and all sutures are directed either medially or laterally over the canthal area, draped across the upper or lower lid, and held in place with ophthalmic ointment or steri-strips. After combination antibiotic/steroid ointment is applied to the eye, an eye patch is used to cover the sutures and prevent inadvertent patient manipulation prior to suture adjustment.

Fornix Approach

A left medial rectus recession through an inferonasal fornix incision is illustrated.

- Step 1. A two-plane inferonasal fornix incision is created as described in Chapter 4.
- Step 2. This procedure may be used for either recession or resection of the horizontal or vertical rectus muscles. If a recession is to be per-

formed, the muscle is isolated, cleaned of surrounding anterior Tenon's capsule, sutured, and disinserted from the sclera by the standard fornix recession technique as described in Chapter 5 (double-armed suture recession). As with the limbal adjustable suture procedure, additional dissection of the anterior Tenon's capsule, intermuscular septum, and check ligaments from the distal 5 mm of muscle is required to allow free muscle movement and to prevent interference with the sutures during adjustment. If a resection is to be performed, initial muscle isolation, cleaning, suture placement, and muscle resection are performed as described in Chapter 6 (double-armed suture resection). However, it is helpful to resect 2 or 3 mm more than suggested by standard tables or surgical judgment. This causes the resected muscle to be left recessed 2 or 3 mm behind the original insertion, allowing the additional flexibility of either further advancing (increasing the resection effect) or further recessing (reducing the resection effect) the muscle at the time of adjustment. Because a resected muscle is considerably tighter than a recessed one, it is generally not difficult to further recess a resected muscle during adjustment.

- Step 3. Using locking 0.5-mm Castroviejo forceps placed on each pole of the original insertion for stabilization, the muscle is resutured to the original insertion site with half-thickness scleral bites entering 1 mm from each pole and exiting the sclera, touching in a crossedswords fashion as shown in Figure 9-7. A small Stevens hook held in



Figure 9-7

the surgeon's other hand may be used to retract conjunctiva from the scleral exit site during suture placement. It is extremely important for the functioning of the adjustable slip noose that the two muscle sutures exit the sclera at nearly the same point.

- Step 4. The muscle is pulled up so that both poles are tight against the original insertion, and the two muscle pole sutures are crossclamped with a needle holder 6 to 8 cm from the scleral exit site, as shown in Figure 9-8A.
- Step 5. The two muscle pole sutures are tied together just distal to the needle holder using either a square knot or figure eight knot to form the *pole knot*, as illustrated in Figure 9-8B. The longer of the two suture ends is then removed just distal to the pole knot (Fig. 9-8C); its needle is removed and then set aside for use in creating the slip noose. This procedure re-









sults in sutures of identical length connecting each pole of the muscle to the pole knot and allows symmetric recession or advancement of each pole of the muscle by increasing or decreasing traction on the pole knot or remaining single distal suture.

Step 6. The conjunctiva is gently massaged back into its original location, closing the fornix incision using either a moistened cottontipped swab or a Stevens hook. The remaining needle is then passed through the wound, beneath the conjunctiva and Tenon's capsule along the scleral surface, and up through the conjunctiva to exit at a point directly overlying the point of exit of the pole sutures from the sclera, as shown in Figure 9-9. As the needle is pulled through the conjunctiva, it is followed by the pole knot and two pole sutures: the muscle position can now be entirely controlled by manipulating the pole sutures through the intact conjunctiva.

Step 7. To control the muscle position and allow for its adjustment, a sliding noose, made from the remaining piece of 6-0 Vicryl suture previously removed, is tied tightly around the pole sutures using first three throws and then a single throw tightened with two needle holders. The noose must be tight enough to hold the muscle in place between adjustments, vet loose enough that controlled adjustments of its position can be made with moderate traction. Test the degree of friction by gently sliding the noose back and forth once or twice. Replace the noose if it is too loose. The ends of the noose suture are then tied together to form a 2-cm noose handle, carefully constructed to be much shorter than the pole sutures (Fig. 9-10) so



Figure 9-9



Figure 9-10

that proper identification is assured at the time of adjustment.

Step 8. To complete the procedure, a 6– 0 black silk traction suture is secured to episclera near the limbus on a radial line between the noose knot and pupillary center (Fig. 9-11). This suture allows control of



Figure 9-11



the globe during suture adjustment without the need for painful forceps.

- Step 9. Finally, the initial muscle position is set by pulling the muscle all the way up with the traction on the pole suture while simultaneously providing counter traction on the traction suture. The sliding noose is then moved to a measured distance (X) from the point of exit of the pole sutures from the conjunctiva, as illustrated in Figure 9-11. (X is the desired amount of initial recession as determined by standard tables or surgical judgment plus 2 or 3 mm so that the muscle will initially be slightly over-recessed, since it is easier to advance a muscle during adjustment than to further recess it.)
- Step 10. The muscle is allowed to retract spontaneously or, if necessary, pushed back manually with a Stevens muscle hook inserted through the fornix insertion, until the noose suture reaches the con-

junctival surface (Fig. 9-12). If desired, the exact amount of muscle recession (X in Fig. 9-12) can be verified at this time by direct measurement after gentle retraction of the conjunctiva with a Stevens hook to expose the original insertion and recessed muscle.

Step 11. On completion of the procedure, the fornix incision is massaged closed and the lid speculum is removed. The sutures are directed either medially or laterally over the canthal area, draped on the upper or lower lid, and held in position with ophthalmic ointment or steri-strips. An eye patch is then applied to protect the sutures until adjustment.

POSTOPERATIVE CARE

Suture Adjustment

Postoperative suture adjustment is ideally performed as soon as 4 to 6 hours after surgery, but can be postponed for as long as 24 hours. In general, the theoretical advantage of postponing the suture adjustment as long as possible is more than outweighed by the increased patient discomfort and physical difficulty moving muscles that have become adherent to the sclera and conjunctiva by fibrin as soon as 8 to 12 hours after surgery. Prior to adjustment, the patient should be alert with full ocular rotations and brisk saccades. If possible, sedatives and narcotics should be avoided within 4 hours before suture adjustment as these agents may affect patient alertness and eye position. Acetaminophen (Tylenol) may be used for pain.

Adjustment is generally performed in a standard examination lane with the patient in a reclining examination chair. It can be performed, if necessary, in the patient's hospital bed using hand-held or ceilingmounted fixation devices. Topical anesthesia with proparacaine or tetracaine provides adequate anesthesia in most patients who have been prescreened with the Q-tip test. Strict sterile technique is not required, although some surgeons now wear surgical gloves to protect themselves as well as to protect their patients.

The amount and direction of adjustment should be based on objective motility testing at relevant distances, in relevant gaze positions, and, when appropriate, while wearing optical correction to properly control accommodation and improve image clarity. If only prism glasses are available for adjustment, the ground-in prisms can be neutralized with press-on Fresnel prisms before adjustment. Again, before final tiedown in any patient, and especially in those with complex or incomitant deviations, the patient must be evaluated in all relevant or symptomatic gaze positions and distances.

Adjustment Technique

Step 1. After objective assessment of ocular alignment and fusional status, the patient is placed in the reclining position and additional topical anesthesia is applied to the adjustment site. Lid retraction for proper exposure can be provided by having an assistant gently retract the lids with cotton-tipped swabs (Fig. 9-13) by rolling the swabs toward the lid margin, being careful not to apply pressure to the globe. Alternatively, if no assistant is available, a Burke or Lancaster lid speculum can be comfortably used in most patients.



Figure 9-13

- Step 2. The black silk traction suture, the longer Vicryl pole suture, and the shorter noose handle are carefully and gently separated so that muscle position is not altered.
- Step 3. If the initial goal of over-recession at the time of surgery has been accomplished, then muscle advancement will be required. To accomplish this, the patient is instructed to gaze into the field of action opposite that of the operative muscle. This will result in decreased tone in the muscle to be advanced. While gentle traction on the pole sutures is provided by a needle holder, counter-traction on the silk suture is used to pull the globe into the field of action of the muscle to be advanced, as illustrated in Figure 9-13. This results in movement of the noose knot away from the conjunctiva by an amount equal to the amount of muscle advancement. After the appropriate amount of muscle advancement has been accomplished (usually 1 to 2 mm per adjustment), the silk traction suture can be released and, while traction on the pole suture is maintained with one needle holder, the sliding noose knot can be pulled down to the conjunctival surface to restabilize the muscle in its more advanced position, as shown in Figure 9-14A.
- Step 4. If initial assessment suggests the need for additional recession the patient is instructed to gaze into the field of action away from the adjustable muscle to relax it. Brief traction on the pole suture and counter-traction on the silk suture is used to advance the noose knot a fraction of a millimeter away from the conjunctiva. The traction suture is then released and the needle holder used to grasp the pole su-

tures just on the proximal side of the noose knot. The other needle holder that was previously holding the distal pole sutures is used to move the noose knot 1 or 2 mm distally away from the conjunctiva. The pole suture is then released and the patient is instructed to gaze into the field of action of the operative muscle, which causes it to contract, and results in further recession until the noose knot again contacts the conjunctiva. If spontaneous retraction does not occur. counter-traction with the silk suture pulling the eye out of the field of action of the adjustable muscle may be required to develop enough tension on the pole sutures to cause them to retract through the scleral tunnels. Because this maneuver is painful for many patients, every effort should be made to initially over-recess so that additional recession will not be required.

- Step 5. After the desired alignment has been obtained, the pole knot is removed with sharp iris scissors to separate the two pole sutures, which are then tied together using a simple square knot that is gently snugged down on top of the noose knot. The extra ends of the pole sutures as well as the noose handle are removed by cutting with a sharp iris scissors just above the knot. The silk traction suture is removed last, after there is no longer any risk of inadvertently pulling on the pole or noose sutures and moving the muscle from its desired postadjustment position, or inadvertently cutting the noose knot.
- Step 6. When using the limbal approach, the knot is left exposed on bare sclera just anterior to the recessed conjunctiva. However, if the fornix approach is used, the patient can be



Figure 9-14

made as comfortable as with the standard fornix technique by inducing the knot to retract through the conjunctival opening into the sub-Tenon's space. This can be accomplished with gentle elevation of the conjunctiva by grasping adjacent to the knot, as shown in Figure 9-14B.

GOALS OF ADJUSTMENT

One of the most difficult and controversial aspects of adjustable suture strabismus surgery concerns the alignment goals at the time of adjustment. Because of the generally predictable occurrence of a small amount of postoperative alignment drift during the first weeks or months following surgery, the goal at the time of adjustment is frequently some position other than orthophoria. Instead, an ocular alignment is sought that will result in the greatest likelihood of long-term success. Guidelines for final ocular alignment in a variety of conditions that commonly benefit from adjustable sutures are shown in Table 9-1. In general, when performing bilateral recessions for either esotropia or exotropia, slight overcorrections are preferred, as postoperative drift is back toward the original deviation. An attempt must be made to avoid very large adjustable recessions that may initially drift back but later seem to drift toward increasingly large overcorrections. Patients with fusion potential undergoing a recess/resect procedure demonstrate less overall drift and do well with minimal ov-

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Diagnosis	Fusion Potential	Operation	Adjustment Goal
Esotropia			
Accommodative	+	Bilateral MR recession	$0 - 5^{\Delta} \text{XT}$
Nonaccommodative	+	Recess/resect	$4 - 6^{\Delta} \text{ XT}$
Nonaccommodative	_	Recess/resect	$5 - 7^{\Delta} ET$
Thyroid myopathy	+	MR recession	$4 - 6^{\Delta} \text{ XT}$
Exotropia			
Intermittent	+	Bilateral LR recession	$8 - 10^{\Delta} \text{ ET}$
Basic	+	Recess/resect	$4 - 6^{\Delta} ET$
Basic	-	Recess/resect	$5 - 10^{\Delta} \text{ ET}$
Hypertropia/hypotropia			
Thyroid myopathy	+	IR recession	$6 - 10^{\Delta}$ undercorrection
Nonmyopathic	+	Vertical recession	$0 - 5^{\Delta}$ undercorrection
	+	Vertical resection	$0 - 5^{\Delta}$ overcorrection
Palsy, trauma, mechanical	+	Depends on diagnosis	Maximize central binocular field
Sensory			
Esotropia	_	Recess/resect	$5 - 10^{\Delta} \text{ ET}$
Exotropia	-	Recess/resect	$6 - 8^{\Delta} ET$

Table 9-1. Guidelines for Final Ocular Alignment

Abbreviations: MR, medial rectus; LR, lateral rectus; IR, inferior rectus; XT, exotropia; ET, esotropia.

ercorrection. Patients with sensory deviations, either esotropia or exotropia, are best left slightly esotropic, since the long-term trend is toward exotropia. Finally, when performing vertical rectus muscle surgery, a slight undercorrection with recessions and overcorrection with resections is recommended. When recessing an inferior rectus for thyroid myopathy, however, late progressive overcorrections are common, especially when inferior rectus recessions greater than 6.5 mm are performed. In these cases, initial moderate undercorrections (adjusting patients for moderate hypotropia in primary position and fusion with 10° to 15° chin up posture) yield the best long-term results.

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Special Muscle Procedures

INTRODUCTION

Chapters 5 through 9 reviewed the commonly performed strengthening and weakening procedures for the horizontal and vertical recti, as well as the superior and inferior oblique muscles. In addition, there are a number of additional muscle procedures which do not strengthen or weaken muscles, but instead alter their force vectors, to affect ocular alignment in unique ways for treatment of unusual or complex forms of strabismus. Although less commonly performed, it is important to understand the indications and techniques involved in these procedures, since alternatives are frequently not available.

Vertical Transposition of Horizontal Rectus Muscles for A- and V-Patterns

A- and V-pattern strabismus is present when horizontal nonconcomitance is present between up gaze and down gaze. By convention, an A-pattern is present whenever the ocular alignment measured in 30° down gaze is at least 10^{Δ} more divergent than that measured in 30° up gaze. A V-pattern is present whenever alignment in 30° up gaze is at least 15^{Δ} more divergent than that in 30° down gaze. In both A and V-patterns, primary position ocular alignment may be orthophoric, esotropic, or exotropic, which results in A-pattern esotropia, A-pattern exotropia, V-pattern esotropia, Vpattern exotropia, and so forth. Patients frequently employ chin-up or chin-down face postures for fusion when a position of orthophoria is present in either up or down gaze.

A- and V-patterns are frequently caused by oblique muscle dysfunction: an A-pattern by overaction of the superior oblique muscles and a V-pattern by overaction of the inferior oblique muscles. Therefore, a careful search for oblique muscle overaction is necessary in all patients with A- or V-patterns, since appropriate oblique muscle weakening, as described in Chapters 7 and 8, is the most effective therapy to eliminate the A- or V-pattern in patients with oblique overaction. In other patients, an Aor V-pattern may be caused by nonconcomitant action of horizontal rectus muscles. In patients without oblique muscle dysfunction, vertical transposition (sometimes called vertical shift or vertical offset) of the horizontal rectus muscles is an effective means of correcting the A- or V-pattern and restoring vertical gaze concomitance.

The rationale for using vertical transposition of horizontal rectus muscles to treat idiopathic A- and V-patterns was first presented by Knapp in the *Transactions of the American Ophthalmological Society*



(57:666, 1959). Although the details are bevond the scope of this chapter. Figure 10-1 summarizes the key principles involved in using vertical transposition of horizontal rectus muscles in the treatment of both Aand V-patterns. A V-pattern (Fig. 10-1A) can be corrected by elevation of lateral recti, depression of medial recti, or a combination of both. Likewise, an A-pattern (Fig. 10-1B) can be corrected by elevation of medial recti, depression of lateral recti, or both. A unifying concept for both A- and V-patterns, obvious from Figure 10-1, is to remember to always move the lateral rectus toward the *legs* of the A or V and the medial rectus towards the apex. The magnitude of the transposition is controversial. Some surgeons perform a half-tendon width transposition for smaller patterns (less than 20 to 25^{Δ} and a full-tendon width transposition for larger patterns. In our experience, a fulltendon width transposition is safe and effective for any clinically significant A- or Vpattern not caused by oblique dysfunction. The procedure is effective when performed symmetrically (i.e., elevation or depression of the lateral or medial rectus of each eye), but can also be performed asymmetrically (e.g., elevation of the lateral rectus and depression of the medial rectus on the same eye). One caveat is that in patients with bifixation and 40 seconds of arc stereopsis, performing both transpositions on one eye can result in significant torsion with torsional diplopia.

In general, vertical transposition of horizontal muscles does not alter horizontal alignment in primary position. Therefore, this procedure can be combined effectively with either recession or resection of the rectus muscles that has been calculated to correct the horizontal misalignment in primary position. If no horizontal misalignment is present in primary position, then vertical transposition alone can be performed.

SURGICAL TECHNIQUE

- Step 1. For vertical transposition of a horizontal rectus muscle, the rectus muscle is isolated and prepared for recession, resection, or transposition alone, as described in Chapters 4 to 6. Either a limbal or fornix incision can be used. However, if a fornix incision is used, a little advanced planning will simplify the operative technique. If the muscle is to be elevated, a superior quadrant fornix incision is indicated; if the muscle is to be depressed, an inferior quadrant incision is indicated. This will allow transposition of the muscle towards the conjunctival incision for easier reattachment, with minimal conjunctival stretching.
- Step 2. The most important aspect of the vertical transposition procedure is



proper determination of the new scleral reattachment site, without inadvertent advancement (strengthening) or recession (weakening). Figure 10-2A illustrates the technique for localizing the new insertion when elevating (or resecting and elevating) a rectus muscle one full-tendon width. The new insertion site (dashed line) is measured radially from the limbus a distance (A) equal to the distance of the old insertion site from the limbus.

Step 3. If a recession as well as a transposition is to be performed, the measurement technique illustrated in Figure 10-2B is used. First, the amount of planned recession (B) is radially measured for the pole of the new insertion nearest the original insertion. After this suture is

passed through the sclera in the standard fashion, the new location of the other pole is established by measuring radially from the limbus a distance of A plus B, as shown. This will establish a new insertion, 8 to 10 mm wide, parallel to the limbus. Since the distance between adjacent rectus insertions is not much larger than 10 mm, it is important to remember that the new insertion, after full-tendon transposition, will be very near the insertion of the adjacent rectus muscle. The recession with vertical transposition can also be performed on an adjustable suture; however, the hang-back suture technique reduces the transposition effect, which lessens the amount of A- or V-pattern correction.



Step 4. Figure 10-3 shows the final result of a unilateral full tendon transposition procedure performed on the right eye to correct a V-pattern in a patient with straight eyes in the primary position. In this case, the lateral rectus muscle is elevated one tendon width and the medial rectus depressed one tendon width, without recession or resection of either muscle. A similar procedure could be performed in association with a recess/resect procedure to correct any esotropia or exotropia present in primary position.

Vertical Transposition of Horizontal Rectus Muscles for Vertical Strabismus

Graded vertical transpositions of horizontal recti are also useful in correcting small concomitant vertical deviations in association with horizontal strabismus. Using this technique, vertical deviations of up to 8 to 10^{Δ} can be corrected while performing recession or resection of horizontal rectus muscles for esotropia or exotropia. In addition to requiring operation on fewer muscles, the procedure eliminates the need to operate on more than two muscles on a single eye, thereby reducing the risk of anterior segment ischemia (see Ch. 13).

In this procedure, the medial and lateral recti are depressed (infraplaced) if operating on the hypertropic eye, or they are elevated (supraplaced) if operating on the hypotropic eye. Although the procedure can be performed in association with symmetrical surgery (e.g., by elevating the lateral rectus of the hypotropic eye and depressing the lateral rectus in the other [hypertropic] eye) it is most effective and predictable when performed as part of a recess/resect procedure in the same eye.

As a general rule, a correction of approximately 1^{Δ} of vertical deviation can be expected for each millimeter of measured vertical transposition (when performed during a recess/resect procedure in the same eve). Therefore a 6-mm vertical transposition of both rectus muscles will correct approximately 6^{Δ} of vertical deviation, and one of 3 mm will correct approximately 3^{Δ} . However, as would be expected, the major vertical force occurs in relation to the resected rather than recessed muscle. Therefore, less effect would be expected when performing the procedure during a bilateral recession, and a greater effect is expected with a bilateral resection. In addition, the vertical transposition procedure is not effective in cases of vertical strabismus in



Figure 10-4

which mechanical restriction is present. In such cases vertical muscle surgery to relieve the restriction must be performed. These cases generally present with vertical nonconcomitance and can be confirmed by forced duction testing.

SURGICAL TECHNIQUE

Step 1. Graded vertical transposition of horizontal rectus muscles for vertical strabismus is performed in the same way as for A- and V-patterns (Steps 1 and 2 of the previous technique). However, here the amount

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of elevation or depression is graded according to the amount of vertical deviation.

- Step 2. Again, proper determination of the new scleral insertion site is critical for predictability of both the horizontal and vertical effects. Figure 10-4 illustrates the surgeon's view of the correct technique for recessing a left medial rectus Y millimeters while simultaneously elevating it X millimeters. In this case the vertical location of the new insertion is established first by measuring, with a caliper, X millimeters vertically from both the inferior and superior poles as illustrated. These two points are then grasped with a locking 0.5-mm Castroviejo forceps. This technique will assure that the new insertion is the same width as the original insertion, thereby preventing central sag of the recessed and transposed muscle. The new insertion site can then be measured directly with a caliper Y millimeters posterior to each forceps, as illustrated, and the muscle resutured to the sclera at these points.
- Step 3. Figure 10-5 illustrates the final result of a 10 mm (full-tendon) infraplacement of both horizontal recti in association with a recess/resect procedure. The rectus muscle on



Figure 10-5

the left has also been recessed B millimeters, while the rectus muscle on the right has been resected. Performing a vertical transposition procedure in association with a recess/resect procedure is the most common and predictable use of this procedure.

Rectus Muscle Transposition for Extraocular Muscle Palsy or Lost Muscle

Several muscle transposition procedures have been developed to improve ocular alignment and rotation in patients with palsy, congenital absence, or acquired loss of a horizontal or vertical rectus muscle. The procedures involve transposing healthy contracting adjacent muscles toward the insertion of the weak or absent rectus muscle. These transposed muscles provide a tonic force vector similar to that previously provided by the paretic muscle. Then, when the antagonist muscle is inhibited on attempted gaze into the field of action of the paretic muscle (Herring's law), the new tonic force vector induces movement of the globe past the midline in the field of action of the lost or paretic muscle. In general, if a muscle has been lost or paretic for more than 1 to 2 months, its antagonist becomes contracted and should be weakened by recession (preferably on an adjustable suture) or by botulinum toxin injection prior to or at the time of muscle transposition. Forced duction testing, both preoperatively and intraoperatively is helpful in determining the necessity of antagonist weakening.

PROCEDURE SELECTION

Complete 6th (abducens) nerve palsy is by far the most common indication for a transposition procedure of this type. Patients first seen for evaluation of acute 6th nerve palsy should be followed for at least 6 to 12 months to determine whether any nerve regeneration will occur. At least 6 months after onset, when the alignment has stabilized, complete evaluation of lateral rectus function should be performed using subjective or objective saccadic velocity measurement and active force generation testing (see Ch. 1). If any lateral rectus function can be demonstrated, then a large recess/resect procedure on an adjustable suture is indicated. However, a recess/resect procedure is contraindicated in the presence of complete palsy, where no lateral rectus function is present. This is because, although the eye can be mechanically straightened acutely using a very large recess/resect procedure, the dead lateral rectus muscle eventually stretches out and the esotropia returns. Then unfortunately, because the anterior ciliary arteries in both horizontal recti have already been transected, the options for transposing the vertical recti are greatly limited since it is undesirable to transect all anterior ciliary vessels and risk the development of anterior segment ischemia syndrome.

Instead, in cases of complete lateral rectus palsy, an ipsilateral medial rectus weakening procedure (either recession \pm adjustable suture or botulinum toxin injection) along with a transposition procedure (either Jensen or total transposition) is indicated. The Jensen procedure is preferred by many surgeons because it theoretically spares the anterior ciliary arteries located in the nasal half of the superior and inferior rectus muscles, thereby reducing the risk of anterior segment ischemia. However, the Jensen procedure is technically more difficult and time consuming to perform and results in significantly more periocular scarring, which makes reoperation, if necessary, much more difficult. In addition, in spite of the theoretical sparing of the anterior circulation with the Jensen procedure, docu-
mented cases of anterior segment ischemia following a Jensen procedure have been reported. Therefore, a total tendon transfertype operation may be preferable since it is simpler to perform, easy to take down if necessary, and leaves the lateral rectus entirely unoperated to provide anterior segment circulation. In addition, studies by Repka and Guyton in monkeys have suggested that the limbal conjunctival circulation may also contribute significantly to the anterior segment circulation. Therefore, the use of fornix rather than limbal incisions with any transposition procedure, especially with the total tendon transfer operation, may be advantageous.

The other significant indication for transposition surgery is the presence of double elevator palsy or a lost or congenitally absent rectus muscle. A vertical total tendon transfer procedure (Knapp procedure) is generally the procedure of choice for patients with double elevator palsy and little or no inferior rectus fibrosis or contracture. If positive forced duction testing suggests inferior rectus restriction, then inferior rectus recession \pm adjustable suture is necessary before or concurrently with the Knapp procedure. In addition, recession of the superior rectus (possibly with a posterior fixation suture) on the contralateral eye may be necessary to reduce or eliminate any residual vertical deviation in up gaze.

The congenitally absent or otherwise lost rectus muscle presents a particular challenge to the strabismus surgeon, since the anterior segment circulation that would have been provided by this muscle is not present, thus limiting the therapeutic choices. Obviously, a thorough search for any lost muscle is indicated, since only by its recovery and reattachment to the globe, can a reasonably normal range of ocular rotation be reestablished. However, if the lost muscle can not be recovered, then the treatment of choice consists of botulinum toxin injection into the antagonist muscle with total or partial tendon transfer of the remaining adjacent rectus muscles to the insertion of the previously lost muscle.

SURGICAL TECHNIQUES

The two most commonly used horizontal transportation procedures, the Jensen procedure and the total transposition (or total tendon transfer) procedure, as well as the Knapp procedure, a vertical modification of the total transposition procedure are described below. An additional technique, the partial tendon transfer or Hummelsheim procedure is also recommended by some surgeons. However, we have found this procedure to be significantly less effective and therefore rarely indicated.

Jensen Procedure

A Jensen procedure on the left eye through two separate fornix incisions (superotemporal and inferotemporal) is illustrated.

The Jensen procedure is a split-tendon, partial muscle transfer with adjacent halves of the vertical recti and lateral rectus joined together, but not disinserted. The procedure was designed to preserve the nasal anterior ciliary arteries from the superior and inferior rectus muscles. However, as previously discussed, anterior segment ischemia has been described even with the Jensen procedure.

Step 1. The superior rectus is isolated through a superotemporal fornix incision, as described in Chapter 4. The temporal half of the muscle insertion is carefully cleaned of adjacent Tenon's capsule and temporal intermuscular septum posteriorly to the point (at least 15 mm posterior to the insertion) of penetration through Tenon's capsule. Care is taken to avoid dissection of Tenon's capsule or intermuscular



Figure 10-6

septum adjacent to the nasal half of the muscle, as this portion of the muscle will not be operated on.

- Step 2. The surface of the superior rectus is carefully inspected to document the location and branching pattern of all anterior ciliary arteries. The muscle is then split exactly in half with a small Stevens hook inserted from the underside of the muscle, as illustrated in Figure 10-6. This split is extended posteriorly at least 15 mm from the insertion by blunt disection with two Stevens hooks or by sharp dissection with a blunt Westcott scissors (Fig. 10-6). Only minimal bleeding will occur if the posterior dissection is carried out parallel to the muscle fibers and does not transect major ciliary vessels.
- Step 3. A 5-0 Mersilene suture is then placed around the temporal half of

the superior rectus muscle and the superior rectus is released to fall beneath the conjunctiva (Fig. 10-7). The lateral rectus is isolated through the same fornix incision; cleaned of adherent Tenon's capsule, check ligaments, and intermuscular septum; and split posteriorly in an identical fashion. The Mersilene suture around the temporal half of the superior rectus muscle is then passed around the superior half of the lateral rectus. as shown in Figure 10-7.

Step 4. The adjacent halves of the superior and inferior rectus muscle are loosely joined together by tying off the Mersilene suture as shown in Figure 10-8. Care must be taken to avoid a tight muscle union, which could interfere with the blood flow through the muscles. The union sutures between the superior and lat-





Figure 10-8

eral rectus and inferior and lateral rectus must be placed near the equator of the globe and should measure 12 to 14 mm posterior to the limbus. Great care should be taken to ensure that both the superotemporal and inferotemporal union sutures are the same distance from the limbus, since any asymmetry in their location can result in vertical force imbalance and a secondary vertical deviation. To maintain the correct union suture location postoperatively, it is helpful to fix the union suture to the sclera by taking a small scleral bite with one arm of the Mersilene suture, just temporal to the muscle union (Fig. 10-8), when it is in its final location. Attaching the Mersilene union suture to the sclera will stabilize the muscle union in its correct location, and prevent its later migration with loss of transportation effect or development of secondary unwanted vertical deviations.



Figure 10-9

Step 5. An inferotemporal fornix incision is then created and the identical procedure is performed to create a muscle union 12 to 14 mm posterior to the limbus between the temporal half of the inferior rectus and the inferior half of the lateral rectus, as shown in Figure 10-9. The self-closing fornix incisions are then massaged closed, generally completing the procedure without the need for conjunctival sutures.

Total Transposition Procedure

A total transposition procedure or total tendon transfer procedure on the left eye through two fornix incisions is illustrated.

Step 1. The inferior rectus is isolated through an inferotemporal fornix incision as described in Chapter 4. The insertion is then completely cleaned of adherent Tenon's capsule, check ligaments, and intermuscular septum posteriorly to the point of penetration of the inferior rectus muscle through Tenon's capsule. As with any vertical rectus muscle procedure, this thorough lysis of all attachments to the inferior rectus is necessary to prevent alteration of the lid position during the transposition operation. The insertion is then secured with a double-armed 6-0 Vicryl suture in a standard fashion, as described in Chapter 5, and disinserted from the sclera as shown in Figure 10-10. The lateral rectus is secured through the same inferotemporal fornix incision, as shown in Figure 10-11, and the inferior rectus muscle is resutured to the sclera to create a new insertion site adjacent to the inferior border of the lateral rectus. Several options for locating this new insertion have been de-



Figure 10-10



Figure 10-11



Figure 10-12

vised and are illustrated in Figure 10-12. In Figure 10-12B, the inferior rectus is sutured with its new insertion parallel to the inferior border of the lateral rectus. This technique produces maximum lateralization of the inferior rectus. However, it also places the temporal pole of the inferior rectus more posterior on the globe, thereby slackening, and theoretically reducing, the tonic force on the muscle. In Figure 10-12C, the new insertion is established parallel to the limbus with the temporal border of the inferior rectus adjacent to the inferior border of the lateral rectus. This technique maintains maximal stretch on the inferior rectus, particularly the temporal fibers, which contribute most to the abducting force. However, it places the rest of the muscle in a less temporal, and theoretically less abducting, location. The position illustrated in Figure 10-12A, represents a compromise between the other two locations. This insertion is created by placing the temporal pole suture at the inferior border of the lateral rectus, and the nasal pole suture on a point concentric with the limbus, with both sutures existing at the inferior pole of the lateral rectus as shown. This localization minimizes the recession effect on the inferior rectus while maximally lateralizing its location to increase the abducting force. Additional tension on the central portion of the muscle can be created by performing a central sag procedure, as described in Chapter 12, to pull the central portion of the muscle belly anteriorly to the inferior border of the lateral rectus.

Step 2. When the full tendon transfer of the inferior rectus has been completed. the superior rectus is isolated through a superotemporal fornix incision, and the identical tendon transfer procedure performed. The final result of the total transposition procedure is illustrated in Figure 10-13. It is extremely important that both the superior and inferior rectus are treated symmetrically in terms of muscle isolation, cleaning and lysis of adhesions and intermuscular septum, and reattachment to the sclera adjacent to the lateral rectus. If complete symmetry in all steps is not maintained, then vertical force imbalance may result in secondary vertical strabismus. Again, it is frequently necessary to weaken the antagonist medial rectus either through recession (\pm adjustable suture) or botulinum toxin injection to allow fusion in primary position and some degree of abduction.

Knapp Procedure

A vertical full-tendon transposition operation was originally described by Knapp for treatment of double elevator palsy. The procedure, illustrated in Figure 10-14, consists of a total transposition of the medial





Figure 10-13



rectus and lateral rectus superiority, adiacent to the insertion of the superior rectus. The procedure is performed in a fashion identical to the horizontal total transposition operation described above. Again, three potential techniques for localizing the new transposed muscle insertion are available (Fig. 10-12). However, for the Knapp procedure, most surgeons seem to prefer the localization illustrated in Figure 10-12C, and Figure 10-14. This procedure is generally performed through two fornix incisions, one in the superotemporal quadrant and one in the superonasal quadrant. In addition, weakening of the inferior rectus, if it is fibrotic or contractured, may be required to allow for a successful Knapp procedure.

Y-Splitting of the Lateral Rectus for Duane Syndrome

In patients with Duane retraction syndrome, surgery is indicated, as discussed in Chapter 1, to correct the following:

1. Significant esotropia or exotropia in primary position

2. Significant face turn for fusion

3. Significant globe retraction on attempted adduction

4. Significant up shoot or down shoot of the eye in attempted adduction

The Y-splitting procedure of the lateral rectus is effective in eliminating or greatly reducing the up shoot or down shoot (leash phenomenon) of the Duane's eye in attempted adduction. If esotropia is present in primary position, or a significant face turn is present, then a standard large medial rectus recession (\pm adjustable suture) can be performed at the same surgical session. On the other hand, if primary position exotropia is associated with an up shoot or down shoot, then recession of the Y-split

lateral rectus can be performed to correct both problems simultaneously.

SURGICAL TECHNIQUE

Y-splitting of the left lateral rectus through an inferotemporal fornix incision is illustrated.

- Step 1. The lateral rectus is isolated through an inferotemporal fornix incision as described in Chapter 4, and the distal 15 mm of the muscle are thoroughly cleaned of adherent Tenon's capsule, check ligaments, and intermuscular septum. The distal muscle is then split into equal halves for a distance of 15 mm posteriorly by blunt disection using two Stevens hooks, or by sharp disection using a small Stevens hook and blunt Westcott scissors, as illustrated in Figure 10-15.
- Step 2. A separate double-armed 6–0 Vicryl suture is then used to secure each half of the insertion separately, using the suturing technique



Figure 10-15



Figure 10-16

described in Chapter 5. Both halves of the insertion are then disinserted from the sclera using a blunt Westcott scissors as shown in Figure 10-16.

Step 3. The two halves of the lateral rectus are reattached to the sclera as shown in Figure 10-17. The superior half is reattached such that its inferior pole is adjacent to the superior end of the original insertion, and the inferior half is reattached such that its superior pole is adjacent to the inferior end of the original insertion. Be careful to maintain the full width of each half of the muscle as it is reattached to the sclera. When completed, the procedure results in a very broad lateral rectus insertion that stabilizes the lateral rectus position and prevents it from flipping superiorly or inferiorly over the globe and producing the up shoot or down shoot



Figure 10-17



Figure 10-18

Step 4. If exotropia in primary position is also present, the Y-splitting procedure can be combined with muscle recession by merely recessing each pole of the muscle the same amount measured radially from the superior and inferior pole of the original insertion.

Posterior Fixation Procedure

The posterior fixation procedure (or Faden operation) was first described by Cüppers in 1972. The procedure is designed to selectively weaken a rectus muscle primarily in its field of action by decreasing the mechanical advantage of the muscle acting on the globe. The procedure may be performed alone to treat nonconcomitant strabismus, with good alignment in primary position. However, it is more commonly performed, and generally more effective, when performed in conjunction with a recession of the same rectus muscle.

Figure 10-18 illustrates the theoretical mechanism of the gaze-dependent weakening. Figure 10-18A illustrates the normal effective lever arm of the medial rectus (X) running from the point of muscle tangency to the center of rotation of the globe. Even if the eye is adducted more than 25°, such that the medial rectus insertion rotates to the point of tangency with the globe, the lever arm remains the same length, as illustrated in Figure 10-18B. In addition, a very large medial rectus recession, with reattachment at the equator, as in Figure 10-18C, does not change the lever arm in primary position and only slightly shortens it in marked adduction, as seen in Figure 1018D. However, when a posterior fixation procedure is performed, either with or without recession, there is not only minimal shortening of the lever arm (X') in primary position (Fig. 10-18E) but now a marked shortening (Z) with reduction in rotational force, as the eye is adducted into the field of the action of the medial rectus.

INDICATIONS

The posterior fixation procedure has been proposed for the treatment of a variety of strabismus problems:

1. Null point nystagmus with face turn

2. Nystagmus blockage or compensation syndrome

3. Dissociated vertical deviation

4. Esotropia with convergence excess or a high AC/A (accommodative convergence/ accommodation) ratio

5. To augment a maximal recession

6. Nonconcomitant strabismus

7. To prevent up shoot and down shoot in Duane syndrome

In null point nystagmus, nystagmus blockage syndrome, and dissociated vertical deviation, the posterior fixation procedure has proven to be no more effective and less predictable than a large recession alone. The posterior fixation procedure has proven to be effective in some patients with convergence excess esotropia, especially if little deviation is present in primary position. Although the procedure is effective in preventing the up shoot and down shoot in Duane syndrome, the equally effective and easier Y-splitting procedure of the lateral rectus has largely replaced the posterior fixation suture for this indication. Probably the most important application for the posterior fixation procedure is in patients with nonconcomitant strabismus, especially those with little or no deviation in primary position. In these patients, the posterior fixation procedure is performed on the normal eye to weaken the yoke of the paretic muscle. By weakening the rotational force of the yoke muscle on the globe, as it moves into its field of action, alignment is improved both by limiting the rotation of the normal eye and simultaneously increasing innervation to (by Sherington's law) and therefore rotation of the palsied eye. Examples of this usage would include

1. Placement on the contralateral superior rectus in double elevator palsy

2. Placement on the contralateral medial rectus in patients with partial 6th nerve palsy

3. Placement on the contralateral inferior rectus in patients with a blow out fracture and limitation of depression secondary to ipsilateral inferior rectus weakness

If a nonconcomitant strabismus is associated with a significant deviation in primary position, a large recession of one muscle is usually preferable to the posterior fixation procedure, especially if the recessed muscle can be placed on an adjustable suture. The single large recession produces a balancing nonconcomitance as does the posterior fixation procedure, but it can produce the necessary alignment correction in primary position as well. Therefore, because of the difficulty and danger of performing the posterior fixation procedure, as well as the availability of other excellent alternatives, we use the posterior fixation procedure only infrequently; primarily, as noted above, in patients with nonconcomitant strabismus and relatively good primary position alignment.

SURGICAL TECHNIQUE

Recession of the left medial rectus with posterior fixation procedure through a limbal incision is illustrated.

When the posterior fixation procedure is being performed along with a recession,



placement of the posterior fixation suture through the recessed muscle at the proper point is required to obtain the full benefit of both the recession and the posterior fixation. The goal, illustrated in Figure 10-19, is to ensure that all of the muscle slack caused by the recession is posterior to the posterior fixation suture, which becomes the new effective insertion of the muscle. To be effective the posterior fixation suture must be placed as far posteriorly as possible (at least 12 to 15 mm posterior to the original insertion or 17 to 19 mm posterior to the limbus). Keeping this in mind, the proper distance (A) posterior to the insertion for the posterior fixation suture to pass through a muscle is calculated by subtracting the amount of planned recession (C) from that distance (12 to 15 mm) posterior to the original muscle insertion where the posterior fixation suture will be placed in the sclera. In this example, if we assume that the posterior fixation suture can be placed 14 mm posterior to the original insertion and the intended recession is 6.0 mm, then the posterior fixation suture should pass through the muscle 8.0 mm (14.0 - 6.0 = 8.0 = A)posterior to its original insertion.

Step 1. In general, although either a fornix or limbal incision can be used, a limbal incision may be preferable for posterior fixation procedures because of the improved posterior exposure that can be obtained. The medial rectus is then secured on a large muscle hook and its insertion cleaned of Tenon's capsule, check ligaments, and intermuscular septum. After calculation of the location of the desired suture placement site in the muscle (A) (Figs. 10-19 and 10-20), a caliper is used to localize this site and a Stevens hook is used to elevate the edge of the muscle so that a double-armed nonabsorbable suture (Dacron, Mersilene, or Supramid) on a short, flat spatulated needle (e.g., Alcon

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T-5) can be passed through the muscle from the undersurface anteriorly approximately one-third of the distance from the edge of the muscle, as shown in Figure 10-20. A double-armed 6–0 Vicryl suture is then placed through the muscle insertion in a routine fashion for a recession, as described in Chapter 5, and the muscle is dissinserted from the sclera. At this point, it is helpful to tape the Vicryl pole sutures to the drape with a Steri-strip, as shown (Fig. 10-21), to prevent their damage during completion of the posterior fixation suture.

Step 2. The original insertion is grasped by the assistant using two locking 0.5mm Castroviejo forceps to maximally abduct the globe and provide



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Figure 10-22

exposure as far posteriorly as possible. The desired site for posterior fixation suture placement in the sclera (generally 12 to 15 mm posterior to the insertion) is identified with a curved Scott ruler or other appropriate measuring device. Adequate exposure this far posteriorly may require the use of a forked Schepens or malleable ribbon retractor. When the scleral site has been marked, the arm of the posterior fixation suture that extends from the posterior side of the rectus muscle is passed through the sclera at this point, parallel to the original insertion, as illustrated in Figure 10-21.

Step 3. After passing through the sclera, the posterior fixation suture is passed through the muscle adjacent to the original muscle penetration

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site such that approximately onethird of the muscle belly lies between the two suture penetration sites, as shown in Figure 10-22. At this point, the recession is completed in the standard fashion by resuturing the muscle insertion to the sclera to create the desired recession (C), as shown in Figure 10-23A. Finally, the posterior fixation suture is pulled taut and its two ends are tied together snugly against the anterior muscle surface, so that no muscle slippage is possible.

Step 4. If a posterior fixation suture is to be performed without recession, a two suture technique is preferable to eliminate the need to make a scleral needle pass beneath the center of the attached muscle belly. In this case, the scleral site of suture



Figure 10-23

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placement is first measured at least 12 to 14 mm posterior to the muscle insertion, and the edge of the muscle retracted slightly with a Stevens hook to allow placement of the posterior fixation suture through the sclera beneath the edge of the muscle. The muscle belly is then allowed to return to its natural location and the suture needle passed from the undersurface up through the muscle to include approximately one-fourth to one-fifth of the muscle belly. The identical procedure is then performed on the opposite edge of the muscle and the two sutures are tied firmly to secure the muscle against the sclera, as shown in Figure 10-23B.

11

Chemodenervational Treatment of Strabismus (Botulinum Toxin Injection)

INTRODUCTION

The idea of using chemical treatment to improve strabismus is not new, but Dr. Alan Scott at the Smith-Kettlewell Institute in San Francisco was the first to develop effective techniques. In the early 1970s, Dr. Scott and collaborators injected various agents into extraocular muscles of monkeys, including isoflurophate (DFP), alcohol, cobra neurotoxin, rattlesnake venom, and botulinum toxin. These studies suggested that botulinum toxin type A would be most appropriate for creating a temporary muscle paralysis for the purpose of correcting strabismus. Animal studies of this agent continued until 1979, when a prospective multicenter clinical trial on human subjects was initiated under a Food and Drug Administration (FDA) protocol by Dr. Scott to evaluate the safety and effectiveness of this agent for ocular motility disorders, benign essential blepharospasm, and other nonocular muscle disorders. Between 1979 and 1990, over 290 investigators participated in the study using over 17,000 toxin injections in over 8,850 patients. As a result of these studies, FDA approval for the use of purified botulinum toxin type A (Oculinum) was granted in 1990 for the treatment of adult strabismus and essential blepharospasm. The drug is currently available from Allergan Pharmaceuticals, Irvine, CA.

RATIONALE FOR USE OF BOTULINUM TOXIN IN STRABISMUS

Temporary paralysis of an extraocular muscle by botulinum toxin injection may improve or eliminate strabismus in two ways. In paralytic strabismus, botulinum toxin is injected into the normal antagonist (e.g., medial redial rectus in a patient with acute 6th nerve palsy). It is hoped that temporary paralysis of the antagonist will prevent its unopposed contraction and the secondary development of contracture and shortening that often results in long-term strabismus, even after the palsied muscle recovers. In this case, because of the short duration of the botulinum toxin-induced paralysis, repeat injections every 6 to 8 weeks may be required for up to 6 or 8 months to allow for complete recovery, if it is going to occur. The rationale is different in nonparalytic strabismus such as esotropia or exotropia. In this case, the "overacting" muscle is injected to create temporary paralysis, which allows both secondary contracture of the "underacting" antagonist as well as primary weakening and lengthening of the injected muscle. When the effect of the chemodenervation has disappeared, it is hoped that a permanent alteration in muscle forces will have occurred, resulting in a long-term alignment change.

Figure 11-1 graphically demonstrates the use of botulinum toxin chemodenervation for the treatment of nonparalytic left exotropia (Fig. 1-11A: left extropia, preinjection). The left lateral rectus is injected with botulinum toxin A, resulting in its temporary paralysis with marked secondary esotropia as well as shortening and contracture of the left medial rectus (Fig. 11-1B: secondary left esotopria, 1 to 8 weeks after left lateral rectus injection). Following recovery from injection, a new balance of muscle forces on the left eye, with a lengthened and weakened left lateral rectus and strengthened and shortened left medial rectus, results in a permanent alignment change (Fig. 11-1C: 2+ months postinjection, recovery of left lateral rectus and straight eyes).

PHARMACOLOGY OF BOTULINUM TOXIN

Botulinum neurotoxin type A is one of several large molecular weight proteins produced by *Clostridium botulinum* bacteria. The toxin acts at the myoneural junction, interfering presynaptically with the release of acetylcholine. After injection into an extraocular muscle, the toxin is bound and internalized within local motor nerve terminals within 24 to 48 hours, where it remains for many weeks. Paralysis of the injected muscle begins within 2 to 4 days after injection and lasts clinically for 5 to 8 weeks in an extraocular muscle and for 3 or more months in obicularis muscle. Although the drug is a foreign protein, the development of host antibodies is infrequent when it is used in typical therapeutic doses. However, a blocking antibody has recently been developed and may be useful in the treatment of inadvertent overdose (extremely unlikely) as well as in the prevention of spread of the toxin to adjacent muscles.

PATIENT SELECTION

Clinical trials have shown botulinum toxin to be most effective in the following conditions:

1. Small- to moderate-angle esotropia and exotropia (under 30 to 40Δ) in patients with fusion potential.

2. Postoperative small-angle residual strabismus (both under- and overcorrection) during the 2- to 8-week period following surgery.

3. The weakening of an antagonist muscle in acute paralytic strabismus (especially 6th nerve) to block its contracture while the agonist recovers.

4. Providing adjunctive medial rectus weakening to enhance the effect of a transposition procedure for chronic 6th nerve palsy without the need for removing a third extraocular muscle.

5. When surgery is inappropriate, such as in active thyroid ophthalmopathy or in inflamed or pre-phthisic eyes.

6. In patients with fear of hospitals or at particular risk from anesthesia.

Studies have found the results with botulinum to be disappointing in patients with large deviations, restrictive or mechanical strabismus (trauma or multiple reoperations), or secondary strabismus in which a muscle has been over-recessed. Injection is also ineffective in congenital nystagmus (except to shift gaze), A and V patterns, dissociated vertical deviations, oblique muscle disorders, and chronic paralytic strabismus except as noted in number 4



Figure 11-1

Step 2.

above. As with surgical treatment, results are best when there is fusion to stabilize the alignment.

INJECTION TECHNIQUE

- Step 1. Prior to injection, an appropriate Oculinum dose is selected. In general, the following guidelines, recommended by the distributor (Allergan Pharmaceuticals, Irvine, CA), are helpful.
- Step 1.1. Initial dose—use the lower dose for treatment of small deviations and the larger dose only for large deviations:

a. For vertical muscles and for horizontal strabismus of less than 20Δ : 1.25 to 2.5 U in any one muscle.

b. For horizontal strabismus of 20 to 50Δ : 2.5 to 5.0 U in any one muscle.

c. For acute but persistent 6th nerve palsy of 1 month's duration or longer: 1.25 to 2.5 U in the medial rectus muscle.

d. The use of botulinum toxin continues to be investigational in patients under 12 years of age. An initial dose of 1.25 U and a maximum dose of 2.5 U is recommended for children under 5 years of age.

Step 1.2. Subsequent doses for residual or recurrent strabismus:

a. Patients should be re-examined 7 to 14 days after each injection to assess drug effect.

b. Patients experiencing adequate paralysis of the target muscle and requiring subsequent injections should receive a dose comparable to the initial dose.

c. Patients experiencing incomplete paralysis of the target muscle should receive a subsequent dose twice as large as the previous injection. d. Repeat injection should not be administered until the effects of the previous dose are gone, as indicated by duction and version testing.

e. The maximum recommended dose is 25 U in any one muscle.

Once the injection dosage is determined, final drug preparation and dilution is accomplished, remembering that the injected dose should be injected in a volume of 0.05 to 0.1 ml. To reconstitute lyophilized botulinum toxin, the appropriate volume of unpreserved 0.9% sodium chloride iniection is slowly added to a drug vial that has been previously stored in a freezer at or below -5° C. During dilution, care should be taken to prevent agitation or bubbling, which may denature the drug. According to the manufacturer, reconstituted Oculinum should be refrigerated and used within 4 hours. The following dilution table is helpful in drug preparation.

Amount of Diluent Added (0.9% Sodium Chloride)	Resulting Dose (U/0.1 ml vol)
1.0 ml	10.0
2.0 ml	5.0
4.0 ml	2.5
8.0 ml	1.25

Step 3. After the injection technique, possible side effects, and complications are thoroughly discussed with the patient, informed consent is obtained. The patient is then placed in a reclining position, using either a reclining examination chair or a treatment table. Adequate anesthesia is accomplished by placing one drop

of topical anesthetic (e.g., proparacaine) into the eve once per minute for 10 minutes. In addition, two drops of a vasoconstrictor (e.g., 2.5% phenylephrine) are instilled 10 minutes before injection to constrict superficial conjunctival vessels and allow better visualization of the underlying muscle, as well as to help prevent subconjunctival hemorrhage. No skin preparation or draping is generally required. Finally, just before injection, a proparacaine-soaked cottontipped swab is applied to the conjunctiva at the injection site for maximum local effect.

In patients too young or anx-

ious to tolerate the procedure under topical anesthesia, ketamine has been successfully used, especially in young children. Most other general anesthetic agents will suppress electromyographic (EMG) activity, and therefore cannot be used for EMG-guided injection.

Step 4. During instillation of the anesthetic drops, the auditory EMG apparatus is prepared, tested, and hooked up to the patient. The Oculinum injection amplifier (available from Oculinum Inc., Berkley, CA) is illustrated in Figure 11-2. It consists of an auditory amplifier to which a black ground electrode and a white ref-



Figure 11-2



Figure 11-3

erence electrode are connected. The proper Oculinum dose is gently drawn up in a 1.0-ml tuberculin syringe using a 22-gauge needle. This needle is then replaced with a special Tefloncoated monopolar needle that allows measurement of electrical activity only at its tip. After the syringe, needle, and electrodes are connected to the amplifier, as shown in Figure 11-2, the amplifier is tested before use. When turned on, it should emit muffled static or white noise.

Step 5.

The ground electrode, a selfsticking pediatric electrocardiographic electrode, is then attached to the center of the forehead, as illustrated in Figure 11-3. The injection technique is again reviewed with the patient and the procedure is explained step by step: what will be done, what the patient will hear, and what cooperation will be required. To help allay patient anxiety, it is often helpful to place an eye patch over the other eye at this time.

- Step 6. Adequate lid retraction can generally be provided by the fingertips of the noninjecting hand in cooperative patients with comitant strabismus, as shown in Figure 11-3. In large-angle strabismus or paralytic strabismus, access to the overacting muscle may be used for lid retraction so that a toothed forceps can be used to rotate the eye into the opposite field before muscle injection.
- Step 7. With the injecting hand supported on the patient's forehead and the bevel of the needle directed toward the globe, the patient is instructed to gaze into the

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Figure 11-4

field opposite the muscle to be injected. The needle is then passed through the conjunctiva posteriorly in the fornix and the EMG amplifier is turned on. The needle tip is initially directed straight posteriorly until the tip is well past the equator of the globe, and then directed posteriorly and away from the orbital wall along the course of the muscle while the amplifier sound is carefully monitored. Initially, the sound heard can be best described as that of waves on a distant seashore. As the needle tip approaches the myoneural junctions, located in the posterior half of the muscle, the sound becomes louder, as though approaching the beach. Finally, when the needle tip enters the myoneural portion of the muscle,

the character of the sound abruptly changes to a higher pitched, coarser, and louder sound that is similar to the breaking of a large wave. Once heard, the appropriate sequence of sounds is easy to recognize.

It is important to inject the bot-Step 8. ulinum toxin at the point of maximum EMG activity. Strict adherence to the injection technique described above will maximize the likelihood of entering the muscle in the myoneural junction area, as shown in Figure 11-4A (correct injection). Anterior entry into the conjunctiva is to be avoided, especially in previously recessed muscles, which may result in improper injection into the anterior half of the muscle, far from the myoneural junction, as shown in Figure 11-4B (incorrect anterior injection). An additional maneuver that is helpful in verifying proper needle tip location before injection is illustrated in Figure 11-5. The patient is first instructed to look into the field of action of the injected muscle (Fig. 11-5A), which enhances the EMG activity. The patient is then instructed to look into the opposite field and the EMG activity almost disappears (Fig. 11-5B). This maneuver is especially helpful when injecting vertical rectus muscles, since the adjacent inferior oblique and inferior rectus muscles, as well as the superior oblique and superior rectus, will demonstrate maximum EMG activity in opposite fields of gaze. Finally, the needle tip should not be advanced beyond the point of maximum EMG activity since this may indicate that the needle tip has passed completely through the muscle. The presence of this secondary muscle perforation may increase toxin leakage from the muscle, increasing the risk of inadvertent adjacent muscle paresis.

Step 9.

After the injection of toxin is complete, the EMG activity will disappear as the volume of injection pushes firing muscle tissue away from the needle tip. The needle is held in position for several seconds, until the loud sound of EMG activity returns, indicating that the toxin has defused away from the needle tip. The needle can then be smoothly withdrawn from the eve and the patient immediately raised to the sitting position, with an evepad and gentle pressure applied to the injected eve. Clinical experience has shown that sitting the patient up immediately following injection, even before removal of the needle from the orbit, can significantly reduce the likelihood of secondary blepharoptosis.

Following completion of the pro-Step 10. cedure, antibiotic/steroid ointment is applied to the injected eve, and the patient is observed for 30 to 45 minutes in the office for any untoward reactions. The patient is instructed to avoid reclining for 4 to 6 hours following injection to prevent upward spread of toxin with resulting vertical deviation or ptosis. No other restrictions on activity are required. In general, no toxin effect or change in ocular motility will be noted for 2 to 5 days. The patient should be examined again in 7 to 10 days to document the maximum toxic effect and shift in ocular alignment. In 5 to 7 weeks, when the major paralytic effect has gone, the patient is seen again to assess the final results of therapy and to determine if an additional injection will be required.

COMPLICATIONS

Fortunately, serious or long-term complications from botulinum toxin injection have been extremely rare. Results of the large, multi-investigator, FDA-approved clinical trial involving 3,650 botulinum toxin injections in 2,058 adults injected for horizontal strabismus demonstrated an overall incidence of acute ptosis in 15.7 percent of patients, with only 0.3 percent of cases persisting over 6 months. Vertical deviations occurred acutely in 16.9 percent of patients, with only 2.1 percent of cases persisting over 6 months. Scleral perforation was reported in nine patients, with one episode of vitreous hemorrhage but no long-term vision loss. Less frequent complications in





Figure 11-5

this group included retrobulbar hemorrhage in 16 patients (one requiring surgical decompression), pupillary dilation in five patients, and the rare occurrence of corneal irritation, prolonged discomfort secondary to needle trauma to the orbital tissues, and spatial disorientation with past-pointing in patients whose dominant eye was injected. No retinal detachment or visual loss occurred in any patient. In addition, no systemic effects have been reported in any patient injected with botulinum toxin for strabismus or blepharospasm.

RESULTS OF CHEMODENERVATION IN STRABISMUS

Initial clinical studies suggest that EMGguided injection of botulinum toxin into

extraocular muscles for the treatment of strabismus can be beneficial in selected patients. It has shown the most promise in the treatment of acute 6th nerve palsy and recent surgical overcorrections from conventional incisional strabismus surgery. Botulinum toxin has proven to be useful in some patients with small- to moderate-angle esotropia or exotropia, and possibly in patients with strabismus following retinal detachment procedures, in which incisional strabismus surgery can be very difficult. Its use in children, especially for congenital esotropia, is controversial and must be considered experimental at this time, since incisional surgery has proven to be more predictable in these patients. In addition, botulinum toxin injection has proven to be ineffective and therefore should not be considered in the treatment of restrictive or mechanical strabismus.

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Pearls in Strabismus Surgery

INTRODUCTION

One of the major features separating the successful strabismus surgeon from less successful peers is careful attention to detail. Attention to proper handling of delicate periocular tissues and maintenance of proper anatomic relationships is critical to maximize surgical success. Also, as discussed previously, loupe magnification is essential to facilitate this process. Only with proper magnification and attention to detail can optimal surgical principles be followed, minor problems quickly detected and corrected before they become significant, and an optimal surgical result obtained. This chapter discusses several surgical "pearls" that are helpful in preventing and correcting common surgical problems and simplifying difficult surgical situations.

CENTRAL SAGGING OF THE MUSCLE INSERTION

When recessing or resecting a rectus muscle, it is important to maintain a new muscle width equivalent to that of the original insertion. There are two details that are important in accomplishing this. First, proper placement of the lock bites at the edges of the muscle insertion will prevent suture slippage, which bunches the muscle and narrows the new muscle insertion. Second, when recessing a muscle, it is neces-

sary to carefully measure all recessions along an imaginary line perpendicular to the original muscle insertion that extends posteriorly from its most distal extent, as shown in Figure 12-1A. This will create a properly splayed new muscle insertion of width equal to the original insertion (Fig. 12-1A). On the other hand, if the new muscle insertion is narrower than the original, then the central redundant portion of the muscle insertion will sag posteriorly, as shown in Figure 12-1B. This results in an unequal recession effect, with the edges of the muscle recessed the planned amount (x), and the central portion recessed a larger amount (y). This may result in an unpredictable increase in recession effect.

If central sag of the muscle insertion is detected after tie-down of the muscle suture, in spite of proper precautions, a simple procedure, illustrated in Figure 12-2, can correct the problem.

Step 1. Before removing the suture needles, one needle is passed through the central sagging portion of the insertion from posterior to anterior as shown in Figure 12-2A. Be careful to avoid (1) passing the needle through the sclera (this is facilitated by passing the suture from the underside of the muscle as shown) and (2) cutting the transverse length of suture buried within



the muscle insertion. This is avoided by passing the suture through the muscle well proximal to its end.

Step 2. Pull up on this suture to advance the central portion of the muscle insertion in line with the ends. The two ends of the double-armed suture can then be tied together to hold the muscle in place, as shown in Figure 12-2B. Repeat measurement with a caliper at this time will document equal recession of the peripheral and central portions of the muscle insertion for a more predictable recession effect.



Figure 12-2

CUT OR LOOSE POLE SUTURE

Sometimes, while excising a muscle from the sclera during muscle recession or transecting a muscle during resection, the intramuscular portion of the suture will be inadvertently cut. This is particularly likely if the intramuscular portion of the suture inadvertently passes through superficial sclera, since transection of the muscle will certainly cut across the suture and one or both poles may be released if the lock bites slip. Maintenance of proper tension on the pole sutures when disinserting or transecting a muscle, as described in Chapters 5 and 6, will allow for immediate identification of this problem, should it occur.

Once it has been determined that the intramuscular portion of the suture has been cut, it is necessary to replace the entire suture, even if both pole sutures are apparently well secured by the lock bites, since later slippage and muscle loss may occur. In fact, transection of the intramuscular portion of the suture, undetected at the time of surgery, is perhaps the most frequent cause of a lost muscle after eye muscle surgery. If transection of the intramuscular suture is noted before the muscle is completely excised, replacement of the suture is simple. Merely grasp the already excised pole of the muscle with a locking forceps, splay the muscle to its original width, and replace the entire double-armed suture in the same double locking fashion as it was initially placed. However, if suture transection is not identified until after the muscle is completely excised or transected, much greater care is required to replace the suture before both lock bites slip out and the muscle retracts posteriorly, especially if the muscle has been resected. In this case, the surgeon should gently stabilize the position of the globe with a toothed forceps, since rotation either toward or away from the free muscle may increase the risk of it retracting posteriorly. At the same time, the conjunctival wound is delicately opened by the as-

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sistant, using two pairs of toothed forceps, to expose the transected muscle edge posteriorly along the surface of the globe. Visually tracing the course of any remaining pole sutures is helpful in identifying the cut end of the muscle. When adequate exposure has been accomplished, gentle traction on any remaining pole sutures may expose the cut end of the muscle. The surgeon may then secure the muscle by reaching posteriorly with a forcep, pulling the cut end of the muscle anteriorly, and then identifying and securing the original muscle poles with a pair of locking forceps. With the muscle secured in this way, a new double-armed 6-0 Vicryl suture can be inserted in the standard double locking fashion, as described in Chapters 5 and 6.

Another problem occasionally encountered, especially when pulling up and tying off the suture on a tight resected muscle, is slippage of one of the pole sutures, as illustrated in Figure 12-3A. This results in excessive recession (or underresection) of one pole of the muscle relative to the other, and may result in an unpredictable or incomitant surgical result. When detected by careful examination of the new insertion site after tying the suture knot, this problem can be easily remedied by the following technique.

- Step 1. Pass one end of the knotted doublearmed suture through the sclera anterior to the knot, along an imaginery line made by the intrascleral portion of the suture connected to the slipped muscle pole, as shown in Figure 12-3A.
- Step 2. Pull up on this suture to advance the original knot toward the new scleral bite, advancing the muscle pole and eliminating the slippage, as shown in Figure 12-3B. When both poles of the muscle are pulled up tightly to their desired final position, the two ends of the doublearmed suture can be tied together to stabilize the proper final muscle position (Fig. 12-3B).

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Figure 12-3

HANG-BACK SUTURE TECHNIQUE

Occasionally, it is desirable to recess a rectus muscle by a hang-back technique rather than the techniques described in Chapter 5. This technique is especially useful with very large recessions, such as in Graves' eye disease, or in severe mechanical restriction or muscle palsy, in which the very large recessions required for a successful result would necessitate very dangerous far posterior placement of scleral suture tracts. The hang-back technique is also required when large superior rectus recessions (greater than 5.0 mm) are needed, such as in the treatment of dissociated vertical deviation. This is because placement of scleral bites posterior to 4 or 5 mm behind the original superior rectus insertion would interfere with the normal slippage of the superior oblique tendon over the surface of the sclera in this area. In addition, the hangback technique can be helpful in cases of strabismus surgery on eyes with previous

retinal detachment surgery in which broad silicone bands and buckles located behind muscle insertions prevent direct scleral suturing. In these cases, the hang-back technique allows the pole sutures to be secured to the original insertion site, with the muscle recessed posteriorly and hanging over the surface of the buckle. In fact, some strabismus surgeons recommend the use of hang-back sutures for nearly all large rectus muscle recessions, especially when performed by infrequent strabismus surgeons, to reduce the risk of scleral perforation.

When performing hang-back recession surgery, either the standard absorbable Vicyl suture may be used, or a nonabsorbable Dacon or Mersilene suture may be substituted to facilitate re-identification of the muscle insertion in the case of reoperation, or to prevent late muscle loss in the case of very large muscle recessions, where reattachment of the muscle to the sclera may be problematic.

Some strabismus surgeons (Repka, 1988; Wright, 1991) have suggested reducing the amount of hang-back recession approximately 0.5 to 0.1 mm as compared with the amount recommended by standard recession tables, as discussed in Chapter 3. This increased effect is thought to occur because the hang-back recession of a muscle narrows its new attachment and increases the amount of central sag of the resulting insertion, thereby increasing the recession effect. However, if care is taken to maintain a broad insertion by wide spacing of the scleral bites, as shown in Figure 12-4B, then central sag is greatly reduced and standard table recession can be performed.

- Step 1. The muscle is isolated, cleaned, and secured with a doubled-armed 6–0 suture in the standard fashion, as described in Chapter 5. The muscle is then disinserted from the sclera.
- Step 2. Each pole of the original scleral insertion is grasped with a 0.5 locking Castroviejo forceps to stabilize the globe. Each arm of the suture is

then secured to the original insertion site by half-thickness scleral passes, beginning near each pole and angling anteriorly and toward one another so the needle tips cross within the sclera. The widely spaced, suture entry sites created in this way will maintain a new muscle insertion nearly as wide as the original insertion, and will largely eliminate central muscle sag, with its unpredictable recession affect. It is important that both arms of the suture emerge from the sclera near the same point so the muscle will hang-back symmetrically.

- Step 3. The muscle pole sutures are then pulled up until both poles of the muscle are tight against the old insertion site, as shown in Figure 12-4A.
- Step 4. With the muscle pulled up tightly, the two pole sutures are crossclamped with a needle holder at a





Figure 12-4

point measured with a caliper set at the distance (a) of desired final muscle recession. The distance must be measured from the exact point of suture exit from the sclera to the distal side of the needle holder, as shown in Figure 12-4A.

Step 5. The two pole sutures are then tied together tightly against the distal side of the needle holder with a square knot.

> This maneuver creates an equal length of suture from each muscle pole to the pole suture knot; the distance from the knot to the scleral exit site is equal to the desired amount of muscle recession.

Step 6. The recession is then completed by allowing the muscle to retract (or by manually pushing it posteriorly to pull the pole sutures through the scleral tunnels) until the knot makes contact with the sclera, which will result in a measured recession (a) as shown in Figure 12-4B. A caliper may be used to confirm the recession by measuring posteriorly from the original insertion site. The final knot is further secured with an additional one or two overhand knots and the excess suture ends are trimmed. The conjunctiva can then be closed in a routine fashion, depending on the type of conjunctival incision.

Complications of Strabismus Surgery

The occurrence of unfavorable results after strabismus surgery, just as with surgery for other indications, is inevitable. The goal of strabismus surgeons, therefore, is to minimize those complications over which they have control. Obviously, this necessitates careful and thoughtful patient evaluation and examination, correct diagnosis, optimal surgical planning, meticulous surgical technique and when necessary, appropriate nonsurgical, preoperative or postoperative intervention. Nevertheless, in spite of our best efforts, complications will occur and all strabismus surgeons must be aware of potential complications and their management in order to administer optimal care.

Although literally hundreds of complications have been described during or after strabismus surgery, fortunately, most are uncommon. In this chapter, because of space limitations, we will consider only those complications or unfavorable results that are relatively common, or are uncommon but serious in nature and require expeditious and accurate diagnosis and treatment.

Complications of all kinds may be considered to fit into four categories:

1. Errors in patient examination and diagnosis

2. Errors in surgical judgment

3. Errors in surgical technique

4. The unacceptable or undesirable final ocular alignment

In order to better understand, evaluate, and define these complications, it is desirable to consider the criteria for an optimal result from strabismus therapy. These include

1. Minimal pain and discomfort both during and after surgery

2. No long-term conjunctival scars or redness

3. Normal palpebral fissures, lid position, and absence of postoperative proptosis or enophthalmos

4. Orthophoria

5. Normal ductions and versions

6. Normal and equal visual acuity in each eye

7. Normal stereopsis and binocular vision

8. Attainment of these criteria with minimal or no limitations of activity, rapid healing, and, most important, lifetime stability of the result

Unfortunately, this ultimate result is rarely if ever completely obtainable. It is therefore important that all strabismus surgeons understand the inherent limitations in strabismus procedures so that they can determine reasonable treatment goals and establish appropriate patient expectations.

ERRORS IN EXAMINATION AND DIAGNOSIS

Many errors in patient examination and diagnosis are possible and obviously can lead to incorrect surgical planning and a poor surgical result. A few of the more common errors of this type are listed in Table 13-1. Certainly, failure to observe or appreciate variability in alignment can lead to incorrect diagnosis, poor surgical timing, or inaccurate determination of surgical amount. Strabismus of recent onset, especially, may be variable in frequency or amount, and must be monitored with repeat examinations until some stability has been achieved. Identification of amblyopia, or other sensory factors such as lack of binocular vision development or central loss of binocular function must be identified and treated, if possible, before proceeding with strabismus surgery. The contribution of such sensorimotor factors as the accommodative state during examination (especially in patients with high refractive errors) and the accommodative convergence/accommodation (AC/A) relationship to the measured deviation must be clearly established.

 Table 13-1. Errors in Examination Caused by

 Failure to Observe or Appreciate

Alignment variability
Amblyopia
Sensory factors
AC/A relationships
Contributions of accommodative state
Nonconcomitance
Combined horizontal and vertical deviations
DVD versus overacting inferior obliques versus true
hypertropia
A- and V-patterns
Paretic muscles
Restrictive or mechanical problems
Craniofacial and genetic syndromes
Development delay and neurologic problems

AC/A, accommodative convergence/accommodation; DVD, dissociated vertical deviation.

Other examination errors relate to the failure to appreciate important examination features such as nonconcomitance, combined horizontal and vertical deviations, the presence of A- and V-patterns, oblique muscle overactions, and especially, the contribution of restrictive or mechanical factors to the ocular deviation. While delineation of the contribution of these features to the final diagnosis may be difficult, especially in young children with whom examination compliance is suboptimal, failure to identify these features will almost certainly lead to incorrect diagnosis and/or surgical therapy.

Finally, knowledge of systemic associations and diseases is important. Failure to identify significant congenital malformation or genetic syndromes can make understanding the correct strabismus diagnosis impossible. Especially important is any association between childhood strabismus and developmental delay or other neurologic problems, since children with these associations are especially prone to variability in clinical course and unpredictability in response to surgery, and frequently benefit from postponement of surgery until the patient is older.

ERRORS IN SURGICAL PLANNING AND JUDGMENT

Failure to understand the etiology, differential diagnosis, and important surgical principals will frequently lead to unfavorable surgical results. Important decisions, such as which muscles to operate on and whether to perform surgery on one or both eyes, require detailed knowledge of the magnitude and pattern of the deviation, presence and type of previous strabismus or other ocular surgery, and determination of whether secondary mechanical or restrictive factors are playing a role in the patient's motility disorder. At times, general health risk considerations are important in surgical planning; for example, the need to avoid general anesthesia in certain frail patients with cardiac or respiratory disease. The decision of whether to perform symmetric surgery (e.g., bilateral medial rectus recession) or asymmetric surgery (e.g., a recess/resect procedure) may at times be based on examination findings, and at other times be a matter of personal preference.

Sometimes the decision becomes merely one of surgery versus no surgery. Again, accurate patient examination, and detailed understanding of the diagnosis and therapeutic possibilities is necessary to minimize complications. When the decision that surgerv is indicated has been made, other questions must be answered; such as when should the surgery be done, which muscles need operation and by what technique, and how much surgery must be performed. The details of this important decision-making process are discussed in some detail in Chapter 1. However, in general, surgery should be performed as soon as the diagnosis is definite, the alignment stable, and the patient older than 5 or 6 months of age so the anterior segment and extraocular muscle anatomical relationships have begun to stabilize. In addition, failure by patient or surgeon to fully understand the goals of therapy, whether functional (improvement in binocular function, elimination of diplopia) or cosmetic, frequently leads to unfavorable results in the view of patient, surgeon, or both.

Since the complications or the risk of the complications are inevitable, each surgeon must establish guidelines for avoiding and/ or treating these complications. The surgeon should acquire and maintain sufficient skills to arrive at the proper strabismus diagnosis and to carry out the treatment procedures that must be undertaken. Obviously, one should have sufficient knowledge of one's patient, and should prepare both one's self and one's patient to maintain realistic expectations with regard to expected and potential outcomes of the proposed strabismus surgery.

ERRORS IN SURGICAL TECHNIQUE

Many, or possibly most complications of strabismus surgery are related in some way to errors in surgical technique. The most common, and most serious complications caused by errors in technique are listed in Table 13-2. Many are relatively minor and self-limited, while others are serious and require urgent diagnosis and treatment. The following guidelines are presented for diagnosis and management of the more common complications of strabismus surgery.

Suture or Drug Reaction or Allergy

With the development of synthetic sutures for strabismus surgery, suture reactions are now uncommon. However, significant reactions, which can be mistaken for superficial or orbital infection, are still seen even with Vicryl sutures. These reactions usually occur 5 to 10 days after surgery and are associated with increasing irritation, marked injection, chemosis, epiphora, and sometimes severe pain. Similar reactions are sometimes associated with the postoperative use of topical antibiotics, especially Neomycin or a Neomycin-containing combination such as Maxitrol.

Table 13-2.	Complications	Related	to	Errors	in
	Surgical Tec	hnique			

Suture or drug reaction or allergy Conjunctival inclusion cyst Prolage of Tenon's consule
Puogonia granulama
Dellen
Changes in lid fissure or position
Conjunctival scarring
Recession of the semilunar fold and plica
Internal ophthalmoplegia
Anterior segment ischemia
Orbital infection (cellulitis or endophthalmitis)
Slipped or lost muscle
Creation of restriction and nonconcomitance
Fat adherence syndrome
Operation on the wrong muscle
Scleral perforation
Retrobulbar or orbital hemorrhage

Severe suture and drug reactions can be difficult to differentiate from true infection, although the delayed onset and proper time course can be helpful. Prevention, where possible, includes a detailed history concerning previous suture reactions or allergies to topical or systemic medications. Treatment consists of stopping any suspected medications and institution of intensive topical steroid therapy, which generally results in a prompt response.

Epithelial Inclusion Cysts

Conjunctival inclusion cysts occur regularly after extraocular muscle surgery, especially near the site of conjunctival incisions. The cysts may remain small and superficial; sometimes they become quite large, extending posteriorly into the orbit. They are generally simple to diagnose by hand light or slit lamp examination. Because some resolve by spontaneous rupture, a period of observation is generally indicated. However, the definitive treatment is simple excision. The entire cyst should be removed without rupture, if possible, to be certain no residual lining tissue is left behind. Alternatively, the cyst can be marsupialized if it cannot be completely excised.

Prolapse of Tenon's Capsule or Fat

Tenon's capsule may prolapse through conjunctival wounds as a result of edema during the postoperative period. Prolapsed Tenon's capsule sometimes presents as a very large, foamy mass, protruding between the lids, and can be very upsetting to patient and family alike. However, in most cases, the prolapsed Tenon's capsule will retract or disappear spontaneously without surgical intervention. Topical steroids may speed the process, and are indicated for 1 to 2 weeks after diagnosis.

More problematic is anterior prolapse of orbital fat if Tenon's capsule is violated.

This condition presents as an unsightly injected yellowish mass or bulge under the conjunctiva, and is most commonly seen medially. Although fat prolapse may be treated by careful excision of the fatty tissue, frequently with conjunctival recession, it is better to prevent this condition than to treat it. Great care should be taken to avoid rupturing Tenon's capsule with scissors or muscle hooks while isolating or cleaning extraocular muscles.

Conjunctival Scarring

Unsightly conjunctival scarring can present functional as well as cosmetic problems for many patients. Most common in patients who have undergone multiple surgical procedures, the associated subconjunctival fibrosis often contributes to mechanical restriction with secondary nonconcomitance. Again, this problem is best managed by prevention rather than treatment. Careful tissue handling, accurate wound closure, and proper placement of conjunctival incisions will all contribute to reduced conjunctival Significant conjunctival scars scarring. often appear as bulky, irritated, injected conjunctiva within the palpebral fissure. Especially after reoperations, complete conjunctival healing may take many months, with mild residual scarring and injection under even the best circumstances. However, bulky or fibrotic conjunctival scars that do not resolve spontaneously usually can be improved by wound revision, with excision of fibrotic conjunctiva and associated conjunctival recession that leaves bare sclera to spontaneously re-epithelialize. Medial scarring in the area of the plica can be especially disfiguring, and therefore conjunctival incisions in the area of the plica should be avoided. In addition, one of the major advantages of the fornix or culde-sac conjunctival incision is its resultant lack of conjunctival reaction or scarring within the palpebral fissure, which results in rapid painless healing.
Dellen

Dellen of the cornea or adjacent bare sclera may occur in association with adjacent conjunctival swelling, with disturbance of local tear flow and secondary drying. This condition is associated most commonly with limbal conjunctival incisions that place a swollen conjunctival wound adjacent to the cornea. Although corneal dellen may present a picture of marked corneal thinning, the change in corneal thickness is due to dehydration alone, and generally responds well to topical steroids, lubricants, and patching. Small dellen are not uncommon, and most resolve spontaneously without treatment.

Changes in Lid Fissure, Lid Position, or Postoperative Proptosis or Enophthalmos

Abnormalities in lid fissure, with secondary lid ptosis or retraction occur most commonly after a large recession or resection of a vertical rectus muscle; recession may result in lid retraction and resection or advancement may result in lid ptosis. In fact, some change in lid position is very common under certain clinical circumstance, such as when inferior rectus recession is performed for thyroid ophthalmopathy, or when large superior rectus recession is performed for dissociated vertical deviation. In these situations, and in all others in which large recession or resection of vertical muscles is contemplated, patients should be warned of the possible risk of lid fissure changes. Many times these changes can be avoided or at least minimized during surgery on vertical rectus muscles. This is accomplished by careful dissection of intramuscular septum, check ligaments, and associated Tenon's capsule far posteriorly to the point of muscle entry through Tenon's capsule. This eliminates any attachments between muscle and eyelid, which contribute to alterations in lid position. However, when secondary lid ptosis or retraction does occur after successful strabismus surgery, the specific lid problem can be corrected secondarily by performing the appropriate ophthalmic plastic surgical procedure to match the lid position to the new globe position.

In addition, some patients undergoing recession will manifest proptosis after release of the normal muscle tension on the globe after recession of one or more rectus muscles. This problem is most common in patients with thyroid ophthalmopathy, but may also be seen in some patients with very large superior rectus recessions. Again, the cosmetic appearance can be improved after satisfactory ocular alignment by performing an ophthalmic plastic lid-lengthening procedure in one or both lids of the involved eye.

Internal Ophthalmoplegia

Internal ophthalmoplegia with secondary mydriasis and occasional loss or reduction of accommodation is seen rarely, primarily following inferior oblique surgery. This complication is considered to be related to traction on the third nerve and ciliary ganglion caused by excessive traction on the inferior oblique muscle and its associated neurovascular bundle. No specific therapy is indicated or possible for this condition. Its incidence can be minimized by limiting traction on the inferior oblique nerve, especially during more aggressive procedures such as denervation and extirpation or anteriorization. The clinical course is one of spontaneous resolution in some patients, and little or no improvement in others.

Anterior Segment Ischemia

Anterior segment ischemia may occur when the anterior ciliary arteries are interrupted during the course of strabismus surgery. The condition is most common in elderly patients with poor cardiovascular status. Although it is has been reported when only two muscles were detached from the

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globe, as a rule, detachment of at least three rectus muscles is required before significant risk exists. While it is probably safe to remove three muscles at the same time in children and young adults, such surgery frequently can be performed in two stages, 3 to 4 months apart. Alternatively, when weakening of the medial rectus is planned along with total transposition of the vertical recti for treatment of sixth nerve palsy, the medial rectus weakening can be performed with botulinum toxin injection rather than recession to reduce the risk of this problem.

Clinical signs vary from mild iritis and an irregular pupil to severe corneal decompensation, iris ischemia with loss of pupillary reaction, and cataract. Treatment with large doses of topical and systemic steroids may be beneficial; however, in most patients, especially with mild forms of the disease, spontaneous resolution occurs without sequelae. In addition, recent studies by Repka and Guyton have suggested that the limbal conjunctival vessels contribute significantly to the anterior segment circulation. This suggests that, in patients at risk, the use of a fornix rather than limbal conjunctival incision may help protect against the development of anterior segment ischemia.

The Slipped or Lost Muscle

1

A "slipped" muscle occurs when poor surgical technique during suture placement results in suturing of the muscle capsule rather than the muscle itself to the sclera. Postoperatively the muscle slips posteriorly within the muscle capsule, usually to the point where the capsule penetrates Tenon's capsule. The problem generally presents during the first day or two following surgery, with restricted duction into the field of action of the slipped muscle, but definite movement beyond primary position. Force generation and saccadic velocity into the field of action of the slipped muscle are normal or only slightly reduced, which differ-

entiates this condition from the "lost" muscle. Surgical exploration reveals a whispy, empty muscle capsule attached to the sclera at the expected point. However, only when this empty capsule is carefully followed posteriorly, can true muscle tissue be identified, documenting the diagnosis. Treatment requires placement of a new suture securely into posterior muscle tissue, resecting the empty capsule and advancing the muscle to form a new scleral attachment. Because the result of this surgery can be unpredictable, the use of an adjustable suture technique, as described in Chapter 9, is advised in patients old enough to tolerate this procedure. Nevertheless, the best treatment for this problem is prevention by careful placement of muscle sutures, especially the full-thickness locking bites, at the time of original muscle surgery.

One of the most serious complications of muscle surgery is the lost muscle. A lost muscle is one which has completely released from the sclera, retracting posteriorly into the orbit. In the case of a lost superior rectus, inferior rectus, or lateral rectus muscle, secondary attachments of these muscles to the adjacent oblique muscles generally prevent their complete loss. Instead, they retract posteriorly 10 to 15 mm and can be located adjacent to the associated oblique muscle. However, the medial rectus has no adjacent oblique muscle, and can therefore retract more posteriorly through Tenon's capsule.

If a muscle has become completely detached from the globe, the problem is usually readily apparent by complete lack of duction of the globe even to the midline in the field of action of the lost muscle. There is generally widening of the palpebral fissure, particularly in the case of a lost medial rectus muscle, during attempted gaze into the field of action of the lost muscle. Active force generation and saccadic velocity testing are markedly abnormal in this condition.

The surgical approach to the lost muscle is best left for the strabismus specialist, since the initial attempt at repair is the only one likely to succeed.

Creation of Restriction and Nonconcomitance

Mechanical restriction of ocular rotation, once present, greatly limits our ability to treat a strabismus patient. Unfortunately, some mechanical restriction secondary to development of scar tissue with multiple reoperations frequently occurs. Nevertheless, the development of postoperative scarring can be minimized by careful tissue handling, proper placement of incisions, and planning surgery that minimizes the number of operations at a particular operative site. Once present, any mechanical restriction from scarring must be identified preoperatively and corrected intraoperatively for successful strabismus therapy. This may involve exploration in the affected area, with lysis of adhesions and freeing of involved muscles, or en block recession of scarred conjunctiva and Tenon's capsule.

One particularly dreaded complication related to scarring is the fat adherence syndrome. This condition, originally described by Parks, is most commonly seen after any type of inferior oblique surgery that has been associated with inadvertent rupture of Tenon's capsule and prolapse of orbital fat adjacent to the sclera. Postoperatively, the fat, and associated hemorrhage, develop into a dense, adherent fibrous scar that restricts elevation and adduction of the globe, giving a pseudo-Brown syndrome. Treatment of the fat adherence syndrome is extremely difficult, because the aggressive fibrous adhesions recur rapidly following lysis, and the best possible surgical result frequently is associated with continued marked limitation in globe rotation, but with the globe at least able to reach to primary position. This condition is easily prevented by carefully following the surgical principals outlined in Chapter 7 when performing inferior oblique surgery. Especially avoid

blind hooking or sweeping of muscle hooks into the inferotemporal quadrant to localize the inferior oblique muscle, as this maneuver is likely to rupture the adjacent Tenon's capsule and release orbital fat.

Operation on the Wrong Muscle

Failure to maintain proper orientation during strabismus surgery, with resulting operation on the wrong muscle is fortunately a rare complication of strabismus surgery. Most commonly associated with oblique muscle surgery by the infrequent strabismus surgeon, this problem is avoided by carefully planning the surgical approach, maintenance of surgical landmarks, and when in doubt, isolation of adjacent muscles to document their location. It is particularly important to keep in mind the location of the inferior and lateral rectus when performing inferior oblique surgery, since inadvertent transection of these muscles during attempted inferior oblique myectomy is a definite risk. If this should be noted at the time of surgery, appropriate repositioning of the improperly operated muscle should be carried out, and any other appropriate surgery that is indicated should be performed. However, whether the problem is diagnosed at the time of surgery, or later, the muscle transection is frequently far posterior, making repair difficult and the development of a "lost" muscle syndrome likely.

Scleral Perforation

Scleral perforation during reattachment of a rectus muscle probably occurs more frequently than is appreciated. Many of these are clinically unimportant; however, every effort to avoid this complication and identify it when it occurs is indicated. A properly placed scleral needle track should allow visualization of the needle through the sclera along its entire length. This is facilitated by keeping the needle parallel to the sclera as the sclera is approached to prevent an excessively deep scleral entry. In addition, a clue to scleral perforation is the presence of black choriodal pigment exiting from the scleral track as the needle and suture are pulled through.

Just as during the scleral bite, needles should always be held with their points directed away from the center of the eye whenever they are handled near the globe, even before and after the scleral bites. The surgeon is on guard while passing the scleral bite, but a careless movement of a needle is more likely at other times during the procedure and can easily result in scleral perforation if the needle is being handled with its point directed toward the center of the eye.

If a scleral perforation occurs or is suspected, the pupil should be dilated and the retina studied. The proper management of inadvertent scleral puncture during strabismus surgery is controversial. A simple puncture of the sclera probably needs no treatment in most cases, especially in pediatric patients in whom the well-formed vitreous gel prevents passage of fluid into the subretinal space. Some surgeons have advocated the use of cryotherapy over a point of scleral perforation, as is standard for other retinal holes. However, several reports suggesting an increased risk of total retinal detachment and vitreous fibrosis after cryotherapy in this setting are worrisome. Therefore, in our opinion, no treatment should be carried out unless retinal detachment is present or impending.

UNDESIRABLE FINAL ALIGNMENT

In spite of our best efforts at surgical planning and meticulous surgical technique,

we will still occasionally have unexplained undesirable postoperative alignment, either undercorrection or overcorrection. Multiple studies using many surgical techniques suggest that a success rate of 70 to 80 percent (as defined by a postoperative alignment within 8 to 10^{Δ} of the desired alignment) is the best attainable with current surgical techniques. In general, a 6- to 8-week period following surgery is required for complete healing and stabilization of the ocular alignment. During this time, nonsurgical orthoptic therapy such as the use of overminus lenses, duction practice, fusion training, antisuppression therapy, and alterations of accommodative state can be helpful in salvaging an acceptable final alignment. In addition, injection of botulinum toxin into muscles in the postoperative period has been a worthwhile technique for correcting small to moderate overcorrections or undercorrections. If bothersome diplopia is present, it can frequently be temporarily treated with Fresnel prisms or permanently treated with ground-in prism spectacles if the residual deviation is less than 10 to 15^{Δ} . A few patients may have diplopia on the basis of central disruption of fusion, a condition that is not correctable by either surgical or optical means. It is advisable to identify these patients preoperatively through the use of prism adaptation testing, so that both the patient and surgeon will understand this risk before surgery. In other patients, nonconcomitance of globe rotation will result in intermittent diplopia in some fields of gaze because of the basic problem. These patients must learn to use head posturing, rather than ocular rotations, to eliminate their diplopia. Finally, patching of one eye, the use of an opaque contact lens, or best of all the patient's own suppression mechanism may be the only available therapy.

14

Congenital and Juvenile Cataract Surgery

INTRODUCTION

Congenital and juvenile cataracts are common ocular abnormalities and represent one of the leading causes of treatable childhood blindness. It has been estimated that 1 in 250 newborns (0.4 percent) have some form of lens opacity. Several recent studies have suggested that congenital cataracts may account for 10 to 20 percent of childhood blindness.

Fortunately, many advances have been made in the diagnosis and management of pediatric cataracts over the last 10 years. Advances in surgical technique and optical rehabilitation especially seem to have significantly improved the prognosis for visual function in these children. Nevertheless, early diagnosis and prompt therapy, as described in this chapter, are necessary to maximize visual function in children with infantile and juvenile cataracts.

INDICATIONS FOR TREATMENT

Unlike cataracts that occur in adults, pediatric cataracts present during the unique period of visual development from birth until the age of 7 to 10 years. Any lens opacity that is large enough, dense enough, and central enough to interfere with normal visual development must be rapidly eliminated; otherwise, profound and irreversible deprivation amblyopia will develop. In preverbal infants, assessment of the optical or visual significance of a lens opacity can be particularly difficult.

The most valuable test for determining the visual significance of a cataract is analysis of the red reflex through the undilated pupil with the retinoscope. The retinoscope demonstrates, by retroillumination, not only the absolute area of lens opacity, which appears black against the red reflex, but also the extent of optical distortion produced by adjacent areas of what may appear to be clear cortex.

Important therapeutic criteria to consider for evaluating a child with cataracts include (1) extent of lens opacity, (2) age of patient at onset, (3) duration of visual deprivation, (4) type of cataract, and (5) monocular versus binocular involvement. Dense ocular opacities greater than 3 mm in diameter are visually significant. In addition, an opacity somewhat smaller but with marked surrounding cortical distortion may also prove to be vision limiting.

Opacities documented during the neonatal period require urgent therapeutic intervention to prevent permanent deprivation amblyopia. It is generally accepted that significant unilateral congenital cataracts must be treated by 2 or possibly 3 months of age for the best prognosis. Similarly, bilateral cataracts known to be present from birth probably require therapeutic intervention by 3 or 4 months of age, before the development of nystagmus, to obtain visual acuity better than 20/200.

In children with acquired progressive opacities, such as posterior lenticonus or lamellar cataracts, the visual outcome depends on the age of the patient at onset and the duration of visual deprivation. Children whose lenses are relatively clear during the first 6 months of life may develop excellent acuity even if the lens opacity is not detected and treated until 2 or even 3 years of age.

Careful examination of cataract morphology, along with associated findings, is frequently helpful in determining the etiology and prognosis. For example, most anterior polar cataracts are small, measuring less than 1 to 2 mm, and are usually not progressive. Surgery is seldom required and the visual prognosis is excellent. Lamellar cataracts are characterized by layers of opacification peripheral to Y sutures with a clear nucleus. They are generally bilateral, 5 mm or more in diameter, of variable density, and found in normal-sized eyes. They are considered acquired and progressive rather than truly congenital. These cataracts are frequently inherited as an autosomal recessive trait. Many of these children do not require surgery, or require it late, and the visual prognosis in this type of cataract is very good. Nuclear cataracts are typically congenital dense axial opacities of 3 mm or more. They are frequently associated with mild to moderate microphthalmia and inherited as an autosomal dominant trait. Visual results are generally only fair even if surgery is done early, and poor if it is done late. Posterior lenticonus/lentiglobus presents as a posterior lens opacity associated with bulging of the posterior lens capsule. Although frequently mistaken for a congenital cataract, this is usually acquired in infancy and is slowly or rapidly progressive. The eyes are normal in size, and the visual results are excellent with surgery. Finally, congenital cataracts may be associated with posterior hyperplastic primary vitreous (PHPV) in microphthalmic eyes. These eyes frequently develop secondary glaucoma, either with or without surgical intervention, and the visual results following surgery are variable, depending largely on the degree of posterior segment involvement.

With some partial cataracts, especially unilateral developmental cataracts of uncertain visual significance, a trial of pupil dilation and occlusion therapy may be worthwhile. However, chronic dilation results in significant photophobia and reduced accommodation, and therefore is generally most useful as a diagnostic tool to demonstrate that visual improvement can be accomplished or as a short-term treatment to allow as much visual development as possible before surgery is performed.

SELECTION OF SURGICAL TECHNIQUES

Pediatric cataract extraction requires techniques somewhat different from those used in adult cataract surgery. Adult cataract extraction techniques (extracapsular cataract extraction with nucleus expression and phacoemulsification) were developed to preserve the posterior lens capsule at the time of surgery since, if it opacifies, a secondary capsulotomy can be easily performed with a slit lamp-mounted YAG laser. Unfortunately, the posterior lens capsule opacifies rapidly in nearly all infants and young children, creating a high risk for the development of amblyopia. Therefore, cataract extraction in children under the age of 7 to 9 years should be planned to permit, in a single procedure, (1) removal of all opaque lens material, (2) creation of minimal astigmatism, (3) proper management of the posterior capsule and vitreous to prevent secondary cataract formation, and (4) simple, rapid postoperative optical correction.

Generally, these goals are best met through a combination of mechanized lensectomy, central posterior capsulectomy, anterior vitrectomy, and early postoperative fitting of an extended-wear pediatric aphakic contact lens. Most pediatric ophthalmologists currently favor lensectomy through a small limbal incision using a vitreous suction/cutting instrument, as detailed in this chapter. The basic mechanics of this technique are similar to those used in adult cataract extraction, and therefore easy for anterior segment, pediatric, and general ophthalmic surgeons to learn and master. Other surgeons, especially those with retina/vitreous surgery experience, often prefer a pars plana or pars plicata approach.

Maximal preoperative pupil dilation can be accomplished with a combination of 1% cyclopentolate and 2.5% phenylephrine. In addition, wide pupillary dilation can be maintained throughout the procedure with the addition of 0.25 ml of 1:1,000 intracardiac epinephrine into the 500-ml bottle of irrigating solution.

Endocapsular lensectomy can be accomplished through a 1.5- to 2.0-mm limbal incision at the 10:30-o'clock position (for a right-handed surgeon) or the 1:30-o'clock position (for a left-handed surgeon) using one of the newer suction/cutting instruments (Ocutome, SITE, A-Vit, etc.), with irrigation provided through the same incision by an integrated silicone infusion sleeve. This system provides the advantages of allowing either one- or two-handed control of all surgical functions with irrigation provided immediately adjacent to the suction port, thereby minimizing the flow of irrigating solutions throughout the anterior chamber. Occasionally, especially when extracting long-standing traumatic or other fibrous cataracts, a separate irrigating port is useful, consisting of a 23- or 25-guage needle inserted through a separate limbal incision 45° to 120° away from the vitreous cutting instrument. This two-handed approach allows bimanual manipulation of fibrous membranes and iris adhesions as the needle tip can be used to retract iris or feed fibrous membranes into the cutting port.

SURGICAL TECHNIQUE

This technique can be used for either eye.

- Step 1. As with all intraocular procedures, proper lid draping is required to prevent lid or lash contamination of instruments that will be introduced into the eye. An adhesive drape such as the Alcon 1060 drape works well. With an assistant or nurse everting and slightly separating the lid margins with the stick end of a pair of cotton-tipped applicators, the adhesive portion of the drape is placed over the eve, taking care that all lashes are retracted outside the lid margins. The drape is then incised 2 mm inside the lid margin, and the lid speculum placed so as to fold the free edge of the drape beneath the lid, completely isolating the lid margin and lashes from the operative site.
- Step 2. Although not absolutely required, a 4–0 silk traction suture placed through the superior rectus insertion is frequently helpful for positioning the globe during incision and wound closure. The traction on this suture should be released during the lens extraction to allow for freer globe manipulation and better visualization.
- Step 3. A fornix-based conjunctival flap is created by tenting the limbal con-

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Figure 14-1

junctiva at the 10:30-o'clock position with a toothed forcep and incising the conjunctiva using sharp Westcott scissors held perpendicular to the limbus, as shown in Figure 14-1. The incision is enlarged by sharp and blunt dissection in a plane over the sclera surface from the 9:00-o'clock to 12:00-o'clock positions, as shown in Figure 14-2. The conjunctiva must be undermined sufficiently so that the conjunctiva spontaneously retracts at least 3 to 4 mm posteriorly, allowing access for suture preplacement as described in Step 5. Bipolar underwater cautery of exposed limbal and sclera vessels is accomplished at this time to prevent future bleeding from the wound or suture sites.

Step 4. The anterior chamber is entered with a grooved two-plane incision



Figure 14-2

with a preplaced suture. In infants and children with flexible sclera, the eye is often so soft at the end of the procedure that suture placement and anatomic wound closure may be difficult. Grasping the sclera with a 0.3-mm Castroviejo forceps, a half-thickness scleral groove is created from the 9:30o'clock to 11:30-o'clock positions, as shown in Figure 14-2.

Step 5. The wound is grasped with a Colibri forceps and a preplaced 10–0 nylon (or 9–0 Vicryl) suture is inserted either in mattress fashion, as illustrated in Figure 14-3A, or as a single interrupted stitch placed across the center of the wound. The segment of suture bridging the anterior and posterior lip of the wound is then lifted and "butterflied" on the scleral surface using jeweler's forceps, as





Figure 14-3

shown in Figure 14-3B. This will allow entry into the anterior chamber through the base of the groove without cutting the suture.

Although somewhat more time consuming to initially place, the mattress suture allows for a more secure wound closure at the end of the procedure that rarely requires postplaced sutures.

Step 6. The anterior chamber is entered with a 15° blade (e.g., Beaver 7515) introduced in a second more horizontal plane through the base of the groove, as shown in Figure 14-4. Cutting the preplaced suture as it crosses the wound must be

avoided. The blade tip is then passed over the iris to create a small, 3-mm anterior capsulotomy for introduction of the suction/cutting instrument. Some surgeons prefer to use a 2.8- or 3.2-mm Keratome to enter the anterior chamber. However, because it has a sharp blade on both edges, its use increases the risk of cutting the preplaced mattress sutures. If a single-edged 15° blade, as illustrated in Figure 14-4, is used, then some practice is required to get the correct incision width to allow a snug fit around the suction/cutting tip. When using a 19-gauge



Figure 14-4

tip, such as the Cooper Vision A-Vit tip with sleeve, a 2.8- to 3.0mm incision is required.

Step 7. The A-Vit tip is then inserted snugly through the wound and across the anterior chamber, and its tip is inserted through the anterior capsulotomy into the central lens cortex. With the suction port directed anteriorly in direct view, the soft lens nucleus can then be gently aspirated from within the capsular bag using mild to moderate suction, as shown in Figure 14-5A. The lens nucleus and cortex in infants, children, and young adults up to the age of 25 to 30 years is generally soft and gelatinous, and easily aspirated using suction alone. Phacoemulsification, with its increased risk for complications, is not required except for long-standing (generally traumatic), calcified juvenile cataracts.

cortex have been aspirated completely, the peripheral and equatorial cortex is then removed using a stripping motion. With irrigation on and suction off, the suction port is initially introduced beneath the iris and anterior lens capsule toward the 6:00-o'clock position. Using mild to moderate suction with the port directed anteriorly, the peripheral cortex is engaged in the tip and slowly stripped centrally, where the cortical material can be aspirated under direct visualization with increased suction force. The tip is then moved back beneath the iris and adjacent cortex engaged and again stripped centrally before aspiration, as shown in Figure 14-5B. Using this technique, it is generally best to first remove all peripheral cortex at the 6:00-o'clock position. Then, by following along either nasally or temporally, it is possible to engage the edge of the

Step 8. After the lens nucleus and central



Figure 14-5

adjacent cortex and strip around in both directions from inferiorly to superiorly. It is important to use suction and stripping alone, without any cutting action, until the equatorial cortex has been stripped well into the pupillary space. Premature use of cutting action will leave residual cortex in the equatorial lens capsule, which is obscured from view by the iris and difficult to remove completely. In addition, this inferior to superior cortex removal strategy is important since, if inadvertent posterior capsule rupture should occur, it will not be necessary to cross the ruptured area to remove the remaining cortex.

Finally, the cortex beneath the iris at the 10:30-o'clock position is removed by rotating the port posteriorly and superiorly just behind the plane of the iris to engage this cortex. Once the superior cortex is engaged, the port is rotated anteriorly and pushed centrally to strip the superior cortex, being careful not to engage iris or lens capsule.

Step 9. The entire lens cortex has now been removed, with all instrumentation entirely within the capsular bag (endocapsular extraction). This technique greatly reduces the risk of irrigating fluid and flying lens cortex from damaging the corneal endothelium. The cutting port is rotated anteriorly and placed against the anterior capsule at the 6:00-o'clock position approximately 1 mm central to the iris edge. Using mild to moderate suction and cutting action, the anterior capsule can be removed simply by sweeping an arc from the 6:00-o'clock position to the 12:00-o'clock position, as shown in Figure 14-6. The capsulectomy is then completed from the 6:00o'clock to the 12:00-o'clock position in the opposite direction, as indicated by the dashed line in Figure 14-6. This technique allows creation of a smooth, round, generous anterior capsulotomy of at least 6 to 7 mm diameter without residual anterior capsule flaps that may subsequently adhere to the iris and create pupillary distortion.

Step 10. Finally, since the posterior capsule will nearly always opacify in children under 4 to 5 years of age, a smooth posterior capsulectomy is easily created by rotating the port posteriorly and using mild suction and cutting to create a posterior capsulotomy at the 10:30-o'clock position. The port is then rotated anteriorly and inserted through the capsulotomy to cut a smooth posterior capsulectomy from the 10:30-o'clock to the 4:30-o'clock position both nasally and temporally (Fig. 14-7) in a fashion similar to that used for the anterior capsule. The posterior capsulectomy should be large enough to facilitate retinoscopy should the remaining peripheral posterior capsule opacify. Generally, a 5- to 6-mm posterior capsulectomy is adequate. The creation of concentric anterior and posterior capsulectomies of nearly the same size allows postoperative fusion of the residual peripheral anterior and posterior capsule to form a fibrous platform that is suitable to support later secondary intraocular lens implantation after eye growth has completed, should the patient desire.

Step 11. After completion of the posterior



Figure 14-7

capsulectomy, an anterior vitrectomy should be performed to prevent later prolapse of anterior vitreous into the anterior chamber as well as tracking of the vitreous out through the surgical wound as the instrument is removed. Although posterior capsular rupture and vitreous loss have been associated with increased risk of complications, such as retinal detachment and cystoid macular edema in adults, there is no evidence for an increased risk of these complications in pediatric cases, possibly because the pediatric vitreous is well formed. Since the pediatric vitreous is crystal clear, it is often difficult to see the vitreous as it is being removed. Therefore, vitrectomy must be performed by slowly moving the vitrectomy instrument in concentric circles, beginning anteriorly to remove a thin anterior layer of vitreous and progressing slowly and more posteriorly to remove more posterior vitreous. It is generally safest to keep the cutting port pointed anteriorly, in direct view, throughout the vitrectomy to avoid inadvertently engaging and cutting tissue other than vitreous. Very low suction should be used throughout the anterior vitrectomy. If variable cutting speed is possible, such as with the Ocutome, then a high cutting speed between 300 and 350 cuts per minute should be used to prevent traction on the vitreous. Special care should be taken to remove adequate vitreous superiorly in the area of the entrance wound to prevent tracking the vitreous to the wound as the instrument is removed.

Step 12. After completion of the anterior

vitrectomy, careful removal of the vitrectomy instrument from the eye is necessary to prevent vitreous wick formation. This can be facilitated by reducing suction to near zero while maintaining rapid cutting action as the instrument is slowly withdrawn from the anterior chamber. Constriction of the pupil by injection of acetylcholine (Miochol) into the infusion line before removal of the instrument can also help maintain the vitreous in the posterior chamber. In addition, air can be infused through the infusion line into the anterior chamber to provide added support of the vitreous as the instrument is removed through the air bubble. Fortunately, if adequate anterior vitrectomy has been performed. the risk of vitreous prolapse at the time of instrument removal is small.

- Step 13. After removal of the suction/cutting instrument, the wound is carefully inspected with a cellulose sponge while carefully observing the pupillary margin adjacent to the wound, as shown in Figure 14-8. Any movement of the pupillary margin as the wound is blotted or stroked with the cellulose sponge confirms the presence of vitreous in the wound, which must be carefully cleared either by reinserting the vitrectomy instrument or by Weck cell vitrectomy.
- Step 14. When absence of vitreous to the wound has been verified, the wound is quickly and securely closed by merely lifting up on the two free ends of the preplaced 10– 0 nylon mattress suture, which are then tied together as shown in Figure 14-9A. The preplaced suture allows for perfect wound apposi-



Figure 14-8

tion to prevent or reduce the creation of postoperative astigmatism. The anterior chamber is reformed with a balanced salt solution to restore normal intraocular pressure. The wound can then be carefully inspected by gentle pressure on the posterior wound lip with a cellulose sponge to verify that it is watertight. Special attention must be paid to the corners of the wound, where wound leakage is most likely to occur. Should any fluid leak from the wound during this maneuver, as may occur if excessive wound stretching or tearing has occurred during the vitrectomy procedure, a postplaced, interrupted 10-0 nylon (or 9-0 Vicryl) suture can be inserted across the area of wound leak, as shown in Figure 14-9B. The anterior chamber is





Figure 14-10

again reformed and the wound reinspected with a cellulose sponge. In general, however, proper creation and sizing of the two-planed incision as well as preplacement of the mattress suture make the interrupted postplaced suture rarely necessary.

Step 15. The conjunctival flap is then closed in a "hood" fashion, as illustrated in Figure 14-10. Interrupted absorbable sutures at one or both ends of the wound may be used or the wound may be closed using bipolar cautery, as illustrated in Figure 14-10. Antibiotics and steroids may be injected subconjunctivally if desired. Atropine drops and a combination antibiotic/steriod ointment are then instilled and a patch and shield applied.

POSTOPERATIVE CARE

The family is instructed to leave the patch and shield in place for the first day, and the

patient can be discharged following recovery from anesthesia. The patient is then seen in the office on the first postoperative day and the patch and shield removed. Since little pain is present in most children, a thorough but gentle examination can be done, with special care taken to check visual acuity, when possible, as well as to verify clarity of the anterior segment and to obtain a good view of the fundus. In addition, a preliminary retinoscopy can generally be performed, which will be helpful in arranging availability of the proper contact lens for the next visit. The patient is then discharged with topical atropine 0.5% drops twice a day to be used for 3 to 4 weeks and a combination antibiotic/steriod ointment to be used until contact lens fitting. Although no patch or shield is generally used during the day, use of a shield during sleep for the first week is advised. A second follow-up visit is arranged from 3 days to 2 weeks following surgery, depending on patient age and risk of amblyopia, at which time repeat thorough examination is accomplished and contact lens fitting is performed.

OPTICAL MANAGEMENT AND AMBLYOPIA THERAPY

In large part, the successful management of pediatric cataracts is more a reflection of successful optical rehabilitation during amblyopia therapy than of surgical success. Since the parents and other caregivers will have a major role in the day-to-day amblyopia management, detailed discussions with parents concerning their willingness to comply with the rigors of long-term contact lens care and patching therapy must precede any surgery.

Optical correction of aphakia should be initiated as soon as possible after cataract removal and modified frequently as the refractive power of the infant eye changes. While it is possible to fit children while still in the operating room at the end of surgery, it is generally adequate to wait until 1 week after surgery to prescribe refractive correction. This allows data from two consecutive retinoscopic refractions (1 day and 7 days postoperatively) to be used in calculating initial contact lens or spectacle power. In bilateral cataracts, cataract extraction and aphakic correction should be performed as close to concurrently for each eye as possible, generally within 7 days of each other. Infants are generally provided with +3.00diopters of overcorrection during the first 15 to 18 months of life to focus their eyes at arm's length, where most of their early visual world is centered. Bifocal correction or overcorrection is introduced at 18 months of age or as soon as the children begin ambulating and require better distance vision.

Although aphakic spectacles are still valuable for selected bilateral pediatric cataract patients, especially those whose families cannot master the rigors of contact lens care or who cannot afford the expense of lens loss, contact lenses are selected by most pediatric ophthalmologists for initial aphakic management. Although hard and hydrophilic soft contact lenses have been used successfully by some ophthalmologists, the development of the Silsoft (Bausch & Lomb) extended-wear pediatric aphakic contact lens has revolutionized aphakic optical management for patients, parents, and ophthalmologists alike. Available for young infants in only one diameter (11.3 mm) and three base curves (7.5, 7.7, and 7.9), fitting can be performed empirically and quickly on most infants in the office. Generally, all that is needed is to select a 7.5 base curve and the required power (typically + 26.00 to + 32.00) for initial trial in most infants under 1 to 2 years of age, and possibly a 7.7 base curve for those older than 2 to 3 years of age. Keratometry is not required, as correct fit can be verified by observing lens movement (1 to 2 mm) and optical centration (optical zone over the pupil) or even by assessing fluorescein dve patterns since fluorescein does not penetrate the silicone lens. The relatively small, rigid Silsoft lens is easy for parents to insert and remove, and needs only to be removed every 1 to 2 weeks for cleaning and sterilization. In addition, these lenses seem to adhere more firmly to the cornea, significantly reducing lens loss.

Intraocular lenses and epikeratophakia have been used by some surgeons for treatment of pediatric aphakia, especially for developmental and traumatic cataracts occurring after 4 to 5 years of age. However, these techniques must still be considered experimental and are generally contraindicated as the initial therapy for infants under 1 to 3 years of age. Since the development of the Silsoft lens, successful contact lens fitting and tolerance has become the rule, with a contact lens failure rate of less than 5 percent in our experience.

Finally, amblyopia therapy with adhesive patches should be started in all patients with unilateral cataracts at the time aphakic correction is applied, beginning with occlusion of the sound eye 2 to 4 hours per day for infants under 3 months of age and increasing to 80 to 90 percent of waking time by the age of 6 to 8 months. This aggressive patching regimen is maintained until maximum visual improvement has been documented, at which time many patients can tolerate reduction of the patching to half the time, although most require some maintenance occlusion therapy until 7 to 9 years of age. Occlusion therapy is only instituted in children with bilateral aphakia if examination suggests a relative reduction of vision in one eye.

15 Pediatric Glaucoma

INTRODUCTION

Glaucoma is a relatively uncommon condition during childhood, occurring in between 1 in 12,500 and 1 in 25,000 births. The term congenital glaucoma, often used for all idiopathic childhood glaucoma, should be reserved for the 5 to 10 percent of children with glaucoma present at birth. Other children with primary developmental glaucoma presenting later in life should be referred to as having infantile or juvenile glaucoma. In a third group, consisting of approximately half of all childhood glaucoma patients, the glaucoma is acquired, resulting from a variety of conditions including trauma, inflammation, metabolic disorders, postsurgical insult, and systemic diseases (Table 15-1).

Most cases of congenital and infantile glaucoma are sporadic, that is, not familial. However, genetic transmission does occur in some families. Most genetic cases are inherited as an autosomal recessive trait, with each parent being clinically normal and carrying one of the autosomal recessive glaucoma genes. Subsequent children of the same couple have a 25 percent risk of being homozygous for a glaucoma gene. However, incomplete penetrance of the gene has been reported in 40 to 80 percent of families, so the actual occurrence of congenital or infantile glaucoma is significantly less than the expected 25 percent rate. In addition, autosomal dominant transmission, with parent as well as child affected, is regularly seen. Nevertheless, unilateral sporadic cases are the most common, making genetic counseling of parents with a single affected child and negative family history difficult.

CLINICAL DIAGNOSIS

Developmental glaucoma is truly congenital in 5 to 10 percent of cases, with 60 percent of patients presenting by 6 months of age and more than 80 percent diagnosed within the first 12 months. The condition is bilateral in more than 70 percent of children; however, the findings are frequently asymmetric, with the less affected eye demonstrating only the typical abnormal angle appearance of developmental glaucoma.

Congenital and infantile glaucoma are classically characterized by the triad of photophobia, epiphora, and blepharospasm in an infant with enlarged and possibly hazy corneas. The onset of symptoms may be gradual or sudden. Unfortunately, however, many children initially present with only part of the full-blown syndrome, making early diagnosis more difficult. The child initially presenting with epiphora alone is frequently treated for weeks or even months for congenital nasolacrimal duct obstruction before the true diagnosis becomes clear, when corneal enlargement and clouding becomes more prominent. Even marked corneal enlargement, if symmetric, may mislead parents and pediatricians who feel

Table 15-1. Ocular Anomalies and Systemic					
Disorders Commonly Associated With Pediatric					
Glaucoma					
Ocular anomalies					
Aniridia					
Peters anomaly					
Rieger or Axenfeld syndrome					
Posterior hyperplastic primary vitreous					
Congenital cataract					
Lens dislocation					
Post-trauma (hyphema or anterior segment surgery)					
Metabolic disease					
Oculocerebrorenal syndrome (Lowe syndrome)					
Homocystinuria					
Mucopolysaccharidosis					
Systemic disease					
Marfan syndrome					
Down syndrome					
Rubinstein-Tavbi syndrome					
Sturge-Weber syndrome					
Neurofibromatosis type I					
Rubella syndrome					

Chronic uveitis (juvenile rheumatoid arthritis, sarcoid, etc)

that the baby's large eyes are attractive. Mild photophobia may manifest itself by constant eve closure only when the child is outside in bright sunlight, which is considered a normal behavior. Many times abnormal photophobia is not suspected until the infant maintains tight eye closure even indoors and during feeding. Frequent eye rubbing, when associated with severe photophobia, is often helpful in alerting the parents and pediatrician for the need for further evaluation. The development of unilateral corneal enlargement or diffuse corneal haze is rarely seen in other neonatal conditions and generally alerts parents and physicians of the potential diagnosis of congenital or infantile glaucoma. Unfortunately, however, the infant eve can frequently tolerate pressures in the upper 30s or low 40s for extended periods of time before corneal edema and haze develop. In addition, the cornea and sclera become relatively resistant to distention after the age of 3 years; therefore, if the initial intraocular pressure elevation occurs after this age, corneal enlargement rarely occurs. Instead, severe optic nerve cupping and damage can go unnoticed for months until corneal haze or sensory strabismus results.

If pediatric glaucoma is suspected in patients younger than 4 or 5 years, the diagnosis must be confirmed by an examination under anesthesia or deep sedation. This examination must include measurement of intraocular pressure and corneal diameter, biomicroscopic examination of the cornea, cycloplegic refraction, gonioscopic evaluation of the anterior chamber angle, and careful study of and possible photographic documentation of the optic nerve head in each eye.

Office measurement of intraocular pressure can sometimes be accomplished in very young infants using topical anesthesia as the child sleeps or is feeding. A pneumatonometer or McKay-Marg-type tonometer such as the Tonopen is generally useful since minimal manipulation of the eye is needed for measurement with these instruments. However, the measurement will be artifactually elevated and cannot be trusted if any blinking or squeezing of the eyelids occur. Examination under anesthesia or deep sedation is generally required after 2 to 4 months of age. Deep sedation with either chloral hydrate (50 to 75 mg/kg by mouth) or a combination of meperidine (Demerol)/promethazine (Phenergen)/ chlorpromazine (Thorazine) (2:1:1 mg/kg IM) can be used for deep sedation in an office setting. However, most ophthalmologists prefer examination under general anesthesia in the operating room. Since most general anesthetic agents lower the intraocular pressure to some degree, it is important to measure the intraocular pressure as soon as possible after induction of anesthesia. Pressure reduction is not seen with ketamine anesthetic, but it has seldom been necessary to alter the technique of inducing anesthesia if intraocular pressure measurement can be accomplished rapidly after induction. Several studies have indicated that an intraocular pressure of more than 20 mmHg in infants and children under anesthesia is nearly always abnormal and a firm indication for treatment. In addition, asymmetry in the pressure measurements as well as other signs, such as enlarged corneal diameter, asymmetric optic nerve cups, or breaks in Descemet's membrane (Haab's striae), will confirm the diagnosis of pediatric glaucoma in the presence of borderline pressure measurements.

Careful inspection of the cornea with a hand-held slit lamp biomicroscope or penlight is important in looking for corneal haze and breaks in Descemet's membrane (Haab's striae). The presence of corneal edema can also be assessed by observing the red reflex using a direct ophthalmoscope or retinoscope. Significant corneal haze will cause irregularity of the epithelium, resulting in loss of the normal corneal luster. The normal infant cornea at birth measures less than 10.5 mm in horizontal diameter. With increased intraocular pressure, however, progressive corneal enlargement can result in diameters greater than 15 mm. In general, a corneal diameter of more than 12 mm during the first year of life is indicative of infantile glaucoma until all other signs have been excluded.

Careful cycloplegic refraction can be helpful in evaluating a child with suspected glaucoma. Increasing axial length associated with corneal and scleral distention may result in the development of significant myopia. In addition, asymmetry of the refraction, with less hyperopia or more myopia in one eye compared with the other is frequently helpful in diagnosing glaucoma, especially when intraocular pressure is borderline.

Gonioscopy is an examination technique allowing detailed direct observation of the anterior chamber angle. Using a Koeppe lens in a supine infant under general anesthesia or deep sedation, the examination can be accomplished quickly using a handheld biomicroscope or loupe magnification with a fiberoptic hand-held or head-

mounted light source. The Koeppe lens allows observation of approximately 60° of the chamber angle at one time. In addition, a Koeppe lens can be placed in both eyes simultaneously, allowing rapid comparison of chamber angles in both eves. The typical developmental glaucoma angle has a highinserting flat iris with an absent iris recess. The trabecular meshwork is often poorly visualized and fine iris processes as well as increased fine iris vessels may be prominent. If corneal edema prevents an adequate view of the angle, the epithelium can be removed by gently scraping with a blade or wiping with a cotton-tipped applicator soaked in 70% alcohol.

Dilated fundus examination and careful evaluation of the optic nerve with an indirect or direct ophthalmoscope are the most important parts of the entire examination in pediatric glaucoma. Except in the presence of very high intraocular pressure, the diagnosis of congenital or infantile glaucoma is suspect without increased optic nerve cupping. Asymmetry of optic nerve cupping between both eyes is an especially helpful diagnostic sign. Any abnormalities in optic nerve appearance or cupping should be documented photographically for comparison with future examinations.

MANAGEMENT OF PEDIATRIC GLAUCOMA

Pediatric glaucoma is largely treated with surgery. The objective of therapy is rapid and permanent lowering of the intraocular pressure into the normal range (generally less than 20 mmHg) or to a level slightly higher but without progression of other signs, such as corneal enlargement, increased myopia, or increased optic nerve cupping. Medical therapy in the form of topical beta blockers (timolol maleate [Timoptic], betaxolol [Betoptic], etc), epinephrinelike compounds (dipivefrin hydrochloride [Propine]), and systemic administration of carbonic anhydrase inhibitors (acetazolamide [Diamox]; 15 mg/kg/d divided into four doses) is used primarily to reduce the intraocular pressure temporarily until surgery can be performed and to clear the cornea to facilitate surgical therapy. Chronic use of systemic carbonic anhydrase inhibitors should be avoided in infants and small children since the resulting systemic acidosis frequently results in growth retardation. However, topical antiglaucoma therapy for extended periods of time is sometimes helpful postoperatively to further reduce borderline intraocular pressure elevations without the need for reoperation.

Ideally, as soon as the diagnosis of congenital or infantile glaucoma is suspected, an examination under anesthesia should be scheduled, with sufficient time allowed for definitive surgical treatment under the same anesthesia if the diagnosis is confirmed. If a delay in scheduling surgery is necessitated by other systemic illness or if significant corneal edema is present, then institution of medical therapy before surgery should be considered.

Although authorities agree that surgical, rather than medical, therapy is indicated in children with developmental glaucoma, the selection of surgical technique remains controversial. Many pediatric and glaucoma specialists prefer goniotomy as the preferred initial therapy whenever adequate corneal clarity is present or can be obtained by removal of the corneal epithelium. In goniotomy, a fine knife is inserted across the anterior chamber under direct visualization to incise within the anterior aspect of the trabecular meshwork in the hope of opening channels into Schlemm's canal or other outflow channels to increase the facility of aqueous outflow and normalize the intraocular pressure. Although not a difficult operation, it requires great care since a sharp instrument will be crossing the entire anterior chamber and inadvertent damage to the lens can occur if the anterior chamber shallows. Goniotomy has the advantage of being quick to perform without requiring a conjunctival incision or closure. In experienced hands, the incision location in the trabecular meshwork is monitored by direct visualization and can be precisely placed. In addition, some surgeons believe that the lack of conjunctival incision and secondary scarring is especially important in these patients should they require future filtration surgery later in life.

In cases in which extreme corneal haze and edema make it impossible to view the angle with a gonioprism, trabeculotomy may be performed. Some pediatric and glaucoma surgeons, in fact, choose trabeculotomy as their preferred initial procedure in most patients with congenital and infantile glaucoma. Although requiring a small conjunctival incision, this procedure, when performed properly, assures a deep goniotomy with direct communication to Schlemm's canal opened directly into the anterior chamber. As with goniotomy, this procedure is somewhat difficult to learn initially (especially localization and canulation of Schlemm's canal from an external incision); however, once learned, it is a simple, anatomically based procedure that does not require passing instruments across the anterior chamber with the risk of cataract formation.

Several studies have compared the success rate of goniotomy and trabeculotomy. Most studies suggest that either technique is effective in controlling intraocular pressure in approximately 80 to 85 percent of uncomplicated cases. However, several goniotomies are often needed in a given eye to obtain the same success rate as a single trabeculotomy.

In older children (over 3 years of age) with juvenile or acquired types of glaucoma, simple goniotomy and trabeculotomy appear to be less effective, although some surgeons will attempt these procedures initially since they are less destructive than other procedures. Other surgeons switch to

Type of Glaucoma	Age	1st	2nd	3rd	4th
Congenital and infantile	<3 yr	Trabeculotomy or goniotomy	Trabeculotomy or goniotomy	Trabeculectomy	Molteno implant or cyclo- cryotherapy
Acquired and juvenile (anir- idia, Sturge- Weber, juve- nile rheuma- toid arthritis, postcataract surgery, etc)	Any age	Combined trabe- culotomy/trabe- culectomy	Combined trabecu- lotomy/trabecu- lectomy	Molteno implant or cyclo- cryotherapy	

Table 15-2. Recommended Procedure

a standard filtering procedure, such as a guarded (trabeculectomy) or unguarded fistulization procedure, cyclocryotherapy, or one of the newer valve or shunt implants, such as the Molteno implant. Table 15-2 illustrates an algorithm that we use for selection of the surgical procedure.

SURGICAL TECHNIQUES

Goniotomy

Proper initial preparation before performance of a goniotomy is essential for successful completion of the procedure. The



Figure 15-1

patient is placed in the supine position on the operating table, with the surgeon seated on the same side of the head as the eye to be operated on and the assistant seated on the opposite side. The head is rotated slightly toward the surgeon so the sagittal plane makes an angle of 67° with the horizontal, as shown in Figure 15-1B. A sponge doughnut or rolled towels may be used to stabilize the head in this position.

Proper magnification and illumination are also necessary. Magnification can be provided by using $3 \times$ or $4 \times$ loupes, with illumination provided by a fiberoptic, headmounted light source. Alternatively, an adjustable operating microscope of the type used in neurosurgery or otolaryngology can be positioned properly to provide an excellent view through the goniolens. In addition, the Barkan goniolens offers another $1.5 \times$ magnification for a total of 4.5 to 10 or more power.

- Step 1. After proper patient positioning, skin preparation, and draping, the cornea is inspected for clarity by initially placing the Barkan goniolens on the operative eye to evaluate the view of the anterior chamber angle. If corneal epithelial edema is obstructing the view, then the epithelium can be removed by gently scraping with a sharp blade or by swabbing the cornea with a cotton-tipped applicator soaked in 70% alcohol.
- Step 2. The superior rectus and inferior rectus insertions are each grasped with a locking Elschnig forceps and held by the assistant to stabilize and allow controlled movement of the globe, as shown in Figure 15-1A. These forceps also provide adequate lid retraction, so no lid speculum or lid suture is required.
- Step 3. The smallest Barkan lens available is placed over the cornea and sta-

bilized using the index finger of the nonoperating hand, or alternatively using a muscle hook or forceps hook to grasp the two dimples located on the top of the lens. The temporal edge of the lens is lifted slightly, and a few drops of saline are placed under the lens to displace any air bubbles between the lens and the cornea. Using a combination of globe movements by the assistant and lens movements by the surgeon, the optics and illumination are aligned to provide a satisfactory view of the chamber angle.

- Step 4. A goniotomy knife is selected and placed in the surgeon's operating hand. The blade should be extremely sharp, especially at its tip, so that corneal penetration will be smooth and effortless. A goniotomy knife with an extremely small blade and a slightly tapered shaft is easiest to use since the tapered shaft will provide a continuous corneal seal, without leakage of aqueous, as the knife is moved across the anterior chamber. Nevertheless, the procedure can be simplified, especially during the learning phase if, as soon as the anterior chamber is entered with the goniotomy knife, the aqueous is replaced with viscoelastic material to help maintain a deep chamber throughout the procedure.
- Step 5. When the optics and illumination are satisfactory and the goniotomy knife is positioned for incision, the assistant should maximally rotate the eye in a counterclockwise direction using the preplaced traction forceps.
- Step 6. The incision should be made approximately 1 mm into clear cornea, as shown in Figure 15-2. The tip of the goniotomy knife is then



Figure 15-2

directed parallel to the plane of the iris, as far to the surgeon's right as will be permitted by the area of chamber angle in view through the Barkan lens. In this way, the anterior chamber is traversed as far peripherally as possible, trying to avoid passing over the pupil and exposed lens until the knife blade is clearly visible as it approaches the chamber angle in preparation for goniotomy.

Step 7. The proper incision extends into the anterior trabecular meshwork just posterior to Schwalbe's line and anterior to the insertion of the peripheral iris, as shown in Figure 15-3. The goniotomy knife is then moved clockwise by the surgeon while directly observing as the darker angle tissue separates, leaving the more translucent tissue of the deep trabecular meshwork exposed behind the knife. In addition, a properly placed incision will result in widening of the angle recess and a slight "falling back" of the iris in the incised region. After the surgeon has incised as far counterclockwise as possible, the assistant can then slowly rotate the eye in a clockwise direction to allow the surgeon access to a larger portion of the angle. Care must be taken to maintain the proper pressure on the Barkan lens to prevent the formation of air bubbles beneath the lens if too little pressure is applied and shallowing of the anterior chamber if too much pressure is applied. Proper depth of





the goniotomy incision is monitored by direct observation as the incision separates and the iris falls back, as well as by the smooth butter-like sensation felt when the incision is the proper depth. If the incision is too deep, a bumpy or gritty sensation will be felt as tougher scleral fibers are cut. Using this technique, it is generally possible to incise approximately 120° of anterior chamber angle through a single corneal incision.

Step 8. When the tip of the knife has reached the far left (counterclockwise) end of the angle within view, it is withdrawn smoothly, again attempting to sweep the tip across the peripheral iris, avoiding the pupillary opening. To maintain

visualization of the knife throughout the removal phase, the Barkan lens should be removed from the cornea only after the tip of the knife is no longer visible through its surface. It is not unusual for the anterior chamber to shallow during knife removal, and moderate or even marked bleeding from the goniotomy incision frequently occurs. This bleeding is generally minimized if the anterior chamber is filled with viscoelastic material at the start of the procedure: otherwise, the chamber can be reformed with balanced salt solution through the incision, which will help tamponade the bleeding.

Step 9. If a sharp goniotomy knife has been used and the cornea incised at the proper plane, the wound is generally self-sealing and no suture is necessary. Pilocarpine drops are applied to the eye to constrict the pupil and prevent iris adhesion to the incision sit. Antibiotic/steriod ointment is also applied and a patch and shield are placed.

Trabeculotomy and Trabeculotomy/Trabeculectomy

An operating microscope is used for the trabeculotomy and trabeculotomy/trabeculectomy procedures to provide the increased magnification required. As in all intraocular procedures, proper skin preparation and lid draping is required, as described in Chapter 14, Step 1. To begin either procedure, a 4–0 black silk traction suture is placed under the superior rectus insertion to help position the globe during incision and wound closure.

Trabeculotomy

The trabeculotomy technique can be used for either eye.

Step 1. When performing a trabeculotomy alone, a fornix-based limbal conjunctival flap (limbal incision) is created from approximately the 9 o'clock to 12 o'clock positions down to the bare sclera, as shown in Figure 15-4. If a combined trabeculotomy/trabeculectomy is performed, many surgeons prefer to use a limbal-based conjunctival flap with a conjunctival incision 10 to 12 mm posterior to the limbus. This incision prevents close apposition of sclerostomy and conjunctival incisions, thereby reducing the risk of wound leak, endophthalmitis, or bleb scarring and failure. Bipolar underwater cautery of the exposed limbal and scleral vessels is accomplished at this time to prevent future bleeding from the wound or suture sites. A triangular, two-thirds depth



Figure 15-4



Figure 15-5

scleral flap is created at the 10:30 o'clock position using a 15° blade, as shown in Figure 15-4.

- Step 2. The flap is elevated using Colibri forceps and a no. 57 Beaver microsclerotomy blade, as shown in Figure 15-5A. The flap must be raised at least two-thirds of the scleral thickness so that proper localization of the scleral spur and Schlemm's canal will be possible.
- Step 3. While elevating the scleral flap with Colibri forceps, the base of the scleral flap is thoroughly dried and inspected to identify the "blue-white junction" between the more translucent peripheral cornea (blue) and the white sclera. This junction occurs in the area of the true anatomic limbus and directly overlies Schlemm's canal and the scleral spur.
- Step 4. A radial groove is created in the scleral bed across the blue-white junction using a 15° blade, as

shown in Figure 15-5B. This groove is slowly deepened using gentle strokes with the blade until the roof of Schlemm's canal is incised. Schlemm's canal can be identified by the flow of clear aqueous pouring from its lumen. Sometimes its wall can even be identified directly, having the appearance of the cut edge of a small vessel.

Step 5. The location of Schlemm's canal is then verified by insertion of the inferior probe of the lefthanded Harms trabeculotome, as shown in Figure 15-6A. In most cases, the trabeculotome passes smoothly and easily along Schlemm's canal, parallel to the limbus, for nearly the entire length of the probe without meeting significant resistance. The upper parallel probe is used to monitor the location and path of the inferior probe.







- Figure 15-6
- Step 6. When the inferior probe has been passed completely into Schlemm's canal, its tip is gently rotated into the anterior chamber, tearing through trabecular meshwork, as shown in Figure 15-6B. A soft popping sensation is felt as the probe tears through trabecular meshwork when the procedure is performed properly. The trabeculotome must be in the proper plane, as monitored by the upper probe, to avoid rotating the probe posteriorly into the iris, ciliary body, or lens. or anteriorly into the corneal stroma. Also, the probe should be rotated only enough to just visualize the tip of the probe in the anterior chamber. The probe should not be rotated into the center of the anterior chamber over the surface of the exposed

lens, where shallowing of the chamber would result in lens damage.

- Step 7. The remainder of the trabecular meshwork is incised by withdrawing the probe while the tip remains in the anterior chamber, as shown in Figure 15-6C. In this way, trabecular meshwork is incised along the entire length of the probe, yet the probe tip is always in the periphery of the anterior chamber, away from the lens and pupil.
- Step 8. Schlemm's canal is entered in the opposite direction using the righthanded trabeculotome, and the identical procedure is performed. Successful trabeculotomy allows incision of trabecular meshwork for approximately 60° to 75°, both clockwise and counterclockwise from the entry incision, for a total

of 120° to 150°. Moderate bleeding from the incised chamber angle is common, sometimes resulting in formation of total hyphema. Reforming the anterior chamber with balanced salt solution will help to tamponade the bleeding. In general, however, even large amounts of anterior chamber blood are quickly absorbed (usually within 24 hours) following this procedure and no specific hyphema therapy is required.

Modification for Trabeculotomy/Trabeculectomy

Step 9. After completion of the trabeculotomy, a trabeculectomy opening can be easily created in the base of the scleral flap by deepening the radial incision into the anterior chamber using the 15° blade. An internal lamellar keratectomy is then accomplished using a Kelly Descemet's membrane punch inserted through the slit incision into the anterior chamber, as shown in Figure 15-7A.

Step 10. Multiple punches are used to enlarge the sclerostomy opening to approximately 2×3 mm, as shown in Figure 15-7B. To prevent peripheral iris from occluding the sclerostomy site, a peripheral iridectomy is created through the sclerostomy by grasping the midpheripheral iris through the sclerostomy with a 0.12-mm Castroviejo forceps, pulling the peripheral iris out through the wound and excising it with a sharp iris scissors. The peripheral iridectomy should be large enough to allow direct visualization of several ciliary processes. as shown in Figure 15-7B.



Completion of Trabeculotomy

Step 11. Following completion of the surgical procedure, the wound is closed as illustrated in Figure 15-8. If trabeculotomy alone has been performed, the flap is closed loosely with a 10-0 nylon interrupted suture at the apex, as shown in Figure 15-8A. The conjunctival flap is then closed in a "hood" fashion using interrupted absorbable sutures at both ends of the wound. Antibiotics (gentamicin) and steroids (dexamethasone) may be injected subconjunctivally if desired. Pilocarpine drops and a combination antibiotic/steroid ointment are then instilled and a patch and shield applied.

Completion of Trabeculotomy/Trabeculectomy

Step 12. If a combined trabeculotomy/trabeculectomy has been performed,

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the wound is closed as illustrated in Figure 15-8B. The scleral flap is again closed loosely with a single interrupted 10–0 nylon suture at the apex. The anterior chamber can be reformed at this time with balanced salt solution, and the degree of anterior chamber drainage through the trabeculectomy is assessed. In general, the scleral flap is best closed only loosely, since overfiltration and anterior chamber shallowing in pediatric patients is rare, and underfiltration with failure secondary to scarring is common. The limbal-based coniunctival wound is then closed with a single running 7-0 collagen suture using locked stitches as illustrated in 15-8B. Frequently, a shallow bleb will already be visible at the close of the procedure. Subconjunctival injection of a steroid superiorly to help prevent bleb scarring and antibiotic infe-



Figure 15-8

riorly to help prevent infection are then followed by installation of pilocarpine drops and antibiotic/ steroid ointment.

In older children with acquired juvenile glaucoma, trabeculotomy alone has been less effective. In these cases, a combined trabeculotomy followed by trabeculectomy has increased the initial surgical success.

Cyclocryotherapy

Goniotomy and trabeculotomy are unsuccessful in 10 to 20 percent of pediatric patients. Traditional guarded (trabeculectomy) and unguarded sclerostomy procedures should be attempted in these patients. although the failure rate due to exuberant conjunctival scarring in pediatric patients is significant. Current studies investigating the role of antimetabolites such as mitomycin C and 5-flurouridine in pediatric glaucoma filtration surgery are showing some promise in eliminating this high failure rate. Nevertheless, at the present time, when goniotomy, trabeculotomy, or filtering procedures have failed or are not feasible, cvclocryotherapy may be performed. This procedure is more difficult to control, with undertreatment resulting in little or no change in intraocular pressure and overtreatment resulting in phthisis bulbi. In addition, cataract formation in phakic patients is common. Therefore, cyclocryotherapy must be reserved as a last resort to save useful vision and to prevent or relieve severe pain.

Step 1. Because of severe induced pain, cyclocryotherapy must be performed under general or ketamine anesthesia in a child. Postoperative pain and discomfort can be reduced by retrobulbar injection of 1.5 to 2.5 ml of 0.75% bupivacaine (Marcaine) at the beginning of the procedure.

Step 2. Before skin preparation and drap-

ing, the ciliary body can be identified by transillumination of the sclera with a bright fiberoptic light source. It generally appears as a dark band 1 to 2 mm posterior to the limbus.

- Step 3. After routine skin preparation and draping, a lid speculum is inserted between the lids to expose the cornea and limbal area. Using a 2.5mm retinal cryoprobe with silicone sleeve, the tip is centered over the ciliary body and cooled to at least -70° C for 60 seconds, followed by rapid thawing using brisk irrigation with balanced salt solution. The cryoprobe is then applied over the ciliary body at the next adjacent clock hour and the procedure repeated, as shown in Figure 15-9. In general, one spot per clock hour can be applied over 120° to 180° during the initial treatment with minimal risk of overtreatment. Should the initial procedure fail, an additional 120° to 180° overlapping with the first treatment can be repeated 6 to 8 weeks later. It is generally wise to confine all treatment to 9 clock hours (such as between the 12 o'clock to 9 o'clock positions) and entirely avoid the remaining 3 clock hours to prevent phthisis.
- Step 4. Atropine drops and a combination antibiotic/steroid ointment are applied postoperatively. No patch or shield is generally required.

POSTOPERATIVE CARE

Postoperatively, patients who have undergone goniotomy and trabeculotomy are maintained on 2% pilocarpine drops in the operated eye twice a day for 6 weeks. A combination antibiotic/steroid ointment is used for 2 to 3 weeks. Following trabeculotomy or combined trabeculotomy/tra-



Figure 15-9

beculectomy procedures, some surgeons prefer pupil constriction with pilocarpine while others prefer atropine.

Repeat examination under anesthesia to assess surgical success should be accomplished between 3 and 5 weeks postoperatively. Careful assessment of intraocular pressure, corneal diameter, cycloplegic refraction, gonioscopy, and optic nerve cupping is necessary to assess surgical success. If the examination suggests surgical success with intraocular pressure reduced to less than 20 mmHg and no evidence for glaucoma progression, then close observation with examination under anesthesia at 3- to 6-month intervals is adequate. Should examination reveal reduction in preoperative pressure, but continued borderline elevation in the mid to upper 20s, then a trial of adjunctive medical management with close follow-up may be safely continued as long as no evidence for progression of glaucomatous damage is observed. However, if intraocular pressure remains elevated above 30 mmHg or evidence for progressive optic nerve cupping, increasing myopia, or increasing corneal diameter is detected, then repeat glaucoma surgery should be performed at that time, with prior parental informed consent obtained.

Of special interest is the reversibility of cupping in pediatric glaucoma. Since a significant portion of the optic nerve cupping in children is related to stretching of the sclera and scleral canal, reversal of optic nerve cupping, even from 0.8 or 0.9 to 0.2 or 0.3, frequently occurs when intraocular pressure is brought under control. The degree of reversal in optic nerve cupping can serve as a good prognostic sign, but must be documented carefully since follow-up changes in cupping will need to be compared with the degree of cupping immediately following surgery.

16

Nasolacrimal Duct Procedures

INTRODUCTION

Congenital obstruction of the nasolacrimal drainage system is a relatively common congenital anomaly present in 2 to 4 percent of newborn infants. The obstruction most commonly results from a residual membrane over the valve of Hasner at the inferior end of the nasolacrimal duct where it enters the nose. However, the condition may also be caused by an absence of or a membrane over the punctum, a membranous obstruction or underdevelopment of the canalicular system, lacrimal stones, a bony obstruction caused by underdevelopment or misdirection of the bony portion of the nasolacrimal duct, or a nasolacrimal duct cyst.

CLINICAL PRESENTATION AND DIAGNOSIS

Infants with nasolacrimal system obstruction generally present with tearing and mucopurulent discharge from one or both eyes starting in early infancy. Crusting of the eyelashes may be prominent with a history of the eyelids frequently being stuck shut in the morning. Frank epiphora, when present, is usually exacerbated by cold or windy weather or an upper respiratory tract infection.

The diagnosis may be obvious even to the casual examiner if frank epiphora and

marked crusting of the lashes is present. However, in milder cases, the diagnosis can usually be confirmed by careful observation of an increased lacrimal lake, which gives a "wet look" to the affected eye or eyes. If any doubt remains after physical examination, a dye disappearance test should be performed by instilling fluorescein into the cul-de-sac of each eye. In cases of unilateral obstruction, the dye will disappear rapidly from the normal side but persist on the obstructed side. Bilateral obstruction can be confirmed by examining the back of the child's throat with a cobalt blue light and tongue depressor after 10 minutes. The presence of fluorescein dye in the posterior pharynx confirms patency of at least one side.

TREATMENT PLANNING

The natural history and, therefore, optimal management are controversial. It is clear that many congenitally obstructed nasolacrimal systems will open spontaneously during early infancy, most frequently during the first 2 to 6 months of life. Several studies suggest the possibility of resolution occurring in a majority of patients, sometimes as late as 12, 18, or even 24 months of age. However, other studies and the experience of many pediatric ophthalmologists suggest that spontaneous resolution after 6 months of age is much less likely and the option of nasolacrimal system probing should be presented to the family at that time. Even earlier probing, at 4 to 6 months of age, has been advocated by those pediatric ophthalmologists who prefer to avoid the risks of general anesthesia and perform probing in the office, since patient restraint is much easier in a younger infant. Other specialists who routinely perform probings under general anesthesia in the operating room recommend waiting until at least 12 months of age to minimize the number of children undergoing anesthetic risk. A reasonable compromise, whether one prefers office probing or general anesthesia, consists of offering the option of nasolacrimal duct probing to the parents of any child over 6 months of age with significant tearing, discharge, lash crusting, or recurrent infections.

A treatment plan based on these considerations is presented in Table 16-1. Initial management of young infants with typical signs of unilateral or bilateral nasolacrimal duct obstruction consists of educating the family concerning the pathophysiology and natural history of this condition and teaching them proper techniques for massage of the nasolacrimal sac. The parents should be instructed to place the index finger over the nasal canthal area to obstruct both the upper and lower canaliculus and then, with gentle pressure on the globe, to roll the finger over the inferior orbital rim, thereby compressing the lacrimal sac. This maneuver should be performed several times a day, possibly at the time of each feeding or diaper change. Any acute infection with conjunctival injection or increased discharge should be treated with a 10- to 14day course of topical antibiotics (10% sulfacetamide drops or erythromycin ointment).

Once the child has reached 4 months of age (if office probing is the treatment of choice) or 6 months of age (if general anesthesia will be used) and severe signs or recurrent infections have been present, the option of nasolacrimal system probing should be considered. Many studies suggest that an initial success rate of 90 percent can be expected following the initial probing. The success rate is especially high in those infants with the most common form of obstruction, that of a residual membrane over the valve of Hasner at the inferior end of the nasolacrimal duct where it enters the nose. In general, resolution of signs in suc-

Tuble 1011 Troutmont Fium				
Presentation	Treatment Massage, topical antibiotics for recurrent infection			
Epiphora, discharge in child less than 4–6 months old				
Child over 6 months old, severe symptoms or recurrent infection	Nasolacrimal system probing			
Persistent symptoms following previous probing	Repeat probing under general anesthesia with verification of patency; silicone intubation of system if probing difficult, bony obstruction, or abnormal anatomy suspected			
Persistent symptoms following 2 previous probings	Silicone intubation of system for 6–12 months; consider infracture of inferior turbinate			
Persistent symptoms following removal of silicone tubes or if intubation not possible because of abnormal anatomy	Dacryocystorhinostomy, generally postponed, if possible, until child is large enough (30–35 lb) to sustain blood loss without need for transfusion			
Dacryocystocele/mucocele/amniotocele	Immediate nasolacrimal system probing to decompress sac and avoid infection			

Table 16-1. Treatment Plan
cessful cases can be expected within 7 to 10 days of probing. Therefore, parents of children whose signs have not resolved within 2 weeks of probing should be instructed to schedule further therapy.

In those children in whom initial probing is unsuccessful, a repeat probing under general anesthesia with possible silicone intubation of the nasolacrimal system should be scheduled. Under these circumstances, careful examination of the nasolacrimal anatomy should be done to find and correct abnormalities that were not corrected at the time of initial probing. If it appears that the inferior turbinate is obstructing the exit site of the nasolacrimal duct, infracture of the turbinate should be performed. In addition, verification of successful probing should accomplished by direct visualization of the probe in the nose, "metal on metal" contact with a second probe through the nares, or successful irrigation of fluorescein-stained saline solution injected through the canaliculus and suctioned from the back of the nasopharynx. If any technical difficulty is experienced during the probing or verification process, especially if abnormal canalicular anatomy or bony obstruction of the nasolacrimal duct is found, silicone intubation of the system should be performed, if not on the second probing, then certainly on the third. Fortunately, the combination of nasolacrimal probing and, when necessary, subsequent silicone intubation is successful in 98 to 99 percent of children. However. in the few remaining children in whom successful probing is not possible secondary to abnormal anatomy or in whom recurrent signs are noted following removal of silicone tubes, dacryocystorhinostomy must be planned when the child is old enough to tolerate this procedure.

Rarely, functional obstruction to retrograde flow occurs in the upper portion (at Rosenmüller's valve) in addition to the obstruction in the lower portion of the nasolacrimal system. This results in fluid accumulation in the lacrimal sac in the newborn period, referred to variously as a dacryocystocele, amniotocele, or mucocele. Because secondary infection may occur rapidly and with serious consequences in a newborn infant, immediate nasolacrimal system probing should be attempted if initial manual decompression is not successful.

SELECTION OF ANESTHESIA

Successful office probing of infants under 4 months of age can generally be accomplished with topical anesthesia and restraint alone. Carefully securing the arms and legs in a clean sheet or papoose board will stabilize the infant's body, allowing the assistant to stabilize the head. Alternatively, the arms can be held by the assistant firmly on both sides of the head to obtain excellent stabilization and restraint.

Probing in the operating room can be accomplished using light anesthesia by mask, without intubation. For nasal verification of successful probing, the mask can be briefly removed after the child has been bagged for several deep breaths to maximize blood oxygenation. However, if silicone intubation of the nasolacrimal system is necessary, endotracheal intubation is usually preferable since prolonged access to the nose is required to retrieve the tubes and secure the ends.

SURGICAL TECHNIQUE

Nasolacrimal Duct Probing

Probing of left superior canalicular system is illustrated.

Step 1. The lid margin is gently everted by the surgeon's thumb to expose the superior (or inferior) punctum, as shown in Figure 16-1. Dilation of the punctum is accomplished by using a tapered punctal dilator held perpendicular to the lid margin, as shown in Figure 16-1A. Remembering that the distal portion of the



Figure 16-1

canaliculus running perpendicular to the lid margin is only 1 to 2 mm long, further dilation of the punctum can be accomplished by redirecting the punctal dilator nasally, parallel to the lid margin, and gently advancing it while simultaneously rotating it back and forth. A large sterile safety pin, as shown in Figure 16-1B, serves as an excellent sharp punctal dilator, which is useful if the punctum is hypoplastic or occluded with an epithelial membrane. Special care must be taken not to advance the sharp safety pin tip more than 1 to 2 mm beyond the punctum without redirecting its tip parallel to the lid margin to follow the horizontal portion of the canaliculus, as the sharp tip of the safety pin will easily penetrate the canalicular wall and produce a false passage.

Step 2. After removing the punctal dilator, a #0 Bowman probe is inserted perpendicularly through the dilated punctum and advanced 1 to 2 mm, as shown in Figure 16-2. The probe is then redirected nasally, as shown in Figure 16-3, and advanced along the horizontal portion of the canaliculus and into the lacrimal sac. It is important that the thumb be moved to the temporal portion of the lid to stretch the lid temporally, straightening the canaliculus and eliminating any bends or curves that might block the advancement of the probe. The probe should normally advance smoothly without resistance for a distance of 12 to 15 mm before reaching a firm stop in



Figure 16-3

the fundus of the lacrimal sac against the nasal bone. Special care must be taken if any tightness or soft resistance is encountered that may represent stenosis or kinking of the canaliculus. If such a soft resistance is detected, the probe should be withdrawn slightly, thumb countertraction on the lid tightened, and the probe redirected and gently advanced in a slightly different direction, seeking the smooth passage through the canalicular lumen. Forced advancement of the probe against a soft obstruction may result in perforation of the canaliculus and creation of a false passage. Both the upper and lower canaliculi should be probed to the lacrimal sac to verify their patency. However, it is usually only necessary to probe the nose through one canaliculus; probing should be done in the upper system since the angle of approach is slightly better, the force applied by the probe is not in a direction that would tend to unroof the canaliculus, and any accidental damage is less likely to be physiologically significant than it would be with the lower system.

Step 3. While maintaining pressure on the tip of the probe against the nasal probe is pivoted bone. the smoothly into a more vertical podirected inferiorly. sition and slightly laterally, and posteriorly to advance it through the lacrimal sac and into the nasolacrimal duct. Keeping the probe relatively flat in the plane of the forehead, in contact with the orbital rim, helps in finding the correct angle. The thumb countertraction should be released from the lid during this maneuver to allow nasal migration of the punctum without tearing. Generally, the probe will advance through the lacrimal sac smoothly when it has reached the proper trajectory, until it is funneled and finally wedged into the nasolacrimal duct. A sudden bony stop, rather than gradual wedging of the probe tip into the nasolacrimal duct, suggests misdirection of the probe against the nasal wall or lacrimal crest. The probe tip should then be retracted slightly, redirected, and gently advanced in an attempt to find the bony funnel surrounding the distant lacrimal sac, which leads the probe tip into the naso-When properly lacrimal duct. wedged, the probe will vibrate when its exposed end is gently plucked. If it has been misdirected into a bony wall, no vibration will occur.

- Step 4. Once the probe has been wedged in the nasolacrimal duct it is gently but firmly advanced another 10 to 15 mm, where a firm stop is felt as it encounters the floor of the nasal cavity. In most infants under 2 years of age, the nasal floor will be reached when less than half of the length of the probe from its tip to its wide flat handle has been passed. Occasionally, a popping sensation will be felt as the probe tip passes through an occluded valve of Hasner. At other times, marked stenosis or even complete atresia of the bony portion of the nasolacrimal duct will be encountered, requiring very firm pressure for passage as a crunching sensation is experienced.
- Step 5. Although verification of successful probing may be difficult or impossible in a squirming awake child during office probing, some attempt at verification of successful probing and lacrimal system patency should be attempted in all re-



Figure 16-4

peat probings and any probing carried out under general anesthesia. The most simple means of verification involves direct observation of the probe tip in the nose, coming from behind the inferior turbinate, using a nasal speculum. Alternatively, the probe tip can be felt in the nose by inserting a second larger probe through the nares and directing it posteriorly along the lateral wall at its junction with the floor of the nasal cavity. The larger probe is then moved medially and superiorly until a "metal on metal" sensation is felt, as shown in Figure 16-4A. In addition, the free end of the nasolacrimal probe extending over the brow should wiggle as contact is made in the nose.

Step 6. A more physiologic test of lacrimal system patency can be accomplished by gentle irrigation of fluorescein-stained saline solution through the canalicular system, with its recovery by a suction catheter from the nose. To accomplish this, the superior or inferior canaliculus is probed to the lacrimal sac with a 23-gauge, 1.5-inch, blunttipped, side port cannula attached to a 3-ml syringe filed with fluorescein-stained saline solution, as shown in Figure 16-4B. To prevent the reflux of fluid, a cotton-tipped applicator is used to simultaneously occlude the upper and lower punctae prior to injecting 1 to 2 ml of fluid. Patency of the system is documented by collecting the yellow fluid with a flexible suction catheter passed through the nares on the same side into the posterior nasopharynx. A fully patent system will flush easily with gentle pressure on the syringe. Any resistance to the flow of fluid from the syringe or reflux of stained fluid back

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through the compressed canalicular system suggests continued functional obstruction. This procedure can be performed with or without endotracheal intubation as long as the volume of irrigation fluid is minimal.

Step 7. Successful verification of office probings in an awake child can be accomplished by a modification of the irrigation technique described in Step 6. In this variation, the 23gauge, blunt-tipped, side port cannula is attached to a 5-ml syringe containing 1 ml of saline solution. The lacrimal system is then probed, as described in Steps 3 and 4, using this cannula-syringe combination until the tip of the cannula is felt to be in the nose. Successful probing is then verified by pulling back on the syringe plunger and observing air from the nasopharynx bubbling through the saline in the syringe.

SILICONE TUBE INTUBATION OF THE NASOLACRIMAL SYSTEM

Although primary nasolacrimal duct probing is successful in most children with congenital nasolacrimal duct obstruction, a small percentage of children who have had one or two unsuccessful probings may benefit from silicone tube intubation of the nasolacrimal system. This procedure is most commonly indicated in children with significant abnormalities in the anatomy of the nasolacrimal drainage system, especially those with bony stenosis or atresia of the nasolacrimal duct (where the "crunchy" sensation is felt while probing), those with stenosis or valves in the canalicular system, and, in general, those who have not resolved spontaneously or with probing by 18 months of age. The simple, rapid, and often nearly bloodless technique for silicone intubation developed by Jack Crawford is especially useful in these patients. This procedure is carried out by using a Crawford tube set (order number 28-01-85 from Jed Med Instrument Company, 1430 Hanley Industrial Ct, St. Louis, MO 63144) consisting of a length of silicone tubing with a fine flexible, stainless steel, olive-tipped probe swaged onto each end. This modified probe can be retrieved from the nose using a special Crawford hook (order number 28-01-86, Jed Med Instrument Company).

Step 1. Prior to silicone intubation, dilation of both puncta and nasolacrimal duct probing as described above should be performed to verify patency of the system. Obviously, if the nasolacrimal system cannot be probed, it cannot be intubated. Probing is then repeated using one end of the Crawford tube set inserted through the upper punctum, as illustrated in Figure 16-5. The olive-tipped end of the probe is then gently retrieved from the nose using the Crawford hook. The hook is inserted posteriorly and laterally along the junction of the lateral wall and floor of the nasal cavity, with the opening of the hook facing superiorly. When the hook has passed beyond the probe, it is moved medially until contact with the shaft of the probe is made. The hook is rotated so that the opening faces medially and is withdrawn until the probe shaft is engaged in the hook. The probe is then withdrawn superiorly until the olive tip catches in the Crawford hook, as shown in Figure 16-5B. The Crawford hook is then rotated inferiorly to place a bend in the end of the probe, which locks it onto the hook and directs the hook inferiorly, where it is less likely to catch on the mucosal surface as it is withdrawn. The probe tip can then be gently lifted out

through the nares without abrading the nasal mucosa. Finally, the probe is completely withdrawn from the nose using a slow, steady pull to reduce the chance of the silicone tube separating from the probe as it passes through a tight nasolacrimal duct. A small amount of ophthalmic ointment applied to the probe-tubing junction will help facilitate passage without separation. Occasionally, anterior withdrawal of the probe will drag it across a sharp bony prominence, which strips the tubing off the end of the probe. In this situation, after the tip of the probe has been withdrawn from the nose, the remainder of the probe can be delivered by a different method to eliminate this problem. The probe can either be grasped more posteriorly with a hemostat or passed through a lens loop that is then passed posteriorly into the nose to redirect the force of withdrawal in a more inferior direction.

- Step 2. The identical procedure is now performed, passing the probe at the other end of the tubing through the lower canalicular system and retrieving it from the nose. The use of a Crawford tube set and hook has converted the previously blind, time-consuming, and frequently bloody procedure of retrieving the probe from the nose into a simple, quick, nearly bloodless procedure that can frequently be completed in only a few minutes.
- Step 3. To secure the ends of the tubing together to form a loop within the nasolacrimal system, several techniques have been described. Some surgeons merely tie the two ends of the tubing together with multiple overhand knots. Others thread the two probes through a short segment



of #240 silicone retinal band to prevent the ends from being pulled back into the lacrimal sac. Both of these techniques generally require re-anesthetizing a young child to remove the bulky knot from below through the nose. An excellent solution to the problem, which allows later removal of the tubes in the office using topical anesthesia alone, is illustrated in Figure 16-6A. The parallel tubes are bound tightly together, side by side, using a 6–0 silk ligature secured tightly enough to bind the soft tubing without cutting through it. In addition, if the tubing



is stretched maximally by an assistant and the silk ligature placed as close to the nares as possible, the knot will retract well up into the lacrimal sac when the tubing is released, as shown in Figure 16-7A. thereby leaving two long tails that cannot be inadvertently pulled up into the sac. Whenever traction is applied to the tubing, it is advisable to protect the canalicular system from being torn by placing a large probe or muscle hook through the loop of tubing exposed between the two puncta. Additional protection against inadvertent removal of the tube from above can be provided by suturing the two tails against the internal lateral wall of the nares with a 4-0 Vicryl suture, as shown

in Figure 16-7A. This suture will disintegrate slowly over several weeks, providing additional control of tube position during this critical early time.

An additional technique of securing the tube ends within the nose and yet allowing for office removal from above has recently become available. Crawford tube sets are now available with a silk suture threaded through the lumen of the tubing. It is a simple matter, after tube placement, to incise the proper length of silicone tubing to expose the silk sutures from within the lumen of each arm; the sutures can then be tied together, creating a neat circle of silicone tubing, as shown in Figures 16-6B & C. A



Figure 16-7

tube secured in this manner, however, is extremely vulnerable to inadvertent withdrawal of the tube by a child from above, unless it is also secured to the lateral nasal wall with a 4-0 Vicryl suture.

Step 4. Removal of the tube, if secured side by side or end to end with silk, can generally be accomplished in the office without anesthesia or sedation. Topical anesthesia is applied to the eye. The tubing is then grasped with a needle holder adjacent to one of the puncta and the knot pulled up into the common canaliculus and rotated through the upper and lower canaliculus, as illustrated in Figure 16-7B. The tubing is small and pliable enough to fold upon itself as the point of union is delivered through the punctum. Once the silk knot and long silicone tails have been rotated in the palpebral fissure, the tube can be cut and gently pulled from the canalicular system. Although initially frightening to the child, tube withdrawal is surprisingly painless using topical anesthesia alone.

POSTOPERATIVE MANAGEMENT

A combination antibiotic/steroid ointment applied for 5 to 7 days following nasolacrimal duct probing may help to reduce inflammation during healing. Some surgeons prefer to use phenylephrine nose drops twice a day for 5 days as well. Clinical signs of nasolacrimal duct obstruction generally resolve almost immediately following successful probing, and parents should be instructed to call or return to arrange for additional therapy if signs have not completely resolved within 2 weeks.

The length of time silicone tubing should be left in place in the nasolacrimal system is controversial. Some studies suggest leaving the tubing in place as briefly as 4 to 6 weeks, while others recommend a period of 6 to 12 months. The tubes should be inspected periodically to see that they do not cause punctal erosion or granuloma formation. As long as neither of these occur, there appears to be no contraindication to prolonged tube placement and it is probably worthwhile to leave tubing that is causing no problem in place for 9 to 12 months, if possible. On the other hand, the procedure is occasionally successful if the tubing is inadvertently pulled out even a few days following placement. Therefore, tube replacement should not be scheduled until a satisfactory observation period of 1 to 2 weeks has passed and the need for tube replacement has been documented.

As with routine probings, a short course of antibiotic/steroid ointment may be helpful. Since the tubing maintains patency of the system, there is probably little value to using phenylephrine postoperatively in these patients.



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